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Compilation and analysis of reproductive data from NSW DPI beef cattle research herds

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Abstract

The aim of this project was to compile a large body of data from beef research studies conducted by NSW Department of Primary Industries over many years into a single database format to standardise data storage for past and future cattle projects. Sub-sets of the collated data were then analysed to summarise the levels of fertility and identify the key factors influencing fertility.

Liveweight and body condition at mating and previous calving success were shown to have significant and consistent effects on proportions of cows conceiving during the first 2 cycles and the whole mating period. Intercalving intervals also reflected the overall fertility of the herds examined. Genetic effects on performance were described for crossbred herds, including the interaction with nutrition. It was confirmed that there was no detrimental effect of single trait selection for yearling growth or for increased muscularity on reproductive performance.

Industry benefits will be delivered in the short and long term by using the database and the current results for ongoing extension and research programs. It will be a valuable resource to validate scientific principles underpinning management and selection strategies for efficient cattle production. This database should be further interrogated to examine relationships not able to be addressed within this project.

Executive Summary

Purpose
The purpose of this project was twofold – (i) to compile a large body of data into a 'friendly' and easily accessible format and, (ii) to analyse some of those data to examine effects on herd reproductive performance.

NSW Department of Primary Industries (DPI, formerly Agriculture) has been conducting research in beef cattle for many years, notably since the early 1960's at Trangie and early 1970's at Grafton. Over this time many experiments have been conducted by many scientists, accumulating a huge bank of data but which was stored in several different ways of greater or lesser complexity, and not easily accessible. These data needed to be collated and converted to just one easily managed system, standardising both the system itself as well as the type and format of the information stored. This would then allow retrospective interrogation of historical data across the complete range of past experiments, as well as providing a standardised system for the future.

The data made accessible by this compilation exercise, provided the means to extract sub-sets that could be analysed to describe levels of fertility and to test for specific genetic and non-genetic effects. The results were expected to provide information for use in extension programs addressing beef production needs and to indicate possible issues for future research.

Achievements
The primary aim of this project was achieved in assembling data from NSW DPI beef cattle research projects into databases with standardised format. The 'Informix' SQL relational database system was chosen as the most appropriate as it is considered efficient and friendly, and was already being used to store some of the cattle research records. The data captured, which is continually updated with data from ongoing research, relates not only to reproductive performance, but also many other production and carcass traits associated with the animals involved in the experiments. This will be highly valuable as an ongoing source of historical data for many studies in the future, as well as providing a standardised format for future data collection and storage. The establishment of these 'Informix' databases will facilitate access to the data for research and extension use by a wide variety of personnel.

The data sets now compiled provided the opportunity to extract parameters of the reproductive performance of the herds so that some aspects of fertility could be examined. This was done on a limited basis and restricted by the validity of making various comparisons that were not intended by the original experimental designs. Such 'mining' of data retrospectively can nevertheless yield very valuable information with appropriate caution applied to conclusions.

The size of the task in collating, transferring, checking and cleaning the data from the old data banks in movement to the tables in the new databases was severely underestimated at the outset. There were many delays caused by availability of the staff involved (both external contractors and internal DPI staff). Thus the inputs to the compilation phase of the project far exceeded the original projections, and the time that could be devoted to analyses of the reproduction parameters was considerably restricted. Nonetheless, the basic aims were achieved and, probably more importantly, the data set now presents the opportunity for more detailed analyses in the future if staff and funds are available.

Findings

The specific parameters of reproductive performance nominated for examination were the proportions of cows conceiving in the first 2 cycles of mating and pregnant over the total mating period. These were examined for genetic and non-genetic effects - age and breed of cow, success at previous calving, genetic selection lines where applicable, nutrition, type of mating, and taking into account the effects of repeat performance of the cows mated and variation between years. The effect of various factors on intercalving interval was also examined where possible.

Genetic effects were small compared to those related to liveweight and age at mating. However, differences in performance of the crossbred genotypes at Grafton confirmed previous reports and are important for the management of crossbred cattle in relation to pasture quality. Examination of the single trait selection herds confirmed that there is no detriment to female reproductive performance by selection for yearling growth rate or for muscularity. This is an important result for industry in providing confidence for the use of these traits in genetic improvement programs. The effect of AI sire was able to be examined in one of the data sets and was found to be significant in some analyses. However, this could not be attributed to a genetic basis since there are many other factors that could have reduced the success rate of individual sires.

The strong and consistent associations of liveweight and body condition at mating evident in the data are far from new findings. However, they reinforce the importance of this vital management issue in ensuring the success of mating. The means of manipulating management to consistently present the females for mating at appropriate body status remains a challenge. It has also been long recognised that the status at calving will have a major effect on status at the next mating, since the cow must cope with the high metabolic demands of lactation which impacts on her body stores and ability to resume ovarian activity before next mating. The overall energy balance from calving through lactation and leading up to next mating determines her status and subsequent chance of successful mating.

Cows that calved in the previous year performed better in the current year in 3 of the 4 herds examined. The analysis of the Trangie herd showed that the previous calving had an immediate effect on early conception but the reverse effect on overall pregnancy rate. Thus cows calving in the previous year conceived later but had an overall greater pregnancy rate for the total mating. The earlier conceptions were probably due to better body status at mating resulting from the lack of lactation drain for those cows. This trend was not evident in the other herds examined but may have been affected by remedial management. The positive and negative associations between previous calving and current performance found in the analysis warrants further investigation.

The effect of the proportion of cows pregnant in the first 2 cycles is important to overall reproductive efficiency as it is expressed in the spread of calving of the current breeding season and affects the rate and pattern of pregnancy in the next breeding season. Spread of calving in the herd has significant impact on the profitability of beef breeding enterprises as demonstrated by the spreadsheet calculator described here.

Benefits to industry, research and extension

Industry benefits will be delivered in the short and long term from the use of the database and effects identified in this study for current and ongoing extension and research programs. It will be a valuable resource for validating scientific principles underpinning management and selection strategies for efficient cattle production.

Benefits to industry and research from this project will come from several directions. The merits of having easily accessible data for research and extension use are fairly obvious. Already the databases created by this project have been used in current research within the Beef CRC III programs in creating management strategies for delivery to the industry. Such use will continue as we need data to draw on in developing, refining and testing biological models that have direct application to beef cattle production. A good example is the release by MLA of a management tool at the time of writing this report – the 'BeefSpecs' fat calculator, which gained immediate support from producers and is the first of such tools under development. There are other Beef CRC research projects (such as the Maternal Productivity studies) that will use the information accumulated in these databases, all ultimately directed at outputs to improve productivity and profitability of beef enterprises. These are expected to deliver management strategies to industry within a 5-10 year time frame, with permanent benefits into the future. The data now accessible is available for other studies involving effects of marbling, yield and other carcass traits on meat quality and could also be involved in generation of genetic parameters like marker-assisted EBVs. Any inputs to genetic improvement have potential for long lasting effects on industry.

The benefits from the specific examination of reproduction parameters will flow initially from identification of the main effects emerging from analyses so far. This highlights not only the areas of most potential payoff for future research, but also the areas requiring the most attention in developing or extending management strategies that will achieve worthwhile improvements. Liveweight/body condition at calving and mating have long been known to be important issues for breeding herds and the analyses here have clearly added further support. However, the means of optimising the management of nutrition to achieve targets remains a constant challenge for cattle breeders, and therefore for both researchers and extension staff in devising practical strategies.

Recommendations

This database should be further interrogated to examine relationships not able to be addressed within this project, since the analyses that were completed have shown that the data set has much more to yield if funding and staff resources are available. For example, the issue of repeatability of calving performance, as indicated by the effect of previous calving in the analyses, could be further examined with larger data sets than possible in this study using current and future data. Data from the NFI line at Trangie also warrants further examination as the effects on reproduction for such selection is very important to industry.

The effect of calving spread caused by variation in proportions of cows conceiving in the first 2 cycles should be highlighted in extension programs that deal with cow/calf production and profitability. The management of the cow herd to optimise liveweight and body condition throughout the breeding cycle must however remain the key issue of importance to breeding strategies. This provides the means to maximise both early and total pregnancy rates.

Contents

1 Background

1.1 Historical records, data and databases

NSW Department of Primary Industries (formerly Agriculture) has been conducting research in beef cattle for many years, notably since the early 1960's at Trangie and early 1970's at Grafton. Over this time many experiments have been conducted by many scientists, accumulating a huge bank of data which was stored in several different ways of greater or lesser complexity. Thus the storage and extraction of data was often familiar to only those staff with very close association with the work. As an example, the database system used for storage of the Grafton data was highly efficient in function, but unfortunately not particularly friendly to anyone not involved closely. It was recognised that this large accumulation of data over many sites and years was a very valuable resource, but it was not easily accessible to many people who might make good use of it. It was therefore fairly obvious that we needed to convert to just one easily managed system, standardising both the system itself as well as the type and format of the information stored. This would then allow retrospective interrogation of historical data across the complete range of past experiments, by anyone that was likely to need it, as well as providing a set format for future data collection. The 'Informix' SQL relational database system was chosen as the most appropriate as it is considered an efficient and friendly system, and was already being used to store some of the cattle research records. By chance, at the time of planning our moves internally to address the above, we were made aware that MLA was interested to find out what data were available to investigate the factors affecting reproductive performance in southern Australian beef cattle herds. Thus it was opportune that we could provide such information by extraction and analysis of data that would be collated within the exercise we had been considering. MLA was therefore approached to assist with the funding required for the collation of the data and extraction of the relevant reproductive information, and their support produced the current project.

The herds involved were used (and most bred) within a variety of experiments conducted over many years at the research facilities of NSW Agriculture/DPI located at Grafton, Trangie and Camden (EMAI), as well as those located on the properties of a commercial co-operator (AgReserves Australia Ltd, properties known as 'Kooba' and 'Bringagee'). The latter were involved in a Beef CRC Project known as 'Regional Combinations', which is described by McKiernan et al. (2005), where Hereford females were mated to a variety of sire genotypes for terminal crossbred production.

The cattle at Trangie were all of Angus breed involved in experiments where they were selected for divergence in yearling growth rate over the period 1974 -1992, as described by Parnell et al. (1997) and Archer et al. (1998), or for NFI (net feed intake) over the period 1993 - 1999, as described by Arthur et al. (2005). The cattle at Camden were also of Angus breed, involved in selection for divergence in muscling, as described by McKiernan and Robards (1996,1997). The cattle at Grafton involved a range of crossbred cow genotypes (Bos taurus and indicus) mated to different sire breeds and managed under different nutritional regimes, as described by Barlow et al. (1994).

1.2 Factors affecting fertility and herd reproductive efficiency

In cow/calf production enterprises, the cost of maintaining the breeding herd is a large overhead. The cow, as the production unit, has a high metabolic demand, using 50 to 70% of the energy available from ingested feed for her own maintenance (SCA, 1990). Reproduction must be efficient to provide reasonable profits for individual producers and maintaining a viable beef industry.

Reproductive efficiency is most easily thought of in terms of calving, branding and/or weaning rates. However, the volume and value of the output of a breeding herd is also affected by the distribution of birth dates among the calf crop. Thus the timing of conception following the start of mating, and subsequent spread of calving, is an important aspect of the reproductive efficiency of breeding herds as discussed by Wilkins (2006) and presented below.

In considering constraints to the number of calves produced, there are many stages involved in establishing pregnancy leading to successful calving – puberty, ovarian activity and expression of oestrus, conception rate, embryo loss, calf survival, postpartum anoestrus and re-conception. All stages are subject to genetic and environmental limits and constraints. When conventional management approaches the optimum, the next constraint to output is fecundity, and the use of twinning herds can be considered if management conditions and cost structures are suitable (Hennessy and Wilkins, 2005). The issues of age at first mating and post partum anoestrus are commonly considered the major problems with northern herds (see below - Fordyce, 2006; Fordyce *et al.* 1994), but they can also have significant effects on reproductive efficiency in the southern breeding sector.

Factors affecting reproductive efficiency

Factors affecting reproductive efficiency in beef and dairy herds were discussed in a recent review by McGowan and Holroyd (2008) and by Wilkins (2006). McGowan and Holroyd (2008) concluded that the main effects on weaning rate in beef breeding herds are post-calving interval, embryo-foetal survival and peri-natal survival. They considered that the biological goal of a calf every year for every cow mated was not practically achievable, and that 80 calves weaned per 100 cows mated was a more realistic target for average or better years in the northern Australian beef production areas. The data on industry performance, shown below, suggest that the corresponding target for southern herds should be at least 10 calves/100 cows mated higher. McGowan and Holroyd (2008) quoted the findings of McFadden *et al.* (2004) for a large sample of New Zealand herds as being a benchmark for the intensively managed areas of temperate Australia, showing median pregnancy rates of 91%. However, the mean of 86% for southern Australia from industry statistics (shown below) includes herds managed under much less ideal conditions to those surveyed by McFadden et al. (2004).

Resumption of ovulation following calving was shown to be a major factor for northern Australian herds by McGowan and Holroyd (2008), as had been previously discussed by Entwistle (1983). Although that situation is highly related to the *Bos indicus* genotypes and environment, it can be equally relevant to southern beef or dairy herds, and the factors affecting post partum anoestrus are mainly nutritional as discussed below.

Conception failure is the combined outcome of failure of fertilisation and embryonic loss, resulting in cows usually returning to service or being empty if failure is late and outside the mating period. Rates of embryo loss were reviewed by Sreenan and Diskin (1986) from studies outside Australia. They concluded that the 35% difference between average fertilisation rates of around 90% and calving rates to single service of 55% represented a total embryo loss of the order of 38%. They proposed that the time of greatest pre-implantation loss appears to be around days 15-18, coinciding with the time of pregnancy recognition. Embryo losses after implantation to full term were of the order of 5-8%. Estimates of embryo loss up to day 42 ranged from 20% (Aylon 1978) to 42% (Diskin and Sreenan 1980). These estimates are in agreement with the Australian studies discussed below.
There are few detailed studies for Australian cattle production scenarios to quantify embryo loss, but Fordyce et al. (2005) found that pregnancy rates in *Bos indicus* females varied between 40% and

70%, concluding that embryonic mortality was a major contributor. McGowan and Holroyd (2008) quoted a study by Dunne *et al.* (2000) of embryo-foetal loss in crossbred *Bos taurus* heifers, showing 32% of embryos lost before day 14 (early embryonic loss) compared to 4.2% between day 30 and term (late embryonic loss). Cattle experiencing loss up to day 16 will return to oestrus at the normal expected time. Wilkins *et al.* (1992) found failure of conception of 20-30% (largely due to early loss of embryos), with additional losses of up to 8% of embryos after day 30 in single bearing *Bos taurus* crossbred cows in a study of single and twin calf production.

There are few management strategies that have emerged to control the loss of embryos. The positive association of pregnancy rate with cow body condition at calving was quoted by McGowan and Holroyd (2008), with poorer performance presumed to be due to the contribution of embryo loss. It has also been found that extreme heat/humidity can increase embryo loss (Drost *et al.* 1999), which would indicate avoidance of such conditions during mating.

McGowan and Holroyd (2008) stated that the consequences of increased incidence of embryonic loss are in decreasing the proportion of females calving in the first 6-9 weeks, with the risk that some may not have an opportunity to re-conceive at the next mating. They considered that although the causes of conception failure in beef cattle had not been investigated as thoroughly as in dairy cattle, it is likely they will be similar. Thus additional factors that may have significant contributions to loss were listed as:- venereal infections transmitted during natural matings that can cause early and late embryonic mortality; bull sub-fertility; bovine diarrhea virus (BVDV) or bovine pestivirus, which can result in decreased weaning rates of 30% or more.

It was not possible to examine in detail any of the above factors affecting fertility within the scope of this project, nor were the data suitable. The analyses here were therefore limited to the stated objectives of examining the total proportions of cows calving and those conceiving in the first or second cycle of mating, with the addition of inter-calving intervals, where possible. However, these parameters provide a good overview of herd fertility as a summary of reproductive performance.

Industry performance – differences between regions

Branding rates are higher in the southern states of Australia compared to northern Australia, reflecting largely better year-round nutrition but also involving lower impacts of disease and parasites on reproduction (ABARE, 2004), as well as likely confounding by genotype (Bos *taurus* versus *indicus*). The 8 year mean performance data (from ABARE statistics 2000 - 2007) in branding rates for the southern states and regions within are shown in Table 1.1.

Table 1.1. Eight year mean branding rates for various regions within southern Australian States (ABARE data 2000 - 2007).

<table>
<tr><td colspan="12">New South Wales</td></tr>
<tr><td colspan="2">FarWest</td><td colspan="2">NthWest</td><td colspan="2">Central West</td><td colspan="2">Riverina</td><td colspan="2">TableLands</td><td colspan="2">Coastal</td></tr>
<tr><td colspan="2">78.6</td><td colspan="2">83.2</td><td colspan="2">88.4</td><td colspan="2">83.4</td><td colspan="2">85.6</td><td colspan="2">84.0</td></tr>
<tr><td colspan="12">Victoria</td></tr>
<tr><td colspan="3">Mallee</td><td colspan="3">Wimmera</td><td colspan="3">Cent&Nth</td><td colspan="3">Sth&East</td></tr>
<tr><td colspan="3">91.0</td><td colspan="3">92.0</td><td colspan="3">87.8</td><td colspan="3">90.6</td></tr>
<tr><td colspan="12">South Australia</td></tr>
<tr><td colspan="3">NthnPastoral</td><td colspan="3">Eyre</td><td colspan="3">Murray</td><td colspan="3">SthEast</td></tr>
<tr><td colspan="3">62.4</td><td colspan="3">90.2</td><td colspan="3">87.6</td><td colspan="3">89.2</td></tr>
<tr><td colspan="12">Western Australia</td></tr>
<tr><td colspan="4">CntrlEast</td><td colspan="4">NthEast</td><td colspan="4">SthWest</td></tr>
<tr><td colspan="4">84.8</td><td colspan="4">85.0</td><td colspan="4">88.2</td></tr>
<tr><td colspan="4">Tasmania</td><td colspan="4"></td><td colspan="4"></td></tr>
<tr><td colspan="4">88.4</td><td colspan="8">TOTALS</td></tr>
<tr><td colspan="4"></td><td colspan="4">Southern Australia</td><td colspan="4">Northern Australia</td></tr>
<tr><td colspan="4"></td><td colspan="4">86</td><td colspan="4">74</td></tr>
</table>

The data show an 8 year mean rate of 86% for the combined southern states compared to 74% for northern Australian herds. This difference of around 12% seems fairly typical over time and reflects the differences in production systems and genotypes. The data also suggest much less room for improvement in the southern compared to the northern herds when looking at overall means. However, there is still considerable variation between regions, as there would also be between properties within regions that allows some room for improvement. In fact, any herds with calving rates less than 90% are carrying a significant number of non-productive females that are compromising enterprise profitability. It is unlikely that large increases in branding rate would be achieved across the total southern herd, but seasonal and regional variation can be exploited – there may be greater potential to increase the total value of production in the south by other means, such as compressing the spread of calving, as discussed below. Specific high input strategies such as increasing twin calf production may be attractive, but require superior management conditions and are applicable to only a narrow sector of the industry while constrained by current cost structures (Hennessy and Wilkins 2005).

Estimates of the numbers of breeding females in the southern herds have dropped fairly substantially from around 5.9m head in 2003 to average 3.8m for 2006 and 2007 (ABARE data). This compares with a lesser decline in numbers in the northern herds from around 6.7m to 6.3m for the same period. On these numbers, an increase of 1 or 5% in branding rates in southern herds would be worth ~ $2m or $9.5m, allowing a (conservative) gross value of $50/head for extra calves, while increases of 1, 5 or 10% in northern herds would be worth ~ $3.2m, $15.8m or $31.5m.
Examination of gross margins for a wide range of production scenarios for southern herds showed that the value of 5% increase in weaning rates would produce increases of 6.5% to 9.6% in gross margin per cow (See Appendix Table 2.1 - gross margin analyses for livestock production provided by NSW DPI Farm Enterprise Budget Series - accessible at www.dpi.nsw.gov.au).

Genetic constraints and opportunities
An efficient breeding enterprise will produce as many calves as possible over the lifetime of the individuals in the herd. Thus we want the females to calve first as early as the management system allows, and to maintain annual calf output throughout their life in the herd. Achieving this, from a physiological perspective, is dependent on ovarian function – to produce the first ovulation and oestrus (puberty) as early in life as possible, and resume fertile cyclicity as soon as possible post calving. Genotype sets the upper limit for reproduction (as it does for any production trait), but this is rarely reached due to environmental constraints – the major one being nutrition.

Estimates of heritability and repeatability for adult female reproductive traits are typically very low (10% to 20% - e.g. Meyer *et al*., 1990), suggesting that short term improvements in performance need to be made by management rather than genetic selection. However, this does not negate the value of using some selection pressure for reproduction traits like days to calving (Johnston and Bunter, 1996), which can be used in conjunction with other trait EBV's (estimated breeding values) in forming selection indices for long-term breeding objectives.

The improvement of heifer fertility by genetic selection, based on ovarian function to determine age at puberty, has recently been demonstrated by Johnston *et al.* (2006), but the application of this in relation to lifetime fertility requires testing.

Recent estimates of heritabilities for pubertal traits offer a new perspective on genetic selection for improving reproductive performance. Age at the presence of the first *corpus luteum* (CL), as determined by realtime ultrasound scanning, in puberal *Bos indicus* and composite type females (in northern Australian herds) was recently reported as having moderate to high heritability (>0.5) by Johnston *et al.* (2006) and was also discussed by Fordyce (2006). Age at first behavioural oestrus was reported with moderate heritability (~0.3) by Morris and Amyes (2005) in the Angus breed. Thus it seems that pubertal traits are at least moderately heritable in both *indicus* and *taurus* genotypes and therefore should be valuable aids in genetic selection to improve herd reproductive performance. Using such criteria for selection of replacement heifers would also improve reproductive performance in the current generation.

Nutritional constraints
The time between calving and conception has a major impact on reproductive performance of beef (and dairy) herds, since cows must conceive again by around 80 days after calving to maintain a 12 month calving interval. This is almost entirely governed by the body condition/metabolic status of the cow which in turn is largely a reflection of available nutrition (Randel, 1990; Graham, 1995). At a metabolic level, energy balance at calving and early lactation is the main determinant of post partum anoestrus in beef or dairy cows through its effect on follicular activity in the ovary (Lucy *et al*., 1992). The energy balance of the cow is reflected in its absolute and change in liveweight/body condition. Guidelines for management of the breeding herd have been based on body condition targets using scoring systems – "condition" or "fat" scores. In the extremes, cows that are too fat at calving can have problems with dystocia, while those too lean will have extended post-partum anoestrus intervals (Graham, 1995). Using the Australian cattle "condition score" system (range 0-5), Graham (1995) recommends early calving mature cows should have a condition score of 2.0-2.5, early calving first calf heifers a score of 2.5-3.0 and late calving cows a score of 3.0-3.5. Guidelines for body condition targets used by NSW Department of Primary Industries beef cattle advisory officers are based on a "fat score" system (range 0-6). These are used in the 'Prograze' livestock management workshops for producers (Steve Exton, NSW DPI, *pers. comm.*)

Effect of prior ovulation on conception rates

The herd should be managed to commence normal cyclic activity as soon as possible after calving to allow early re-conception. This will be governed by the energy balance status, driven by body condition at calving and early lactation, as discussed above. It has been shown that cows previously ovulating have a higher conception rate at the current cycle compared to those having their first ovulation (Wilkins and Hoffman, 1997; Nguyen *et al*., 1998). Those studies showed improvements of the order of 10-20% in conception rates to AI (Table 1.2). Cows having prior ovulation had better performance following synchrony treatment in proportions ovulating and presenting for AI and in subsequent pregnancy rates. This is supported by New Zealand research in dairy cows showing improved conception rates in cows having at least one heat before mating (McMillan and Clayton 1980).

Thus, if nutrition allows cows to commence cycling well before the start of mating, earlier and higher overall conception rates can be expected. If an assessment of ovarian activity is possible, it can be used in specific circumstances to select animals best suited for an AI program or as a guide to the need for some intervention (hormonal or nutritional promotion of ovarian activity) before the start of a mating, or for the selection of the most suitable oestrus synchrony system if that is the aim. Alternatively, it may be decided best to delay the start of mating for the particular year, which is a less desirable strategy due to consequences for the following year, but may be the best compromise.

Table 1.2. Least squares means for oestrous activity, ovulation and pregnancy rates following stimulation and synchrony treatments and AI, in relation to prior ovarian activity.

Year	94		95		96		OVERALL	
Pre-treatment ovarian activity	+	-	+	-	+	-	+	-
(n)	43	91	30	113	54	137	127	341
PERCENTAGES OF COWS								
Initially active ovaries	32		21		28		27	
Ovulated following treatment	98*	84	99	94	100*	92	99**	91
Detected in oestrus (overall)	95*	78	93	84	69	61	90*	79
Presenting on first day of AI	88*	68	89	80	61	54	84**	72
Pregnant following AI	67	59	66	50	65	59	70[a]	60

Superscripts indicate significance of differences within years or overall:- *P<0.05; **P<0.01; [a]P ≅ 0.06

The effect of calving spread on weaner output

As previously mentioned, average branding figures might suggest that there is not much room for improvement in southern beef herds, but the available statistical data (like the ABARE means) do not provide any indication of parameters like spread of calving dates. This can have a large effect on weaner turnoff in total and range of weight, both of which have large effects on value. If weaners are too light for the targeted market there may be a price penalty per kg, as well as the penalty incurred by having less total kg for sale. The producer may often choose to keep the lighter animals longer before marketing, but this puts extra pressure on available grazing, or may require supplementation, which affects the cost of production. Calving will be spread out in response to the timing of matings and conception during joining. The timing of matings is regulated by the factors affecting post-partum follicle development, ovulation and oestrus, or age at puberty in the case of first mated heifers. Conception rates may be affected by similar or additional factors.

To estimate potential effects of calving spread, we can simulate the progress of mating and the resultant calf crop. This has been incorporated into a relatively simply operated spreadsheet model. An example of the capabilities of the model in predicting reproductive performance and weaner production is shown by a single screen capture of output in Appendix 3. The model is available as an Excel file on request to the author to any producers or scientists interested in running various 'what if ?' scenarios. By altering 2 parameters at mating viz - % cows in oestrus and successful conception rate, we can calculate the effect on numbers and timing of calves born. By adding in the projected weaning age, weaning weights and value of weaners ($/kg), we can predict the effect on total weight of calf weaned and total value of the weaned calves at that point. This could be further extended to post weaning end points (say feedlot entry or grass finish turnoff), as the variation in weaning weights will impact on meeting subsequent liveweight targets and specifications.

It is shown in Appendix 3 that with a variation in proportions of cows in oestrus in the first cycle of mating of 30 -80%, increasing these over a total of 3 cycles, and with a constant conception rate of 75%, we find a range of 83-97% calves born/cows presented. However, there is a large difference in spread of conception/birth dates – a distribution of 62, 29 and 9% of calves conceived/born to the first, second and third cycles in the best case, compared to 27, 38 and 35% in the worst. At an average growth rate of 0.8 kg/d in young calves, we could expect mean liveweight differences of around 17 and 34 kg (at the end of calving and at weaning) for calves born from successive cycles (mean 21 days apart).

Calculating the total weight of calf weaned using expected weights and numbers showed differences of up to 20% over a range of expected weaning weights. The spreadsheet example shows a difference of $71 gross return per cow presented for mating, between the best and worst scenarios tested.

The example in the spreadsheet model has used a constant conception rate (75%) for the different scenarios. However, lower conception rates in conjunction with lower proportions in oestrus are a possibility, if not likely, situation. This would further aggravate the detrimental effect on weaning weight as well as numbers. The model has not yet been extended to estimate the production and economic effects post weaning.

The effect of reducing the spread of calving on profitability in southern Australian beef herds was recognised by Black and Scott (2002) in their report commissioned by Meat and Livestock Australia (MLA) to assist formulation of Research, Development and Extension strategies. They concluded that there were considerable benefits to be gained by better utilisation of pasture resources in herds with compressed calvings by the management of pregnant cows in groups having a similar pattern of nutrient requirements throughout the year. Thus, there may be further reductions in cost of production that would add to the benefits shown above.

Apart from the effect on the current calving shown in the above example, delayed mating and conception has flow-on effects to the following year's performance. Cows calving later are more difficult to get in calf within the next main mating interval and will be at least later calving again next season, if not missing pregnancy for one year. Achieving the best outcome will depend on providing the nutritional and management conditions to promote high proportions of cows cycling soon after calving which primarily concern optimal cow condition at calving and good nutrition in early lactation.

Conclusion
There are many issues involved in achieving high conception and subsequent calf branding rates. Additionally, reproductive efficiency and enterprise profitability is affected by spread of calving as well as total numbers born. Constraints and opportunities have different emphasis in northern and southern Australian herds due to differences in genotype and environment. However, refinements to efficiency such as compression of spread of calving and the specialised case of increased twinning are suitable only for situations of better or superior nutritional and management conditions. Nutrition is undoubtedly the most important factor in managing breeding herds, particularly due to its effects on post partum anoestrus and re-conception and the impact of this on yearly and lifetime performance. That however does not discount the importance of good nutritional management throughout the complete breeding cycle to achieve optimum live body and metabolic targets for efficient reproduction.

2 Project Objectives

2.1 Project Objectives

The objectives of this project, as originally stated, were :-

1. To compile a data set in an agreed format ('Informix' database). The data set to include :-
   a) data from experiments involving the Grafton, Trangie, Kooba (CRC) and EMAI herds (~ 15,000 records originally projected)
   b) data were from above experiments conducted over the period from 1970 – 2004
   c) data were generated from experiments known as 1st cross heifers, terminal sires, Trangie selection (growth rate), NFI (net feed intake), CRC (Regional Combinations) and muscling selection lines

2. To analyse***** the data to quantify reproductive performance and identify any significant non-genetic and genetic factors that influence it. Specifically, the primary measure of fertility for this exercise is the proportion of females that become pregnant within 2 oestrus cycles after the start of either natural mating or artificial insemination.

3. To provide a report that describes the reproductive performance for the herd(s), the environmental and genetic factors that influence it. These analyses should indicate the areas offering the best opportunities for improvement.

***NOTE:** It was understood that the analyses to be undertaken in this project were an opportunistic and retrospective 'mining' of historic data. The data come from experiments that were specifically set up for purposes other than examining reproduction and have no common experimental design. Thus the parameters that can be extracted and the causal factors analysed are variable across data sets. It was believed that the data would achieve the objectives but the above conditions affected the number of records that could be validly included in any specific analysis, as well as the comparisons that could be validly made.

3 Methodology

3.1 General

The data assembled in this project were previously held in several different locations and formats. These ranged from spreadsheets to permanent databases and they all had different formats and structures. Thus, the first task was to decide on the design of tables for the new relational SQL database ('Informix') chosen as most appropriate for the future storage of these data. In fact some of the data from one site (Trangie) was already contained in the Informix format and structure that we had decided as suitable for the conversion of all others.

3.2 Database table structure

The structure of the tables for the new database was essentially the same as for the one used to store the Trangie data at the time this project was commenced. Thus, we examined those tables and their content to ensure they would accommodate all of the data from the other sites, and created some extra tables and fields within tables where required.

3.3 Data transfer

The transfer of Grafton data from the original ('Unidata') database was sub-contracted to an external commercial company as it had to be converted to the new field format before transfer to the new system. This in fact caused many delays with the contractor before transfer was completed and also required considerable time in checking and fixing data entries that had been incorrectly converted and/or moved between tables in the old and new databases.

Data from the CRC and the muscling selection herds were held in Excel format files and had to be collated and manipulated into suitable fields so they could be uploaded to the tables in the new databases.

The oldest records for Trangie were also in a 'Unidata' format as for the Grafton data, and thus had to be converted for transfer. Later records already held in the Trangie database at the time required updating to accommodate the changes in tables or fields as required by the new database format.

3.4 Data extract and statistical analysis

Data were extracted from each of the site databases that related to the parameters of reproductive performance for analysis as proposed in this exercise.

3.4.1 Parameters for analysis

The objectives stated the primary measure of fertility for this exercise as the proportion of females that become pregnant within 2 oestrus cycles after the start of either natural mating or artificial insemination. The proportions pregnant/calving from the total mating were also examined. These parameters were examined for effects due to genetic or non-genetic factors as described below.

3.4.2 Statistical analyses

Analyses were performed with Genstat PC software (2008, Version 11) using a linear mixed model REML procedure.
Terms for possible inclusion in models for analysis included ;-

the *fixed effects* of - cow breed, age and previous calving success; genetic selection line or herd of origin (if appropriate); nutritional treatment group; liveweight and/or body condition of the cow at mating was examined as a co-variate

the *random effects* of – joining year; mating sire or group; management group; 'dam' was included to account for the effect of repeated performance for cows mated more than once

The fixed and random terms relevant varied according to the available data and validity of comparisons for specific analyses.

The inclusion of previous calving success in the model reduced the data available for analysis (specifically excluding females at their first mating), and thus some analyses were conducted with this term both included and excluded.

Significance of effects in results and discussion assumes $P < 0.05$ unless otherwise stated.

4 Results and Discussion

4.1 General

Data relating to fertility were successfully transferred from the previous data storage systems to the new standardised databases. Additionally, all other data relating to other areas of production (live measurements, carcase information etc) were also successfully transferred at the time of this report.

Various analyses of some aspects of reproductive performance of the herds involved here have been previously reported. These will be referred to in the discussion of results from each site, indicating how the analyses here differ from the previous. There are also many reports from studies of growth and carcass traits that have used the data now collated, but these will not be discussed here.

4.2 Database table structure

Examples of tables containing data relevant to reproductive performance are shown in Appendix 1. The first of these (Appendix Table 1.1) is the 'animal' table, which is the main relational table. It contains the basic information for every animal in the database. The first field in this table – 'animalid' – is the primary relational key, since the 'animalid' field must appear in every other table in the database to allow the link to be made between tables, and to enable input or extraction of information relating to any individual animal. The database will not accept any information for upload unless there is already an 'animalid' entry in the 'animal' table to identify each individual for which the data is being entered.

Tables in Appendix 1 (Appendix Tables 1.1 to 1.3) show examples of the types of fields for each record in a table. The records contained in each of the data sets from various sites and experiments vary in the type of information collected, and thus the number of fields containing data in any table will vary (from none to all) due to the differing nature of the original aims of the experiments involved. However, all of the tables relating to reproduction contain some data that can be used to examine the parameters of fertility of interest in this study. Specific sub-sets of data were extracted from the central sources to provide records relevant to the analyses.

There are 28 tables in total, containing information about various production parameters, but only about 10 of these are used frequently across various experiments. In addition there are 23 'codes' tables that contain the alternatives possible for fields in various tables – e.g. the 'weight' table has many entries for liveweights taken at various stages over the lifetime of animals in the databases, and the 'codes_stage' table gives the terms used to identify at what stage any particular weight was taken, such as birth, weaning, pre-joining etc. Thus there are many tables, and many fields within tables, that may have no records, depending on the group of animals (or experiment), but they are all necessary to retain in the database structure to ensure they are available when required.

4.3 Data transfer

The data from the old sources were transferred to 5 new databases - all now having identical structure, as described above:-

Grafton data	to	'cattle_grafton'
Trangie data	to	'cattle_tarc' and 'dan75'
Muscling line	to	'catemai'
CRC cattle	to	'catwga'

These are now constantly updated, and at the time of writing this report the total numbers of animals with records on the various databases were:-

'cattle_grafton'	15,774
'cattle_tarc'	14,999
'dan75'	13,254
'catemai'	2,222
'catwga'	3,971

The number of records transferred was much greater than originally proposed, but the number of analyses that could be done was limited by the resources available after the higher than expected demand of the collating, transfer, checking and correcting phases of the project.

4.4 Data extract and statistical analyses

The following sections report the results of the analyses that were carried out for each of the 4 sites at which data were collected. The traits examined, as stated in the objectives, were proportions of cows calving to conceptions in the first 2 cycles and to the total mating. Additionally the proportions calving to first cycle conceptions were also examined as well as the intercalving intervals. The factors that were examined for effects in the analyses were covariates of liveweight and body condition at mating where available, age of cow at mating, different mating groups and years, and previous calving performance. In the case of the AI mating in the Wagga data, factors of AI technician and AI sire were included. A term was included in the random structure of the models to account for individual animal effects when cows had multiple records over different matings, which contributed a significant proportion of the random variation in most cases.

The inclusion of previous calving success in the models reduced the data available for analysis (obviously excluding females at their first mating), and thus analyses were done with this term both included and excluded from the models. The reduction was quite large where there were few repeat matings for individual cows, as was the case for the Wagga data. There was considerable confounding of effects in many cases due to lack of cross classification of factors in the models, which also affected the comparisons that could validly be made. This was expected from the outset in using data that were not originally designed for such comparisons, and recognised as a limitation to what could be done.

Variation between years was accounted for by the inclusion of a "year" term in the random structure of the models. This was always a significant component of the variation in the models.

4.4.1 Trangie herds

Reproductive performance for some of the herds at Trangie examined here has been previously reported by Parnell *et al.* (1994) and Archer *et al.* (1998). The report of Archer *et al.* (1998) on the herd selected for yearling growth rate examined a subset of the data for fertility that was used here. The trends were similar although the numbers of records analysed were lower in the Archer *et al.* (1998) report. The authors had specific reasons to choose the data used in relation to the stage of selection of the herds, and the current analyses are intended to test the extension of the previous findings over a wider time frame with more records. The results discussed by Parnell *et al.* (1994) used samples of cows measured between 1986 to 1988, whereas the data examined here covered a wider time frame of matings from 1974 to 1992 (6,516 records), which was the total span of the selection experiment. The data used in the report by Archer *et al.* (1998), involved cows born from 1985 to 1990 (1,452 records), and they concluded that selection for high growth rate did not compromise reproductive performance, while the line selected for low growth rate did have poorer performance than the control line.

Reproduction data from the herd selected at Trangie for residual feed intake were not able to be analysed in the current exercise (due to time constraints). However, results from that study have been reported by Arthur *et al.* (2005). There were no significant differences due to selection line in any of the reproductive performance traits in the data analysed in that report. However, there were significant differences between years of mating, with mean pregnancy rates for 2000, 2001 and 2002 matings of 95.1%, 90.8% and 83.3%, respectively, and corresponding values for calving rates of 92.9%, 89.5% and 81.8%.

Results of the current analyses on the growth rate selection herds are shown in Table 4.1.1 for the significance of effects and in Table 4.1.2 for the predicted means. The number of records involved was 3,159 – 5,929 depending on the analysis. Effects in relation to other sites are shown in the charts in the section below - 4.4.5 *Summary – all sites.*

Table 4.1.1. Trangie data analyses (growth rate selection herds) – significance of main effects on the reproduction traits examined.

	Total calved		Calved 2 cycles		Calved 1st cycle		Intercalving interval	
Effects		No Prev[1]		No Prev		No Prev		No Prev
Wt cov[2]	*	**	**	**	**	**	0.087	**
Cond cov[2]	*	0.11	ns	ns	0.046	**	*	**
Line[3]	ns	ns	ns	ns	ns	ns	ns	ns
Cow age	**	**	**	**	*	**	ns	*

Previous calved	0.002		0.017		**		0.003	

[1]Previous calving success not included in the model ; [2]Weight and body condition at mating as co-variates
[3]Line – lines selected for yearling growth rate
** P < 0.001; * P < 0.05; ns not significant (P>0.05)

Table 4.1.2. Trangie data analyses (growth rate selection herds) – predicted means for main effects for reproduction performance traits.

	Total calved		**Calved 2 cycles**		**Calved 1st cycle**		**Intercalving interval**	
Effects[2]		No Prev[1]		No Prev		No Prev		No Prev
Line[3]								
High	0.7436	0.7393	0.6463	0.6079	0.4221	0.3435	415.2	412.1
Low	0.7269	0.7046	0.6518	0.5953	0.4419	0.3627	416.3	418.4
Control	0.7603	0.7308	0.6515	0.5905	0.4329	0.3372	422.2	423.6
sed	*0.01867*	*0.0179*	*0.02227*	*0.01978*	*0.0225*	*0.01925*	*7.169*	*7.4*
Previous calved[4]								
No	0.7179		0.6720		0.5308		427.3	
Yes	0.7692		0.6278		0.3338		408.5	
sed	*0.01646*		*0.0187*		*0.01828*		*6.45*	
Cow age								
1		0.7486		0.6346		0.4930		463.5
2	0.7349	0.7411	0.6320	0.6094	0.3648	0.3138	423.8	425.9
3	0.7969	0.7842	0.7152	0.6711	0.4434	0.3663	427.1	422.3
4	0.7805	0.7611	0.6818	0.6214	0.4615	0.3489	418.1	411.6
5	0.7838	0.7588	0.6680	0.6009	0.4572	0.3343	411.0	402.2
6	0.7779	0.7458	0.7057	0.6320	0.4737	0.3364	420.8	413.7
7	0.6572	0.6248	0.5860	0.5174	0.4208	0.2949	413.7	405.3
[5]**8+**	0.674	0.6347	0.5604	0.4965	0.4045	0.295	410.6	399.7
sed	*0.02706*	*0.02933*	*0.0308*	*0.03289*	*0.03018*	*0.03275*	*11.24*	*13.21*

[1]Previous calving success not included in the model ; [2]Weight and body condition at mating as co-variates
[3]Line – lines selected for yearling growth rate
[4]Calved or not in the previous year; [5]Cows aged 8 yo or older at mating

There were no significant differences between selection lines in performance for any trait. This is somewhat different to the results reported by Archer *et al.* (1998) in that they found the high line no different to the control, but that the low line had poorer performance. It is likely that some of this is due to the use of the liveweight and body condition covariate in the current analyses, and some due to the extended data set used here. In terms of relevance to the industry, the important conclusion remains that there is no detriment to reproductive traits by selection for increased yearling growth rate. The result of cows performing better for total calved in the current year if calved in the previous year was consistent with the earlier report. However, those not calved in the previous year had higher proportions calving earlier (to the first and second cycles), which is likely to be due to better body status at the start of mating. There was a decline in performance at the second calving, with an increase thereafter before declining at age 7 and greater. There was a general trend for intercalving interval to decline with age, reflecting the improved fertility.

4.4.2 Grafton herds

Some results from the Grafton herds examined here have been previously reported by Barlow *et al.* (1994). The data were from an experiment carried out to compare the performance of straight bred Hereford females with 3 crossbred genotypes – Brahman x Hereford, Simmental x Hereford and Friesian x Hereford - when managed on 3 pasture systems to provide high, medium and low nutritional conditions (Barlow *et al.* 1994).

Results of the current analyses on crossbred production herds are shown in Table 4.2.1 for the significance of effects and in Tables 4.2.2 and 4.2.3 for the predicted means. The number of records involved was 1,886 – 3,506 depending on the analysis. Effects in relation to other sites are shown in the charts in the section below - 4.4.5 *Summary – all sites.*

Table 4.2.1. Grafton data analyses (crossbred production herds) – significance of main effects on the reproduction traits examined.

	Total calved		**Calved 2 cycles**		**Calved 1st cycle**		**Intercalving interval**	
Effects		No Prev[1]		No Prev		No Prev		No Prev
Wt cov[2]	**	**	**	**	**	**	**	**
Cond cov[2]	**	**	**	**	**	**	**	**
Nutrition	**	**	**	**	**	**	**	**
Breed	0.05	0.018	ns	0.055	ns	*	0.004	0.009
Breed*Nut	0.014	*	0.039	0.01	0.044	0.014	*	**
Cow age	0.039	0.02	0.025	0.02	0.002	**	**	**
Previous calved	**		**		**		**	

[1]Previous calving success not included in the model ; [2]Weight and body condition at mating as co-variates
** P < 0.001; * P < 0.05; ns not significant (P>0.05)

Table 4.2.2. Grafton data analyses (crossbred production herds) – predicted means for main effects on reproduction performance traits.

	Total calved		**Calved 2 cycles**		**Calved 1st cycle**		**Intercalving interval**	
Effects[2]		No Prev[1]		No Prev		No Prev		No Prev
Nutrition[3]								
High	0.8827	0.7703	0.7651	0.6013	0.6494	0.4641	373.5	394.1
Low	0.5457	0.5887	0.4001	0.4468	0.2605	0.3188	601.4	609.0
Medium	0.8704	0.8212	0.7340	0.6602	0.5292	0.4359	385.3	413.8
sed	*0.03604*	*0.02767*	*0.04037*	*0.03233*	*0.04047*	*0.03404*	*13.24*	*11.44*
Previous calved[4]								
No	0.8931		0.7915		0.6308		435.2	
Yes	0.6394		0.4747		0.3287		471.6	
sed	*0.01989*		*0.02192*		*0.02318*		*7.87*	
Breed[6]								
BxH	0.8115	0.7523	0.6282	0.5353	0.4384	0.3308	424.2	447.3
FxH	0.7782	0.7563	0.6574	0.6164	0.5077	0.4601	456.2	471.8
HxH	0.7342	0.695	0.6097	0.5476	0.4818	0.4110	468.1	483.4

SxH	0.7411	0.7034	0.6371	0.5783	0.4910	0.4232	465.1	486.7
sed	*0.03029*	*0.02321*	*0.03395*	*0.02744*	*0.03327*	*0.02915*	*10.93*	*10.21*
Cow age								
1		0.6557		0.4105		0.2465		511.3
2	0.6966	0.7082	0.4973	0.4830	0.2558	0.2643	449.4	504.7
3	0.7070	0.6995	0.5433	0.5292	0.4209	0.3892	467.4	472.7
4	0.7724	0.7681	0.6490	0.6415	0.5287	0.5070	451.5	453.3
5	0.8264	0.7936	0.6855	0.6422	0.5541	0.4921	446.0	453.0
6	0.8069	0.7552	0.7065	0.6431	0.5709	0.4894	452.1	459.6
7	0.7982	0.7445	0.7026	0.6370	0.5547	0.4749	446.8	454.9
[5]**8+**	0.7564	0.6890	0.6474	0.5687	0.4730	0.3866	460.5	469.0
sed	*0.0414*	*0.04301*	*0.0466*	*0.04931*	*0.04757*	*0.05046*	*13.21*	*14.77*

[1]Previous calving success not included in the model ; [2]Weight and body condition at mating as co-variates
[3]Nutrition – high, medium and low nutrition treatments
[4]Calved or not in the previous year; [5]Cows aged 8 yo or older at mating
[6]Cow genotypes – Brahman x Hereford, Fresian x Hereford, Hereford purebred, Simmental x Hereford

Table 4.2.3. Grafton data analyses (crossbred production herds) – predicted means for the nutrition x breed interaction on reproduction performance traits.

	Total calved[1]			**Calved 2 cycles**[1]			**Intercalving interval**[1]		
	Nutrition[2]			**Nutrition**			**Nutrition**		
	HIGH	**LOW**	**MED**	**HIGH**	**LOW**	**MED**	**HIGH**	**LOW**	**MED**
Breed[3]									
BxH	0.8590	0.6519	0.9237	0.7005	0.4471	0.7369	394.1	510.2	368.3
FxH	0.9280	0.5705	0.8360	0.8248	0.4441	0.7032	361.0	605.5	402.1
HxH	0.8369	0.5206	0.8450	0.7122	0.3878	0.7290	381.4	632.9	390.0
SxH	0.9069	0.4397	0.8769	0.8230	0.3213	0.7669	357.5	656.9	380.9
[4]*Same nut*									
sed	*0.05132*			*0.05756*			*18.41*		
[4]*Same breed*									
sed	*0.05698*			*0.0639*			*20.7*		

[1]Weight and body condition at mating as co-variates; [2]Nutrition – high, medium and low nutrition treatments;
[3]Cow genotypes – Brahman x Hereford, Fresian x Hereford, Hereford purebred, Simmental x Hereford;
[4]Comparison of breeds within the same nutrition group or nutrition groups within the same breed

There were large effects of nutritional treatment on all traits, with markedly poorer performance in both early and total calving rates in the low nutrition groups. The significant interaction of breed x nutrition was consistent with the previous report of Barlow *et al.* (1994), with the Brahman x Hereford genotype generally performing better on low nutrition, with S x H and pure Herefords performing the worst. There was a clear effect on current year's performance in all traits favouring those not calved in the previous year.

The results here are in agreement with the report of Barlow *et al.* (1994). In general as the level of nutrition decreases, genotypes with potential to achieve larger mature size experience a greater decline in reproductive performance than those of smaller mature size. Thus the Brahman x Hereford genotype performed the best overall generally having the highest predicted means for both medium and low nutrition treatments. However, the larger mature size genotypes (Simmental x Hereford and Friesian x Hereford) had the highest predicted means when on high nutrition.

4.4.3 Muscling selection herd

This selection herd, described by McKiernan and Robards (1996, 1997), was established to create divergence in muscularity, as this is an important trait that affects carcass retail beef yield and thus commercial value. However, as for other selection herds, scientists and producers are aware of the need to examine the effects that such selection might have on other traits, particularly those affecting reproduction. Advantages due to selection for any given trait must not compromise the overall productivity and profitability if there are negative correlated responses in other traits affecting product value and enterprise outcomes.

Most previous reports of results from this selection herd relate to carcass traits in the progeny. However, there is one short communication relating to reproductive performance showing that there was no apparent detriment to young females in early life reproductive development by selection for increased muscling (McKiernan *et al.* 2004).

Results of the current analyses on the muscling selection herd are shown in Table 4.3.1 for the significance of effects and in Table 4.3.2 for the predicted means. The number of records involved was 383 – 987 depending on the analysis. Effects in relation to other sites are shown in the charts in the section below - 4.4.5 *Summary – all sites.*

Table 4.3.1 EMAI data analyses (muscling selection herds) – significance of main effects on the reproduction traits examined.

	Total calved		**Calved 2 cycles**		**Calved 1st cycle**		**Intercalving interval**	
Effects		No Prev[1]		No Prev		No Prev		No Prev
Line[2]	ns	ns	ns	ns	*	*	ns	ns
Cow age	**	**	**	**	**	**	0.065	**
Previous calved	**		ns		ns		ns	

[1]Previous calving success not included in the model
[2]Line – lines selected for high or low muscularity
** P < 0.001; * P < 0.05; ns not significant (P>0.05)

Table 4.3.2. EMAI data analyses (muscling selection herds) – predicted means for main effects on reproduction performance traits.

	Total calved		Calved 2 cycles		Calved 1st cycle		Intercalving interval	
Effects[2]		No Prev[1]		No Prev		No Prev		No Prev
Line[3]								
High	0.7531	0.8146	0.6762	0.7213	0.5005	0.5377	370.4	373.1
Low	0.7161	0.7817	0.705	0.7424	0.5979	0.6136	362.8	366.3
sed	*0.02428*	*0.02406*	*0.0266*	*0.02405*	*0.033*	*0.028*	*5.053*	*4.043*
Previous calved[4]								
No	0.6579		0.6460		0.5154		364.8	
Yes	0.8114		0.7352		0.5830		368.3	
sed	*0.04611*		*0.0543*		*0.0638*		*14.3*	
Cow age								
2		0.7944		0.7198		0.55		396.6
3	0.7839	0.8272	0.7310	0.7512	0.5129	0.5227	379.2	372.7
4	0.7730	0.8746	0.6455	0.7490	0.5102	0.6074	358.6	366.4
5	0.8478	0.9171	0.8051	0.8428	0.5870	0.5877	376.1	376.1
6	0.8704	0.9239	0.8455	0.8718	0.6732	0.6951	358.7	353.7
7	0.8777	0.9257	0.8521	0.8773	0.7236	0.7423	360.2	352.7
[5]**8+**	0.2549	0.3241	0.2645	0.3110	0.2882	0.3245		
sed	*0.04287*	*0.04111*	*0.0513*	*0.04975*	*0.0598*	*0.0578*	*11.27*	*11.58*

[1]Previous calving success not included in the model ; [2]Weight and body condition at mating as co-variates
[3]Line – lines selected for high or low muscularity
[4]Calved or not in the previous year; [5]Cows aged 8 yo or older at mating

There were no significant effects due to selection for muscularity in these cattle, except for the conception rate to the first cycle which became non-significant for 2 cycles and total proportion calving. The effect of age of cow was again evident with the performance lowest for 2 and 3 year olds at mating, 5 , 6 and 7 year olds most fertile and a sharp drop for the oldest cows. This pattern was reflected in the intercalving intervals. Cows calved in the previous year had better performance than those not calved.

The results here support the previous report on the young females from this selection herd (McKiernan *et al.* 2004), showing that their performance has carried through to subsequent calvings as heifers and adults. Thus, as for the selection lines at Trangie, there is no apparent detriment to reproductive performance by selecting for the traits targeted in these herds.

4.4.4 CRC herds

The herds contributing data from the Beef CRC 'Regional Combinations' project were described by McKiernan *et al.* (2005), and there have been many publications from the project describing effects of growth path (nutrition treatment) and genetic potential (in the progeny) on live performance and carcass traits, as summarised in the Final Report to MLA (McKiernan *et al.* 2007). The data have not previously been examined for reproductive performance since the study was designed to examine effects in the progeny of terminal crossbred matings. There were no treatments applied to the cows prior to or during mating since the sole purpose was the generation of progeny by various (designed) sires on which treatments were applied after weaning. Thus there were few factors having variation that could be used in the analyses of these data. Joining group was analysed as a main effect here.

Results of the current analyses on the Beef CRC herds, are shown in Table 4.4.1 for the significance of effects and in Table 4.4.2 for the predicted means. The number of records involved was 117 – 2,629 depending on the analysis (the large range was due to there being only few records when factors like AI technician were included in the analysis). Effects in relation to other sites are shown in the charts in the section below - 4.4.5 *Summary – all sites.*

Table 4.4.1 Wagga data analyses (Beef CRC carcass trait study) – significance of main effects on the reproduction traits examined.

	Calved 2 cycles		**Calved 1st cycle**		**Intercalving interval**	
Effects		Wt cov[1]		Wt cov		Wt cov
Mating weight		**		**		ns
Joining group[2]	**	ns	**	0.049	ns	
Cow age	**	**	**	**	**	**
Previous calved	0.016		**			

[1]Weight at mating as a co-variate
[2]Joining groups (across years) were analysed as source of variation
** P < 0.001; * P < 0.05; ns not significant (P>0.05)

Table 4.4.2. Wagga data analyses (Beef CRC carcass trait study) – predicted means for main effects on reproduction performance traits.

	Calved 2 cycles		**Calved 1st cycle**		**Intercalving interval**	
Effects		Wt cov[1]		Wt cov		Wt cov
Joining group[2]						
2000	0.4038	0.4375	0.3597	0.3665	462.6	
2001a	0.4038	0.4375	0.3597	0.3665	462.6	
2001b	0.4038	0.4375	0.3597	0.3665	462.6	
2001c	0.3337		0.2741		396.8	
2002a	0.387		0.3293			
2002b	0.6088	0.5156	0.5094	0.2334		
sed	*0.03272*	*0.06887*	*0.03169*	*0.06748*	*65.43*	
Previous calved[3]						
No	0.4012	0.4012	0.3169			
Yes	0.5276	0.5276	0.4943			
sed	*0.05242*	*0.05242*	*0.05108*			
Cow age						
4	0.2425	0.2562	0.2272	0.2028		
5	0.4604	0.557	0.3775	0.3437		
6	0.3987	0.3878	0.3861	0.3345		
7	0.5388	0.6195	0.4469	0.4251		
[4]**8+**	0.4769	0.4648	0.389	0.3601		
sed	*0.04881*	*0.09166*	*0.04768*	*0.08893*		

[1]Weight at mating as a co-variate – no weights for matings 2001c and 2002a
[2]Joining groups (across years) were analysed as a source of variation for this site
[3]Calved or not in the previous year; [4]Cows aged 8 yo or older at mating
** P < 0.001; * P < 0.05

The results of these analyses have shown the same effects due to liveweight at mating as seen in herds at the other sites. Effects due to age of cow were again evident in these results, as for other sites, as was an effect of prior calving in those cows contributing multiple records. In this case cows calved in the previous year performed better in the current. This may be an effect of individual animals being genetically more fertile to AI.

There were significant differences between separate mating groups. However, most of this was apparently accounted for by mating liveweight as the term for mating groups became non-significant when liveweight was included as a co-variate in the models for proportions calved in 2 cycles and for intercalving interval.

There was a difference of around 10 percentage points between AI technicians for proportions of cows calved in 2 cycles, however this was not significant (data not shown). There was a difference of around 8 percentage units in proportions of cows calved in 2 cycles in favour of those not calved the previous year. This is most likely operating through cow status (weight and body condition) at mating although that could not be confirmed due to insufficient applicable data.

There were significant differences due to AI sire in proportions of cows calved in 2 cycles (data not shown). There are many reasons for such an outcome including preparation, storage and handling of the semen straws rather than any inherent genetic effects on fertilisation or embryo viability. It would not be wise to speculate on such from the data available here, however the effect has been accounted for in the models when examining the differences due to other factors.

The matings here were quite atypical of normal AI matings in that for some programs there was only one round of inseminations due to the time of calving being out of phase with normal management to satisfy the experimental design. Thus the co-operator did not want to have too many calves at a different time to the main herds. Many of these matings did not have backup paddock matings. In other cases where backup bulls were used, the cows not conceiving to the AI matings were removed at pregnancy test time and the calving results were not known. Thus the analyses for these herds were restricted to the proportions of cows pregnant to 1 or 2 cycles of AI.

The drought conditions prevailing for most of the duration of the CRC study almost certainly affected the success of these AI matings. Rainfall was below the long term average in 3 of the 4 years of the study, often requiring supplementary feeding of the breeding cows and the progeny that were the main focus of the study. The matings in January of 2001 and 2002 were done in quite hot weather and the cows were not in as good body condition as would be preferred for AI programs. However this was unavoidable as the design of the ‘Regional Combinations’ experiment required the matings to be carried out at these times.

4.4.5 Summary – all sites

The effects examined above in the herds at the different sites are summarised in the charts below. Effects due to age/parity of cow and the effect of the previous year’s calving status on the current performance are the only consistent effects common to all sites, apart from the effect of liveweight and body condition at mating. Other significant effects were specific to the experimental design of the individual sites.

The effect of age at mating on the total proportions of cows calving and those calving in the first 2 cycles is shown in Figures 4.4.1 and 4.4.2.

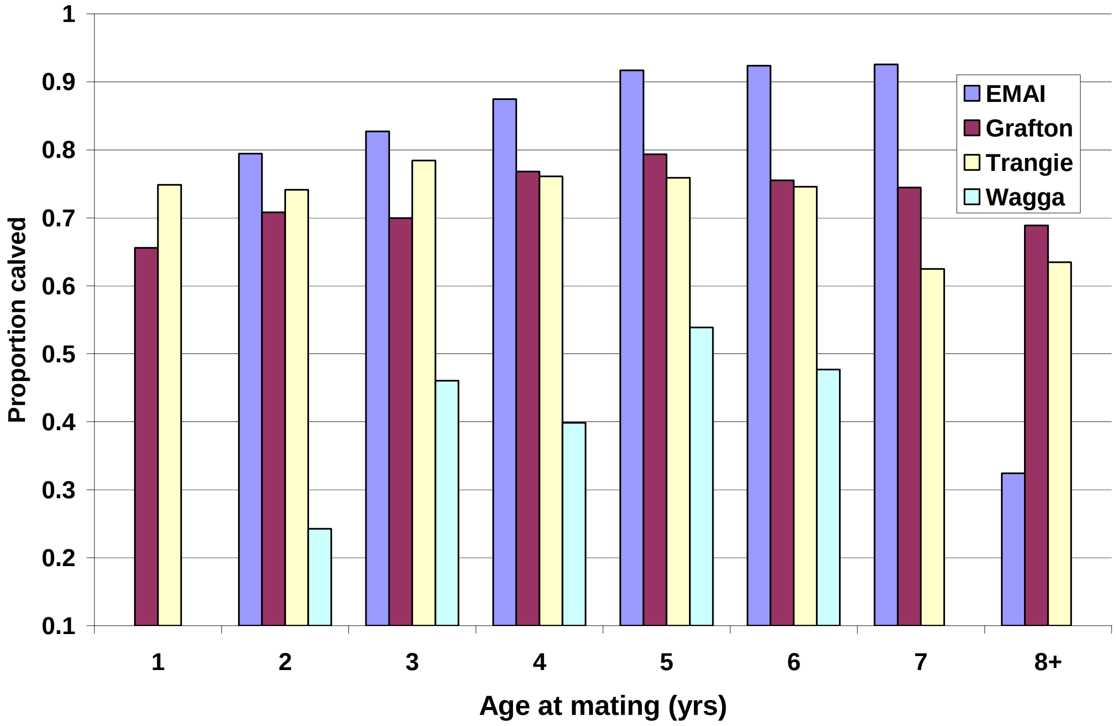

Figure 4.4.1. Predicted means for total proportions of cows calving across all sites as affected by age at mating.

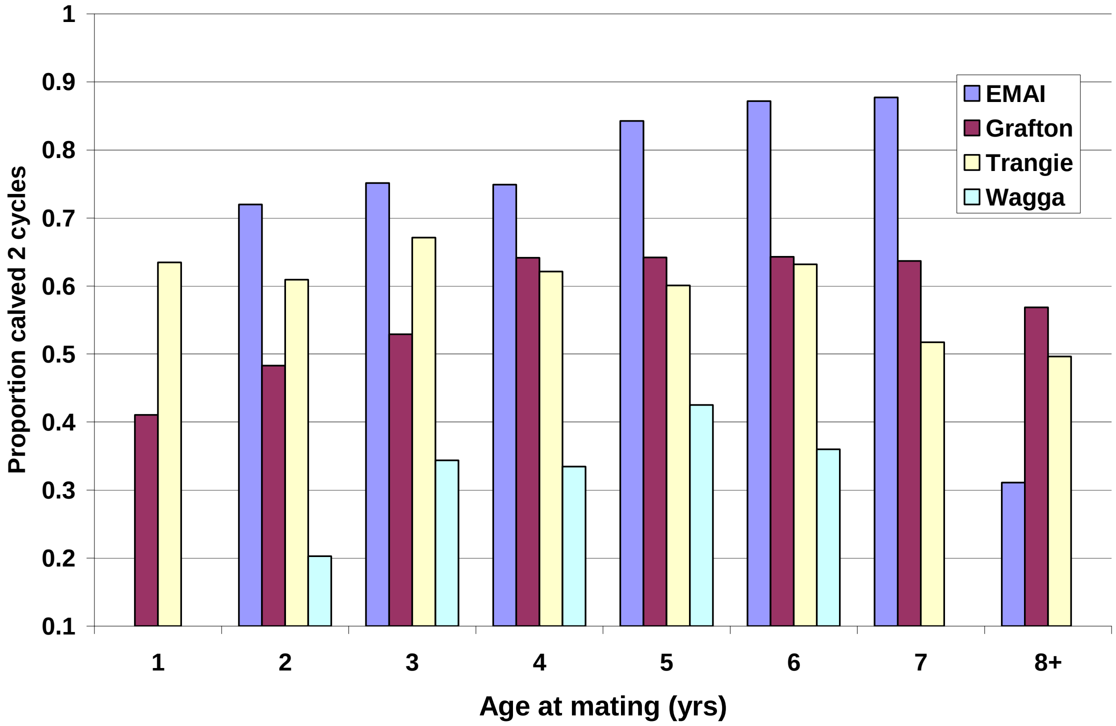

Figure 4.4.2. Predicted means for proportions of cows calving within 2 cycles across all sites as affected by age at mating.

Figures 4.4.1 and 4.4.2 show a consistent trend of increasing reproductive performance with age, reaching a maximum over ages 5, 6 or 7, and declining thereafter. This is consistent with the literature and previous reports using smaller samples of cattle from these herds (Parnell *et al.* 1994; Barlow *et al.* 1994).

The effect of calving in the previous year on the total proportions of cows calving and those calving in the first 2 cycles in the current year is shown in Figures 4.4.3 and 4.4.4.

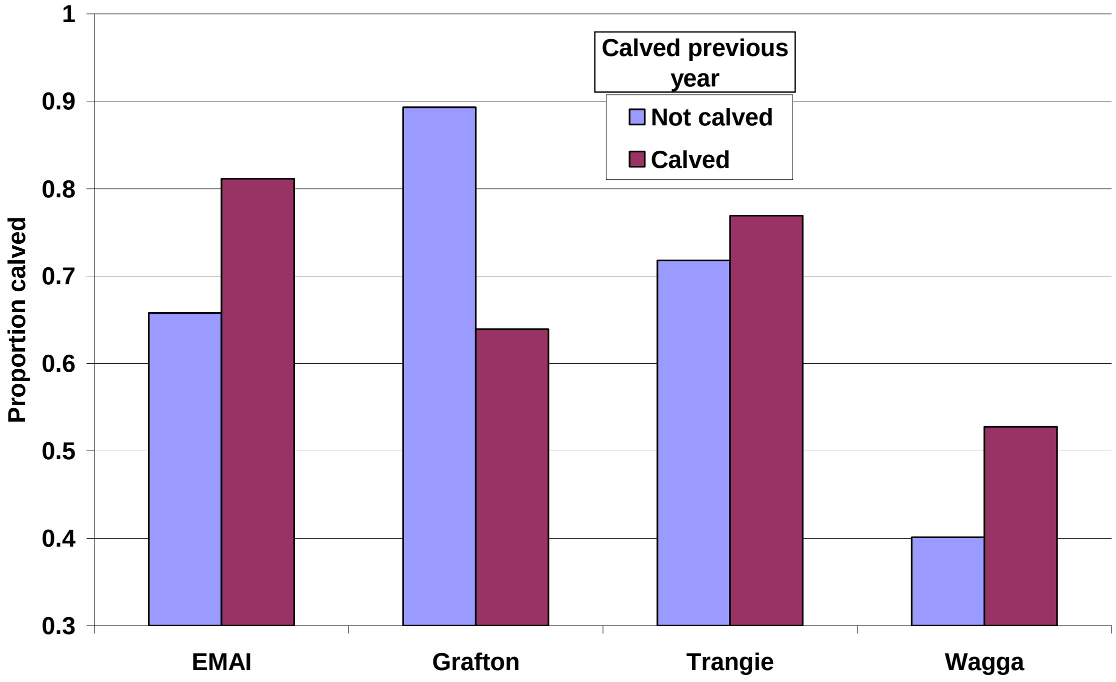

Figure 4.4.3. Predicted means for total proportions of cows calving across all sites as affected by success in previous calving season.

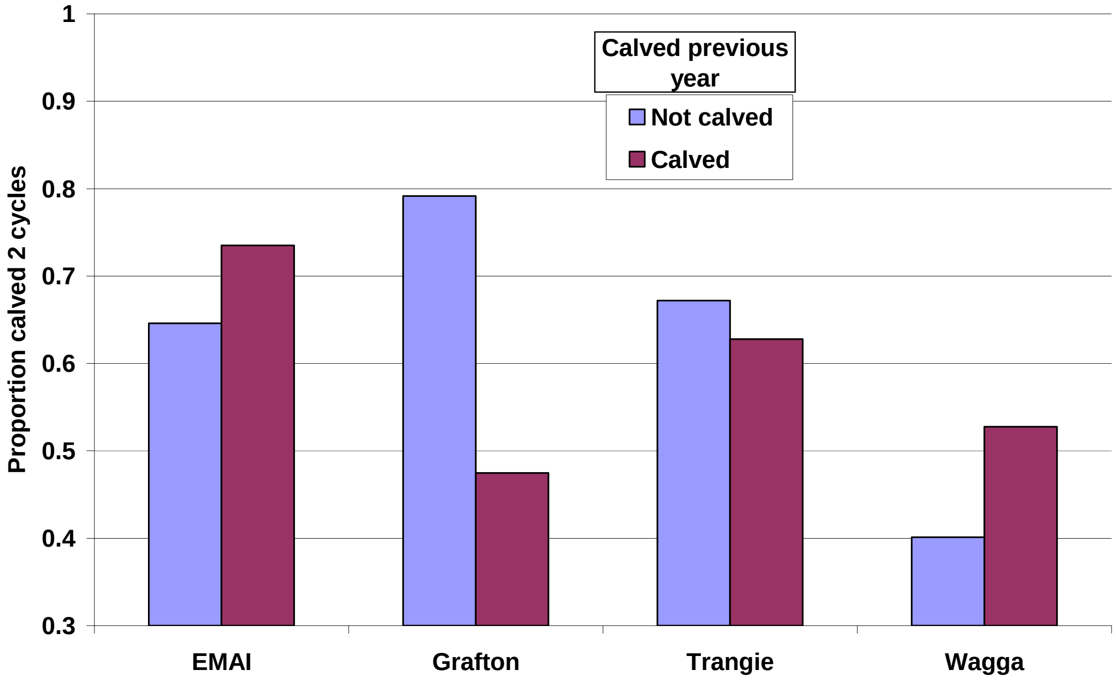

Figure 4.4.4. Predicted means for proportions of cows calving within 2 cycles across all sites as affected by success in previous calving season.

The results shown in Figures 4.4.3 and 4.4.4 indicate a positive effect of calving in the previous year on total proportions calving in 3 of the 4 sites. The Trangie site showed an advantage to those not calved in the previous year for pregnancy to the first 2 cycles.

4.5 General discussion

Liveweight/body condition

The effect of liveweight/body condition on pregnancy was a strong feature of the results, as commonly reported in the literature. This is somewhat a continuous loop throughout the reproductive life of breeding females. The attainment of puberty is dependent of reaching certain liveweight (rather than age), which can be best defined by a proportion of potential mature size, as discussed by McGowan and Holroyd (2008) and Fordyce (2006). Status at first mating affects the chance of first pregnancy; status at first calving affects post partum performance and thus status at second mating. This in turn affects chance and timing of second pregnancy; status at second calving affects status at next mating and chance and timing of pregnancy - and so on for successive matings till the cow is culled or dies. The intervals from calving to next pregnancy (and thus inter-calving intervals) are highly dependent on these body status cycles, and this affects the total number of pregnancies achieved in the lifetime of a breeding cow. Cows calving late or in poor body condition have a lower chance of success at the next joining, and thus a greater chance of missing a year of calf production. Dry cows are a serious drain on herd production costs.

Previous performance

Previous calving performance has direct effects on the liveweight/body condition 'loop' described above. However, there was also an independent effect that was significant when body status was accounted for as a co-variate. This was a positive effect in most cases – cows pregnant last year had a higher chance of repeating this year than those dry last year in 3 of the 4 sites examined. Since last year's pregnancy would be likely to result in poorer body status for this year's mating (unless compensated by additional nutritional management), this result suggests a genetic effect of inherently higher fertility. However, it may also have a component due to different management conditions that are difficult if not impossible to identify.

First and second matings

Lower fertility at first and second mating/calving is a common observation in many herds. The former is mainly due to failure to reach required liveweight if mated before 2 year old. The latter is usually a result of these females being unable to regain sufficient liveweight/body reserves after their first calving and during their first lactation. The situation is exacerbated by conditions of poor nutrition such as experienced in northern Australian herds where this is a major factor of low herd reproductive rates (Schatz and Hearnden, 2008; Entwistle, 1983), although that may also have a genetic component due to the *Bos indicus* breeds predominating the area. The effect of poor nutrition is supported by the results here and those previously reported by Barlow *et al.* (1994) for the Grafton herds. A decline in performance from first to second mating was not seen in general in the analyses here except for lower performance in the proportions pregnant to 2 cycles in the Trangie herds. Management may have compensated for the otherwise effects on liveweight, allowing good first mating results and minimising the effect of first pregnancy on the second mating. Performance to first and second matings was always lower than for subsequently matings.

Liveweight/frame size

In combination with liveweight and body status, fertility at first and subsequent parities may also be affected by frame size. These parameters of body measurement are correlated since frame size is assessed by height at a given age, which is well related to liveweight. Buttram and Willham (1989) suggested that small cows are in fact reproductively more efficient in terms of calving rate than larger cows when managed similarly. Although there was confounding in their experiment between size and breed, these authors proposed that in practical situations any change in the size of animals in the herd is usually achieved only by altering breed composition. However, selection for yearling growth at Trangie within Angus cattle resulted in smaller animals in the downward line, which were in fact less fertile than controls or those in the upward line (Parnell *et al.* 1994; Archer *et al.* 1998). Buttram and Willham (1989) also concluded that differences in reproductive efficiency between size or breed groups were exacerbated by unfavourable management conditions. This is consistent with the results from the Grafton herds reported here and previously by Barlow *et al.* (1994).

Age/parity

In all cases the performance during the first or first 2 matings was lower than those subsequently, before the eventual decline during the final years of the cows' reproductive life. Figures 4.4.1. and 4.4.2 show the general rise in proportions calving after matings at ages 2 and 3, reaching a maximum over ages 5, 6 or 7, and declining thereafter. The shape of the response to age and fluctuations at each site were affected by culling policy but the general trends were quite consistent across sites.

Genetic effects

Apart from the suggestion mentioned above, the examination of genetic effects was limited to comparisons within site of the performance of groups of cows having divergent selection for different traits. In each case – selection for yearling growth rate, net feed intake (not analysed but discussed here) or body conformation (muscling) – there were no indications of negative effects on fertility due to the selection *per se.* In the case of the yearling growth selection herd, there was an indication of lower fertility in the low growth line, but this was probably explained by the effect on liveweight. These are important outcomes for the industry since producers can be hesitant to adopt selection for specific traits until they are sure there will be no negative correlated effects.

Breed

The opportunity to explore differences in fertility that could be attributed to breed effects was restricted to the Grafton crossbred herds. It is difficult to make valid comparisons between purebred herds even in experimental situations. In fact there were no situations here where purebred herds were managed under identical conditions. Even if management conditions are made as equivalent as possible, the degree of ‘representativeness’ of the herd to the breed is always contentious. The maximum potential of any breed may be estimated by providing the best possible conditions, but this is unlikely to be the situation under which the animals are required to perform in commercial production. Thus the results from the crossbred herds at Grafton provide estimates of the ‘breed’ effects that may be applicable for varying management systems. The better performance of the crossbred genotypes was evident in most cases, with the Brahman cross showing the ability to do well under the poorer nutritional conditions. Although not new, this is an important message for beef producers in sub-tropical environments with low to marginal quality feed, as pointed out by Barlow *et al.* (1994).

Mating system

It is not possible to make direct valid comparisons of success rates for AI versus natural mating from these data, since experiments were not set up to do so in any of the herds here. However, the rates achieved are a snapshot of performance under commercial conditions and in this case with fairly large numbers of cows involved. The constraints of the experimental design for the herds from which the data were drawn also limited the assessment of performance to the AI only as opposed to an AI with backup paddock mating as would normally be the case.

AI has very limited use in the beef industry as a whole, being almost completely confined to seed stock producers. There are recommendations for best practice procedures (e.g. Boothby and Fahey 1995), that have essentially come from the dairy industry in which AI is used widely. However, there are recommendations designed for beef production situations for use of the various hormonal synchrony systems, and these are based on underlying physiological principles that are equally applicable to beef or dairy cows.

Success rates for AI vary widely and are often overestimated, but a realistic estimate of conception rates (defined as successful pregnancies divided by total number of services) from survey data from the dairy industry was proposed by Morton *et al.* (2003) as 51% for the best farmers. Thus the rates observed here are around the expected level. The degree of variation between technicians observed here is also a well known factor among users of the technology.

Year/seasonal variation

Variation between years, not surprisingly, was a large source of variation in the data, having its greatest effect on body status at various times throughout the breeding cycle.

Figure 4.5 shows the huge fluctuations between seasons that producers have to deal with. This was particularly evident in the low nutrition treatments, where the severe drought conditions during the 1980's caused large variation, and there was a general decline in all groups which affected even the high nutrition treatments.

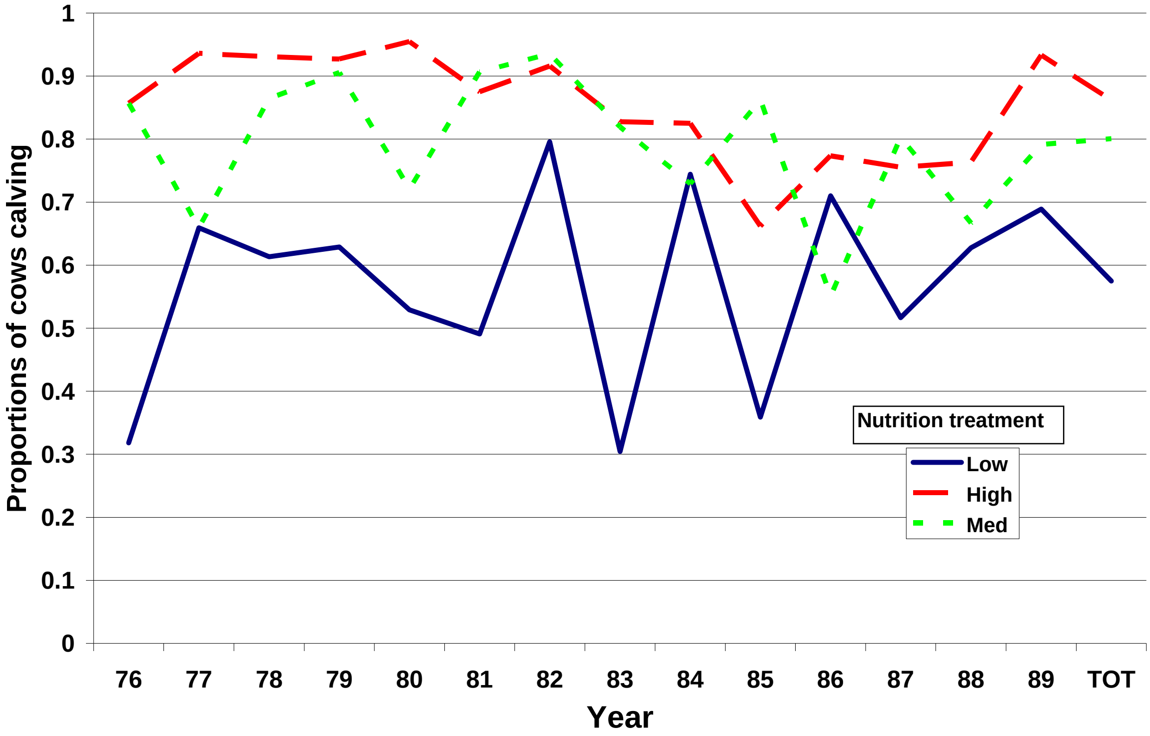

Figure 4.5. Raw data from the herds at Grafton showing the large fluctuation in proportions of cows calving over successive years for the different nutritional treatment groups.

Inter-calving interval

Interval between calvings is a good indicator of herd fertility as can be seen from these results. However, the absolute values can be influenced by the nature of the data available and culling strategy of the herd. For example, there is no interval to the next calving for the year a cow is culled. Thus a cow that fails for 2 or more consecutive years will not be given any larger interval for her last calving than for a cow that was culled (for age or other reason) immediately after a calving year.

5 Success in Achieving Objectives

5.1 All objectives achieved

The objectives of this project were fully achieved ;-

- The data from the various experiments were assembled and stored within 5 new databases with a common table and data structure format.

- This allowed the extraction of the relevant information for analyses to describe levels of fertility and to identify factors influencing performance.

6 Impact on Meat and Livestock Industry – now & in five years time

6.1 Current impact on Meat and Livestock Industry

The major impacts of the work done within this project will be realised by the effects on future research work, which will then filter through to extension to the industry. However the findings here also have immediate direct effects in providing comparative performance levels for various cattle breeding scenarios.

The direct effects of reproduction on profitability of the beef industry were discussed in the background section above. This showed that increasing overall fertility offered potential benefits of ~ $2m or $9.5m, by just small increases of 1 to 5% in branding rates allowing a (conservative) gross value of $50/head for extra calves. Other calculations showed that 5% increase in weaning rates would produce increases of 6.5% to 9.6% in gross margin per cow The demonstration of the effect of spread of calving on profitability at an enterprise level showed a potential difference of up to $71 (gross return) per breeding cow on the value of weaned calves in example scenarios.

A major current and ongoing effect, which is not obvious but extremely important, is to provide a standardised structure for storage of data collected in future research. This allows for easy input, storage and extraction of data for any number of purposes, and makes it easily accessible. The standardised structure now in place means that individuals inputting or extracting data do not need to have intimate knowledge of the original data, although a reasonable understanding of some issues that may affect its use is of course desirable.

The large body of data now captured in an easily accessible form provides the resource for further analysis of many reproductive performance issues that were outside the objectives of this project. The analyses here provide the background for new studies into the factors affecting cattle reproductive performance.

6.2 Future impact on Meat and Livestock Industry – now & in five years time

A major future impact (5 years and beyond) of this exercise is to provide easy access to historical data that will be useful to many and varied cattle production research projects. This may be in the form of using data for validation of future research findings or examining past data to indicate other areas worth investigating, as done here for just a few of the reproductive performance parameters.

The information contained in these databases, and that accumulated into the future, will also be available to generate extension material to demonstrate research findings for the ongoing transfer of technology to the cattle industry.

7 Conclusions and Recommendations

The aim of the project in assembling large bodies of data from various beef research projects and transferring them to a single database format was achieved. This allowed the extraction of data sets for analysis of reproductive performance as projected so that effects due to genetic and non-genetic factors could be assessed.

Genetic effects were small compared to those related to liveweight and age at mating. However, differences in performance of the crossbred genotypes at Grafton confirmed previous reports and are important to the management of crossbred cattle in relation to pasture quality. The trait selection herds examined confirmed that selection for yearling growth rate or for muscularity is of no detriment to reproductive performance. This is an important result for industry in providing confidence for the use of these traits in genetic improvement programs, and the NFI line requires further evaluation.

The strong and consistent associations of liveweight and body condition at mating are far from new findings. However, they reinforce the importance of this vital management issue in ensuring the success of the mating. The means of manipulating management to present the females for mating at appropriate body status remains the challenge. It has also been long recognised that the status at calving will have a major effect on status at the next mating, since the cow must cope with the high metabolic demands of lactation which impacts on her body stores and ability to resume ovarian activity before next mating. The overall energy balance from calving through lactation and leading up to next mating determines her status and subsequent chance of successful mating.

The analysis of the Trangie herd showed that the previous calving had an immediate effect on early conception but the reverse effect on overall pregnancy rate. Thus cows calving in the previous year conceived later but had an overall greater pregnancy rate for the total mating. The earlier conceptions were probably due to better body status at mating resulting from the lack of lactation drain for those cows. This trend was not evident in the other herds examined but may have been compensated by remedial management and requires further investigation.

The effects seen in proportions of cows pregnant in the first 2 cycles are important to overall reproductive efficiency since they are expressed in the spread of calving for the current breeding season and will affect the rate and pattern of pregnancy in the next. Spread of calving in the herd has significant impacts on the profitability of beef breeding enterprises as demonstrated by the spreadsheet calculator described here.

Recommendations

The analyses that were able to be completed within this project highlighted that the data set potentially has much more to yield if funding and staff resources are available. For example, the issue of repeatability of calving performance, as indicated by the effect of previous calving in the analyses, could be further examined in greater detail. Data from the NFI line at Trangie warrants further examination as the effects on reproduction for such selection is very important to industry.

The effect of calving spread caused by variation in proportions of cows pregnant in the first 2 cycles should be highlighted in extension programs that deal with cow/calf breeding enterprise production and profitability. The management of the cow herd to optimise liveweight and body condition throughout the breeding cycle must however remain the key issue of awareness.

8 Bibliography

ABARE (2004). Australian Beef Industry 2004, Australian Bureau of Agricultural and Resource Economics Research Report 04.2, Canberra.

Archer JA, Arthur PF, Parnell PF, van de Ven RJ (1998) Effect of divergent selection for yearling growth rate on female reproductive performance in Angus cattle. *Livestock Production Science* **57,** 33-40.

Arthur PF, Herd RM, Wilkins JF, Archer JA (2005) Maternal productivity of Angus cows divergently selected for postweaning residual feed intake. *Australian Journal of Experimental Agriculture* **45 (7-8),** 985-993.

Aylon N (1978) A review of embryonic mortality in cattle. *Journal of Reproduction and Fertility* **54,** 483-493.

Barlow R, Hearnshaw H, Arthur PF, Darnell RE (1994) Evaluation of Hereford and first-cross cows on three pasture systems. I. Calf growth and reproductive performance of young cows. *Journal of Agricultural Science, Cambridge* **122,** 121-129.

Black JL, Scott L (2002) More beef from pastures – current knowledge, adoption and research opportunities. Final Report – Project SBP.004. Meat and Livestock Australia Limited (ISBN 1 74036 0524 4), September 2002.

Boothby D, Fahey G (1995) Artificial Breeding of Cattle. Agmedia, East Melbourne (ISBN 0 7306 6427 9).

Buttram ST, Willham RL (1989) Size and management effects on reproduction in first-, second- and third-parity beef cows. *Journal of Animal Science* **67,** 2191-2196.

Diskin MG, Sreenan JM (1980) Fertilisation and embryonic mortality rates in beef heifers after artificial insemination. *Journal of Reproduction and Fertility* **59,** 463-468.

Drost M, Ambrose J, Thatcher M, Cantrell C, Wolfsdorf K, Hasler J, Thatcher W (1999) Conception rates after artificial insemination or embryo transfer in lactating dairy cows during summer in Florida. *Theriogenology*, **52 (7),** 1161-1167.

Dunne *et al.* (2000) cited by McGowan MR, Holroyd RG (2008).

Entwistle KW (1983) Factors influencing reproduction in beef cattle in Australia. *AMRC Review* **43,** 1-30.

Fordyce G, Burns BM, Holroyd RG (2005) Minimising pregnancy failure and calf loss. NBP 0.336 Meat and Livestock Australia, Sydney.

Fordyce G (2006) Practical strategies to reach target mating weight in north Austrain beef heifers. In: *Proceedings of the Australian Cattle Veterinarians 2006* – Hobart and Port Macquarie Conferences (November 2006) pp. 142-152.

Fordyce G, Entwistle KW, Fitzpatrick LA (1994) Developing cost effective strategies for improved fertiltity in *Bos indicus* cross cattle. Final Report: Project NAP2/DAQ.62/UNQ.009, Meat Research Corporation, Sydney.

Genstat 11 (2008) Release 11.1 for Windows XP, VSN International Ltd, United Kingdom.

Graham J (1995) Management of beef breeding cows. Agricultural Notes, AG0112 Department of Natural Resources and Environment, State Government, Melbourne, Victoria.

Hennessy DW, Wilkins JF (2005). Efficiency of calf production from twin-bearing beef cows on an intensive pasture system in subtropical Australia. Asian-Australasian Journal of Animal Science 18 **(12):** 1735-1740.

Johnston DJ, Bunter KL (1996). Days to calving in Angus cattle: genetic and environmental effects, and covariances with other traits. *Livestock Production Science* **45:** 13-22.

Johnston DJ, Barwick SA, Holroyd RG, Fordyce G, Burrow HM (2006) Genetics of female reproduction traits. In: 'Australian Beef – the Leader, Impact of Science on the Beef Industry'. Cooperative Research Centre Conference, pp 47-52, Armidale, NSW, 7-9 March, 2006.

Lucy MC, Savio JD, Badinga RL, De La Sota RL, Thatcher WW (1992) Factors that affect ovarian follicular dynamics in cattle*. Journal of Animal Science* **70,** 3615-3626.

McFadden AM, Heuer C, Jackson R, West DM, Parkinson TJ (2004) Reproductive performance of beef cow herds in New Zealand. *New Zealand Veterinary Journal* **53,** 39-44.

McGowan MR, Holroyd RG (2008) Reproductive inefficiencies and opportunities in dairy and beef cattle in Australia. *Animal Production in Australia* **27,** 1-9.

McKiernan WA, Robards GE (1996) The repeatability of muscle score in beef animals between birth and twenty months of age. *Proceedings of the Australian Society of Animal Production* **21**, 151-154.

McKiernan WA, Robards GE (1997) *Proceedings of the Association for Advancement of Animal Breeding and Genetics* **12,** 77-80.

McKiernan WA, Wilkins JF, Barwick SA, Tudor GD, McIntyre BL, Graham JG, Deland MPD Davies L (2005) CRC 'Regional Combinations' Project – effects of genetics and growth paths on beef production and meat quality: experimental design, methods and measurements. *Australian Journal of Experimental Agriculture* **45 (7-8),** 959-969.

McKiernan WA, Wilkins JF, Graham JF, Tudor GD, Deland MPB, McIntyre BL, Orchard B, Walkley JRW, Davies L, Griffith GR, Irwin J (2007). Regional Beef Systems to Meet Market Specifications. Final Report to Meat and Livestock Australia and CRC for Cattle and Beef Quality (MLA project SBP.006V2 / CRC project 3.3.2 "Regional Combinations")

McKiernan WA, Richardson Emma, Wilkins JF (2004) Effect of selection for increased muscling on early female reproductive potential. *Animal Production in Australia* **25:** 283.

McMillan KL, Clayton DE (1980) Factors influencing the interval to post-partum oestrus, conception date and empty rate in an intensively managed dairy herd. *Proceedings of the New Zealand Society of Animal Production* **40,** 236-239.

Meyer K, Hammond K, Parnell PF, McKinnon MJ, Sivarajasingam S (1990) Estimates of heritability and repeatability for reproductive traits in Australian beef cattle. *Livestock Production Science* **25,** 15-30.

Morton J, Larcombe M, Little S (2003) *The In Calf book for dairy farmers.* Dairy Australia, Melbourne.

Morris CA, Amyes NC (2005) Response to selection for age at puberty in an Angus herd. *Proceedings of the Association for Advancement of Animal Breeding and Genetics* **16,** 157-160.

Nguyen TX, Hinch GN, Wilkins JF (1998) The effect of ovarian dynamics on conception rate to artificial insemination in Angus cows. *Proceedings of the Australian Society of Animal Production* **22:** 405.

Parnell PF, Arthur PF, Barlow R (1997) Direct response to divergent selection for yearling growth rate in Angus cattle. *Livestock Production Science* **49,** 297-304.

Parnell PF, Herd RM, Perry D, Bootle B (1994) The Trangie experiment – Response in growth rate, size, maternal ability, reproductive performance, carcase composition, feed requirements and herd profitability. *Proceedings of the Australian Society of Animal Production* **20**, 17-26.

Randel RD (1990) Nutrition and postpartum rebreeding in cattle. *Journal of Animal Science* **68**, 853-862.

SCA. 1990. Feeding Standards for Australian Livestock: Ruminants, CSIRO Publications: East Melbourne, Australia.

Schatz TJ, Hearnden MN (2008). Heifer fertility on commercial cattle properties in the Northern Territory. *Australian Journal of Experimental Agriculture* **48,** 940-944.

Sreenan JM, Diskin MG (1986) The extent and timing of embryonic mortality in the cow. In: *Embryonic Mortality in Farm Animals.* J.M. Sreenan and M.G. Diskin (Eds). Martinus Nijhoff, Dordrecht. pp.1-11.

Wilkins JF, Hennessy DW, Cummins LJ, Hillard MA (1992) Twin calves for commercial beef production in Australia. *Yamaguchi Journal of Veterinary Medicine* **19,** 67-72.

Wilkins JF (2006) Constraints to Reproductive Efficiency in Southern-Australian Beef Herds. In: *Proceedings of the Australian Cattle Veterinarians 2006* – Hobart and Port Macquarie Conferences (November 2006) pp. 153-162.

Wilkins JF, Hoffman WD (1997) Estrus, ovulation and conception rates in cows following stimulation/synchrony treatment, in relation to prior ovarian activity. Proceedings of the Australian Society for Reproductive Biology **28**, 99.

9 Appendices

9.1 Appendix 1

Examples of the data fields in sample database tables.
The records contained in each of the data sets vary in the types and number of fields that are relevant, due to the differing nature of the original aims of the experiments involved. However, all databases contain data that can be used to examine the parameters of fertility of interest to this study.

Sample database tables are presented below as examples of the format of the records contained in the new database in the tables that relate to reproductive performance. As mentioned above there are many other tables that contain other live and carcass data for the animals recorded. Specific sub-sets of data can be extracted from the central source to provide the records relevant to any particular analyses.

Appendix Table 1.1 - 'animal' Table – main relational reference table

Table	Col#	Col Name	Type	Nulls	Size
animal	1	animalid	varchar	Yes	10
animal	2	Tag	varchar	Yes	50
animal	3	tag_colour	varchar	Yes	50
animal	4	prev_tag	varchar	Yes	50
animal	5	prev_tag_colour	varchar	Yes	50
animal	6	prev_tag_date	date	Yes	4
animal	7	collar	varchar	Yes	50
animal	8	brand	varchar	Yes	50
animal	9	breed_code	varchar	Yes	10
animal	10	breedsocietyid	varchar	Yes	50
animal	11	damid	varchar	Yes	10
animal	12	sireid	varchar	Yes	10
animal	13	origin_herd	varchar	Yes	50
animal	14	selection_code	varchar	Yes	10
animal	15	sire_group	smallint	Yes	2
animal	16	sex_code	char	Yes	1
animal	17	birth_year	smallint	Yes	2
animal	18	birth_date	date	Yes	4
animal	19	birth_type	smallint	Yes	2
animal	20	birth_code	smallint	Yes	2
animal	21	conception_date	date	Yes	4
animal	22	new_damid	varchar	Yes	10
animal	23	inbcof	varchar	Yes	50
animal	24	generation	varchar	Yes	50
animal	25	selected	varchar	Yes	10
animal	26	name	varchar	Yes	50

Appendix Table 1.2 - 'ai_mating' Table

Table	Col#	Col Name	Type	Nulls	Size
ai_mating	1	matingid	serial	No	4
ai_mating	2	animalid	varchar	Yes	10
ai_mating	3	aidate	date	Yes	4
ai_mating	4	aitime	smallint	Yes	2
ai_mating	5	animal_type	varchar	Yes	10
ai_mating	6	calving_year	smallint	Yes	2
ai_mating	7	location_code	varchar	Yes	20
ai_mating	8	technician_code	varchar	Yes	10
ai_mating	9	attempt_number	integer	Yes	4
ai_mating	10	aisireid	varchar	Yes	10
ai_mating	11	score	char	Yes	10
ai_synchronisation	1	matingid	integer	Yes	4
ai_synchronisation	2	synchronisation_date	date	Yes	4
ai_synchronisation	3	synchrony	varchar	Yes	30

Appendix Table 1.3 - 'pregnancy_test' Table

Table	Col#	Col Name	Type	Nulls	Size
pregnancy_test	1	animalid	varchar	Yes	10
pregnancy_test	2	test_date	date	Yes	4
pregnancy_test	3	animal_type	varchar	Yes	10
pregnancy_test	4	calving_year	smallint	Yes	2
pregnancy_test	5	test_type	varchar	Yes	10
pregnancy_test	6	technician_code	varchar	Yes	10
pregnancy_test	7	result	char	Yes	1
pregnancy_test	8	joining_cycle	char	Yes	1
pregnancy_test	9	foetus_age	decimal	Yes	tot=9, dec=0

9.2 Appendix 2

Appendix Table 2.1 - gross margin analyses for livestock production provided by NSW DPI Farm Enterprise Budget Series - www.dpi.nsw.gov.au).

Enterpise type	**Value of 5% increase in weaning rate**	**Av GM/cow**	**INCREASE**	**%**
Inland weaner production	21.41	330	0.0648788	**6.5**
EU market	52.67	549	0.0959381	**9.6**
Jap ox market	43.24	566	0.0763958	7.6
Local trade	27.33	312	0.0875962	8.8
Nth coast weaners (improved)	19.05	230	0.0828261	8.3
Nth coast weaners (un-improved)	11.3	126	0.0896825	9.0
Vealer production	26.44	292	0.0905479	9.1
Yearling turnoff	30.29	369	0.0820867	8.2
Heavy feeder production	38.24	445	0.0859326	8.6
Young cattle turnoff (15-20 mths)	33.29	446	0.0746413	7.5

9.3 Appendix

Effect of estrus activity and conception rate on spread in calving time
and subsequently on weaner weights and value, and on cow profit

100 cows / 9 week joining (3 cycles)
(Concept = successful establishment of pregnancy)

Scenario	**Cycle 1**	Nos		Nos		**Cycle2**			New	Accum		**Cycle3**			New	**TOTAL**			
	Estrus	Mated	*Concept*	Calves		*Estrus*	Mated	*Concept*	Calves	Calves		*Estrus*	Mated	*Concept*	Calves	**Calves**			
A	*0.8*	80	*0.75*	60.0		*0.9*	38	*0.75*	28.5	88.5		*1*	12	*0.75*	8.6	**97.1**			
B	*0.5*	50	*0.75*	37.5		*0.7*	48	*0.75*	35.6	73.1		*0.9*	25	*0.75*	19.0	**92.2**			
C	*0.3*	30	*0.75*	22.5		*0.5*	43	*0.75*	31.9	54.4		*0.8*	39	*0.75*	29.0	**83.3**			
	▲		▲																
Enter proportion in estrus			***Enter conception rate***																
		Enter weaning age (mths)				***Enter mean birth wt (kg)***													
		9				***35***												**Total wt**	Av wean
		Enter mean weaning wt 1st cycle calves (kg)																**weaned**	wt
Weaner wt (1st cycle)		***250***		15000	(Nos X wnWt)				6648.4	[Nos x (wnWt-21XgroRt)]					1868			**23516**	242
				9375					8310.5						4121			**21807**	237
Growth rate to weaning			**0.80**	5625					7435.7						6273			**19334**	232
(Calculated)																			
	Calving spread		**A**	**62%**	**(1st cycle)**				**29%**	**(2nd cycle)**					**9%**	**(3rd cycle)**			
			B	**41%**					**39%**						**21%**				
			C	**27%**					**38%**						**35%**				
						Effect on enterprise at weaning time							**A-B**	**Decrease in wt weaned**				**1709**	5
								Enter weaner value ($ per kg)						% decrease				7	2
									$	***1.70***				loss @$	1.70	per kg	$	2906	
														reduction per cow			**$**	**29**	
Other effects on management/returns (not calculated)																			
Extra labour at calving				Loss per cow is on gross return									**A-C**	**Decrease in wt weaned**				**4182**	10
Timing of calf marking				Loss per cow will be greater % of gross margin										% decrease				18	4
Eveneness of weaner lines														loss @$	1.70	per kg	$	7110	
														reduction per cow			**$**	**71**	