final report

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Minimising pregnancy failure and calf loss

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Abstract

This project focused on the capacity of cycling female beef cattle to conceive, maintain a pregnancy and wean a calf in northern Australia. The outcome of this, in association with achieving oestrus, both influence the number and weight, thus value, of calves weaned. Loss of the conceptus before day 18 of gestation, and neo-natal mortality generally account for a majority of post-cycling reproductive wastage. The large variation in these parameters, eg, 30-70% pregnancy rate per cycle and 5-40% neo-natal calf mortality, indicates potential for remedial strategies. Major causes of loss include infectious reproductive diseases, nutritional and environmental factors, and bull factors, with potential significant genetic influences insufficiently understood to be quantified. Benchmarks for fertilisation rates (90%), and embryonic (25%), foetal (3%), neo-natal (5%) and post-natal (1%) losses are proposed. Management recommendations to minimise loss based on current knowledge, and recommendations for research likely to achieve outcomes of practical benefit to the beef industry are presented. The direct benefit to beef businesses in northern Australia by application of such recommendations is estimated to be at least $15M per annum.

Executive summary

To achieve calf output, beef females must first cycle, a bull must achieve impregnation, the conceptus must survive gestation, and the cow must successfully deliver the live calf and suckle it to weaning. Much emphasis has previously been placed on achieving oestrus after calving, a major limitation to achieving reproduction benchmarks. This project has post-oestrus focus as this also affects the number and weight of calves weaned; eg, one NW Queensland observation suggested that a beef producer might increase net returns per breeding female by $15 annually if established pregnancies per cycle could be increased to 70% from estimated prevailing levels of 50%.

Project objectives

- Determine possible causes and level of pregnancy failure and calf loss in northern beef cattle.
- Provide recommendations to reduce current levels of pregnancy failure and calf loss in northern beef cattle.
- Provide recommendations for research to reduce current levels of pregnancy failure and calf loss in northern beef cattle.

Method

A review of international literature was conducted to determine factors that impact on the capacity of female beef cattle to conceive, maintain a pregnancy and wean a calf in northern Australia. Six groups of breeding female cattle (approximately 2,500 cow years studied), representing a range of genotypes and breeding environments in Queensland, were monitored in detail between first oestrus and weaning to establish parameters for pregnancy failure and calf loss.

Significant results

The literature review highlighted that:

- Generally, 90% of cycling females mated to fertile bulls conceive during an oestrus cycle.
- Embryo loss before day 45 of gestation usually accounts for about 75% of total reproductive wastage, with three quarters of this between days 8 and 18 after fertilisation. A benchmark of 50% for established pregnancy rate per cycle was suggested in the literature. Major causes of loss included infectious reproductive diseases, nutritional and environmental factors (that affect folliculogenesis and ova viability), and male factors (sperm attributes; bull behaviour and management), with potential genetic influences insufficiently understood to be quantified.
- Losses between confirmed early pregnancy and weaning in ideal northern Australian situations averages approximately 9%. Losses in the pre-, neo- and post-natal periods can all be high due to a wide range of causes, though infectious diseases and specific nutrient deficiencies appeared most important. Over this period, neo-natal mortalities appeared the highest and most variable, eg, as high as 40%.

Key outcomes from the monitor herd studies were:

- Established pregnancy rates per cycle ranged from 40-70% for most groups of cattle, with no primary factors identified as influencing this rate. However, both pestivirus infection and vibriosis were implicated, though not confirmed causes, in some matings with low pregnancy rates per cycle. Neither *Neospora spp.* nor *Leptospira spp.* present in all herds could be related to losses.

- A NW Queensland herd experienced losses of over 40% in the neo-natal period due primarily to hypovitaminosis A. Excluding this herd, total loss from confirmed pregnancy to weaning was 11%, with neonatal loss accounting for approximately half of this.

Conclusions and recommendations

From the literature review and monitor herd studies, benchmark levels for components of reproductive wastage in north Australian beef herds are proposed as:

Cow may re-conceive within same mating		*Calf usually lost for that year*	
Fertilisation failure	10%	Pre-natal loss (of confirmed pregnancies)	3%
Early embryonic loss	20%	Neo-natal loss (of calving cows)	5%
Late embryonic loss	5%	Post-natal loss (of surviving neo-nates)	1%

The overall effect on calf output depends on rates of cycling and mating management. The literature review, reinforced by results from the monitor herds, indicates that many north Australian herds are not achieving the benchmark levels. Together, they highlight substantial opportunities to reduce calf wastage, with the most significant being to:

- increase the rate of established pregnancy per cycle in breeding female cattle, with specific emphasis on early embryonic mortality.
- reduce neo-natal mortality.

Modelling either embryonic mortality to increase by 20%, or increasing neo-natal mortality rates from 5% to 10% (both realistic industry situations), demonstrated that for a 1,000-cow herd, the impact is a $14,000 reduction in the value of calves weaned; this is due to fewer and smaller calves. Based on only 20% adoption of opportunities developed through recommendations from the project, the direct benefit to beef businesses in northern Australia is estimated to be at least $15M per annum.

To achieve the opportunities highlighted, recommendations were made for adoption of practices based on current knowledge, and for research to provide outcomes that, if applied, would significantly increase both weaning rates and weaner weights. The importance of managing all phases of reproduction were recognised in these recommendations, but with special emphasis on the two primary areas of loss and opportunity to improve as indicated above.

Specific current recommendations to minimise pregnancy failure and calf loss in northern beef cattle included: select females that rear calves to weaning; mate fertile bulls to target low-cost lactation periods; provide adequate nutrition; minimise stress; control infectious reproductive diseases using diagnostics, treatments, and vaccines; prevent dystocia; and control predators.

Research recommendations focused on establishing pregnancy and reducing neo-natal mortality:

- Use research methods that give relatively high security on investment.
- Study the prevalence, cause, and prevention of losses, with emphasis on factors for which there is a reasonable probability of control, eg, infectious reproductive diseases, dystocia, hypovitaminosis A.
- Extend previous studies of semen and sperm attributes, from which practical bull selection strategies may result, and where outcomes consistent across Australia will improve uptake of research outcomes nation-wide.

- Study the mode of action of factors that influence ova and embryo viability and acceptance by the uterus, and develop remedial strategies for negative factors where possible.
- Determine the genetic basis, thus selection opportunities and methods, of male and female effects on all phases of reproduction post-cycling.

Project Team

The project was implemented by a core team, with collaborative scientific and technical support from staff within Qld DPIF and other agencies.

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We also gratefully acknowledge the co-operation of the CRC for Cattle and Beef Quality led by Professor Bernie Bindon and Deputy CEO, Dr Heather Burrow as many of the heifers monitored in this project were part of Project 2.3.

Contents

1 Background

1.1 Project and Industry context

Previous research on reproductive wastage has indicated that maximum pregnancy rate per oestrus is expected to be in the vicinity of 75% (Holroyd *et al*. 1993) and that it may be difficult to consistently reduce losses between confirmed pregnancy and weaning to less than 10% under extensive management conditions in north Australia (Holroyd 1987). The precise reason for pregnancy failure, eg, failure to express behavioural oestrus, fertilisation failure or embryo mortality (due to either the male or female), is very difficult to diagnose as the loss generally occurs by 17 days post-mating, and cycling proceeds as normal. The typically-high levels of pregnancy failure are the reason why matings generally continue for at least 9 weeks when all females are cycling at the commencement of mating, and why pregnancy rates after 3, 6 and 9 weeks of mating are usually not higher than 70%, 90% and 95%, respectively.

Anecdotal evidence from recent observations suggests that depression of weaner weights and weaning rates following extended periods from cycling to established pregnancy and high calf mortality rates in first-lactation heifers may be a more regular feature of the northern beef industry than previously thought.

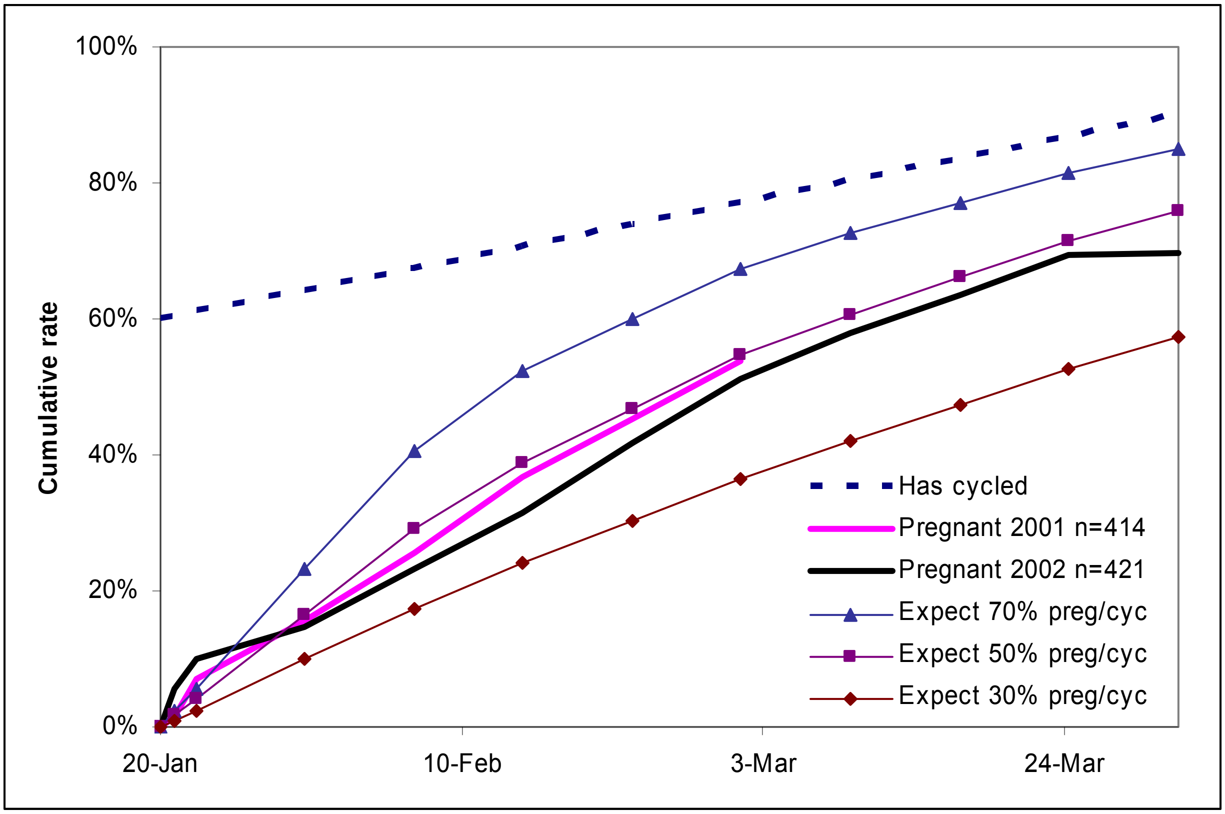
There have been widespread anecdotal reports of losses as high as 50% between confirmed pregnancy and weaning in north Australia in recent times, especially in first-lactation females (Bruce Hill, *pers. comm*. 2005). Others have reported longer-term consistent losses of over 20% in this class of cattle. Recent studies by Stanbroke Pastoral Company and NT DBIRD (Sandi Jephcott, Andrew Brown, and Penelope McGown, *pers. comm*. 2004) indicate that dam behavioural problems may be partially related to high losses.

Figure 1 illustrates percent of females that have cycled (established using ultrasound) and resultant pregnancy patterns (foetal ageing done using ultrasound and manual palpation) in well-grown 2-year-old cross-bred heifers (most over 400 kg and in condition score 4-5 [5-point scale]) at a site north of Julia Creek. Disease status was unknown. Based on the estimates of heifers cycling, and assuming all cycling heifers were mated by fertile bulls (all had passed a standard BBSE), then the pregnancy patterns illustrated in Figure 1 will only occur if the pregnancy rate per cycle was 50%.

The implications are that, in comparison to the potential pregnancy pattern achieved with 70% pregnant per cycle, the average birth date of progeny was about 2 weeks later, even if about 90% of females achieved an established pregnancy in both groups after 3 months mating. This situation results in calves being an estimated 10-15 kg lighter at weaning. For an expected 320 calves from mating 400 heifers, this is about $5,000 less in total calf value at weaning. The financial consequences continue to increase as a result of delayed conceptions in the following year, and reduced value of weaned calves. The cost of delayed conceptions in this simple example is probably in the vicinity of $15 per female mated.

The above example demonstrates the potential for higher financial returns from understanding and ameliorating the losses due to pregnancy failure in north Australia.

Figure 1. Heifer conception patterns on a NW Qld station#



Dotted line indicates estimated percentage of heifers having cycled at least once at that stage of mating. Heavy unbroken lines indicate actual pregnancy rates as determined by foetal ageing. Other lines indicate expected pregnancies with varying pregnancy rate per cycle.

2 Project objectives

1. Determine possible causes and level of pregnancy failure and calf loss in northern beef cattle herds.
2. Provide recommendations to reduce current levels of pregnancy failure and calf loss in northern beef cattle.
3. Provide recommendations for research to reduce current levels of pregnancy failure and calf loss in northern beef cattle.

3 Methodology

The project involved two main activities:

- monitoring of breeding female cattle in representative herds to establish parameters for pregnancy failure and calf loss in northern Australia
- a literature review to establish prevalence and known causes of reproductive wastage in female cattle after commencement of oestrus

3.1 Monitor herds

CRC herds

Brahman and Composite breeding females (n = 1,790; Table 1) aged 2 to 4 years at Belmont Research Station, Brian Pastures Research Station, Swan's Lagoon Research Station, and Toorak Research Station were included in the detailed study (Table 2). These cattle were under study within the CRC for Cattle and Beef Quality Project 2.3. They were vaccinated against campylobacterosis, leptospirosis, pestivirus, and clostridial diseases including botulism. All cattle were mated for 3 months each year to bulls that had passed a BBSE, excluding serving assessment.

Table 1. Numbers of CRC cattle by site, genotype and ages included for monitoring

Year	First	First	Belmont		Brian Pastures	Swan's Lagoon	Toorak	
Wean	mate	wean	Composite	Brahman	Composite	Brahman	Composite	Brahman
2001	2003	2004	111	109	142	186	155	64
2002	2004	2005	138	118	270	218	182	97

Growth of all study animals was monitored. Reproductive tracts of maiden and lactating cows were scanned each 4-6 weeks using real-time ultrasound to determine presence of a CL indicating oestrus cycling and then established pregnancy. Pregnant females were monitored prior to, during, and after calving through to weaning. Time of calving and any difficulties including calf and or cow loss were recorded. Attempts were made to identify the cause of each calf loss. This involved blood and tissue sampling of calves and cows for subsequent assay of potential aetiological agents where possible, with particular emphasis on culture, and antibody detection for the primary reproductive diseases of campylobacterosis, trichomoniasis, leptospirosis, neosporosis, and pestivirus. At one site where major calf losses were experienced, veterinary pathologists were co-opted for detailed investigation to determine the cause of loss.

Table 2. Description of sites where CRC breeding herds were maintained

	Belmont	Brian Pastures	Swan's Lagoon	Toorak
Location	NW of Rockhampton, Central Qld	Gayndah, SE Qld	125 km SW of Townsville, NE Qld	50 km S of Julia Creek, NW Qld
Climate	Dry tropics	Humid sub-tropics	Dry tropics	Dry tropics
Topography	Flat to undulating	Undulating	Mostly flat	Flat
Soils	Alluvial & duplex	Black alluvial & duplex loams	Low-fertility duplex	Fertile black
Vegetation	Cleared open forest	Cleared open forest	Open forest	Grasslands
Grass	Black spear grass dominant	Black spear grass dominant	Black spear grass dominant	Mitchell grass

Commercial herds

Allensleigh Station is located in a dry tropical area 100 km NW of Charters Towers and is representative of the northern forest country. The trial cattle grazed native spear grass pastures in open forest on relatively flat country with low-fertility soils. The 197 individually-identified, non-pregnant, 2-year-old heifers in the study included Brahmans, Brahman x Droughtmaster crosses, and Brahman x European breed crosses. The heifers had experienced very poor seasonal conditions, quite representative for the region, since weaning. They had access to *ad lib* M8U (molasses with 8% urea) through the latter part of the 2003 dry season. The heifers had been vaccinated against botulism.

On 28 November 2003, a representative sample of 101 heifers was intensively sampled during physical measurements of all study heifers. The function of each ovary was determined by ultrasound scanning. A blood sample was collected from each heifer and the serum frozen. The heifers were re-assessed using the same protocol 3 times in the following 7 months.

Mating commenced on 01 December 2003. All bulls passed a full BBSE (25 November 2003). Bulls were only vaccinated against botulism. During mating, bulls were sampled and assayed (using a real-time PCR assay developed in a contemporary project) for the presence of pathogenic *Campylobacter spp.* and *Tritrichomonas spp*. and were found to be negative.

Serum samples were collected pre-mating and subsequently from heifers recording a calf loss. Antibodies to pestivirus and *Neospora spp.* were compared to levels in random samples from heifers that did not conceive or were pregnant.

Bow Park Station, 100 km north of Julia Creek, is also in a dry tropical area, but the cattle graze highly-fertile, black-soil, Mitchell-grass downs. The cattle are Beefmasters, which is essentially a Brahman cross selected objectively for productivity. On the 01 February 2004, 230 2-year-old selected heifers were mated to six similar-age bulls.

Initial measurements at Bow Park were delayed until mid-March as heavy regional rain in mid-January isolated the station. Detailed assessments of heifers, paralleling those at Allensleigh, were conducted on 18 March and 09 September 2004. Disease status of bulls was assessed at the latter muster.

Data analysis

Cycling and pregnancy. For each observation, times of commencement of cycling and established pregnancy were estimated. Results of reproductive tract scans from 1-2 months before mating through to 1-2 months after mating were used. Most scans were conducted each 4-6 weeks. Commencement of cycling was taken as mid-way between the scan when a corpus luteum, albucans or haemorrhagica was detected and the previous scan, as the animal may have commenced cycling at any time between the 2 scans. Time of established pregnancy was calculated from the estimated age of the conceptus at the first confirmed diagnosis of pregnancy.

Animals were grouped within site, year group, genotype, and lactation status at mating. Each mating was divided into 3-week periods (equivalent to the average length of an oestrus cycle) from the start of mating. From dates of commencement of cycling and dates of established pregnancy, the proportion of heifers cycling at least once before the end of mating and the proportions pregnant at the start of mating, and at the end of each 21-day period were calculated for each group. Using the proportions cycling at least once before the end of mating, the percentage expected to be pregnant based on 30%, 50%, and 70% of cycling animals achieving established pregnancy were calculated at the end of each 3-week period. From cumulative curves, an approximate percentage of animals that established pregnancy at each cycle was estimated.

Foetal and calf loss. For each of the age x genotype x site CRC groups, foetal or calf losses were determined as being either pre-natal, neo-natal, or post-natal. Neo-natal loss was taken as calf death at or within 2 days of birth or showing illness within that period, and dying within a week of birth. Percentage loss at each time was the number of losses divided by the number of surviving pregnancies/calves prior to the loss period. The use of real-time ultrasound enabled diagnosis of pregnancy from 3 weeks. However, the few losses in the late embryonic period, and the infrequency of scanning (not more than monthly), did not allow us to distinguish late embryonic mortality (LEM), ie, between days 24 and 45 of pregnancy, from pre-natal loss; therefore, all were considered pre-natal losses.

3.2 Literature review

A full review of the literature was conducted focussing on factors that impact on the capacity of female beef cattle to conceive, maintain a pregnancy and wean a calf in northern Australia. The review is prepared as a paper for submission to a scientific journal for publication.

4 Results and discussion

4.1 Monitor herds

CRC herds

The data presented in Tables 3 to 8 (derived from Figures 7 to 30 in the Appendix) show that the average rate of established pregnancy per 21-day period of mating for the CRC females was close to 60% of oestrus females. Most groups averaged in the 40%-70% range. There was a suggestion that the rate was higher in Composite cattle than Brahmans (~10% units difference). The highest pregnancy rates per cycle occurred at Belmont and Brian Pastures. Age and lactation status did not appear to affect the rate.

Overall 5% of confirmed pregnancies were lost before calving (pre-natal), with no obvious effect of age, lactation status or site on levels of loss. Some of these losses could have been neo-natal losses as cows were found to be pregnant prior to calving, and then non-pregnant at the end of calving with no record of having calved.

Excluding the Toorak site, 5% of calves born from surviving pregnancies were lost in the neo-natal period. At Toorak, losses within this category were 12% for calves born in 2003-04, and 41% in 2004-05. Intensive pathology studies revealed that a high percentage of the losses at Toorak were likely to be due to hypovitaminosis A.

Post-natal losses (of calves surviving the neo-natal period) were 2% for the CRC cattle.

Total loss from confirmed pregnancy to weaning, excluding Toorak data, was 11% (170 losses / 1,495 confirmed pregnancies). Within these cattle there appeared to be no difference in loss rates between Brahmans and Tropical composites.

Animals persistently infected with pestivirus were identified within the oldest age group at both Toorak and Brian Pastures (Table 9). They were identified and removed from these herds after initial mating, and were not included in our analyses. Figure 15 indicates that in the initial Brian Pastures mating, pregnancy rate per cycle was approximately 60%. In the contemporary mating at Toorak, established pregnancy rate per cycle was approximately 40% in the Brahmans, but near 60% in the Tropical composites (Figures 23 and 27). The specific impact of pestivirus on both of these herds is not quantifiable as no earlier serology or virology is available, and it is possible that the effects seen may be a function of another agent.

Eleven heifers were culled and slaughtered from the Swan's Lagoon herd after the 2004 mating for failing to rear a calf from the 2003 mating, and then failing to either conceive or maintain pregnancy in 2004. The advent of new real-time PCR tests for campylobacteriosis and trichomoniasis enabled bulls to be assessed after the 2004 mating. One of the 11 heifers that aborted in 2004 was positive to an ELISA test for *Campylobacter* antibody. Bulls mated to CRC heifers were subsequently found to be positive for *Campylobacter*. Only a third of cycling females established pregnancy in the first 3 weeks of the 2004 mating. After this time, pregnancy rates per cycle rose to 50% for non-lactating animals (Figures 20 to 22), but near 70% for lactating animals.

Sampling from all herds indicated presence of Leptospirosis and *Neospora caninum*, though no link with pre-natal loss was confirmed (Table 9).

Table 3. Mating outcome of Composites at Belmont

Start of mating	Dec-02	Dec-03	Dec-03	Dec-03
Age at mating	2	3	3	2
Lactation status at mating	Dry	Dry	Wet	Dry
Average start of mating weight	349	477	443	376
Average start of mating condition (1-5)	2.8	2.9	2.2	2.7
% cycling at start of mating	55%	69%	1%	72%
% cycled at least once by end of mating	98%	100%	94%	98%
% pregnant at end of mating	96%	100%	84%	97%
Estimated established pregnancy rate per cycle	~60%	~80%	~70%	~70%
Numbers				
Mated	138	13	97	112
Pregnant	132	13	81	109
Pre-natal loss	5	0	6	4
Neo-natal loss	7	1	2	6
Post-natal loss	0	0	4	2
Percentages				
Pre-natal loss (of confirmed pregnancies)	4%	0%	7%	4%
Neo-natal loss (of calving cows)	6%	8%	3%	6%
Post-natal loss (of surviving neo-nates)	0%	0%	5%	2%
Total loss (of confirmed pregnancies)	9%	8%	15%	11%
Weaning rate (of confirmed pregnancies)	87%	92%	71%	87%

Table 4. Mating outcome of Brahmans at Belmont

Start of mating	Dec-02	Dec-03	Dec-03	Dec-03
Age at mating	2	3	3	2
Lactation status at mating	Dry	Dry	Wet	Dry
Average start of mating weight	334	451	416	371
Average start of mating condition (1-5)	2.8	3.5	2.3	3.0
% cycling at start of mating	57%	71%	0%	73%
% cycled at least once by end of mating	98%	97%	74%	98%
% pregnant at end of mating	82%	92%	66%	93%
Estimated established pregnancy rate per cycle	~40%	~60%	~70%	~60%
Numbers				
Mated	110	35	74	118
Pregnant	90	32	49	110
Pre-natal loss	6	2	5	8
Neo-natal loss	7	0	3	6
Post-natal loss	3	2	0	0
Percentages				
Pre-natal loss (of confirmed pregnancies)	7%	6%	10%	7%
Neo-natal loss (of calving cows)	8%	0%	7%	6%
Post-natal loss (of surviving neo-nates)	4%	7%	0%	0%
Total loss (of confirmed pregnancies)	18%	13%	16%	13%
Weaning rate (of confirmed pregnancies)	67%	80%	55%	81%

Table 5. Mating outcome of Composites at Brian Pastures

Start of mating	Nov-02	Nov-03	Nov-03	Nov-03
Age at mating (years)	2	3	3	2
Lactation status at mating	Dry	Dry	Wet	Dry
Average start of mating weight	371	419	410	340
Average start of mating condition (1-5)	3.0	3.0	2.2	2.4
% cycling at start of mating	70%	53%	2%	77%
% cycled at least once by end of mating	97%	100%	94%	99%
% pregnant at end of mating	91%	87%	89%	96%
Estimated established pregnancy rate per cycle	~60%	~70%	~60%	~70%
Numbers				
Mated	145	15	125	266
Pregnant	142	13	112	255
Pre-natal loss	6	0	8	13
Neo-natal loss	8	0	4	13
Post-natal loss	3	1	0	1
Percentages				
Pre-natal loss (of confirmed pregnancies)	4%	0%	7%	5%
Neo-natal loss (of calving cows)	6%	0%	4%	5%
Post-natal loss (of surviving neo-nates)	2%	8%	0%	0%
Total loss (of confirmed pregnancies)	12%	8%	11%	11%
Weaning rate (of confirmed pregnancies)	86%	80%	79%	86%

Table 6. Mating outcome of Brahmans at Swan's Lagoon

Start mating	Jan-03	Jan-04	Jan-04	Jan-04
Age at mating	2	3	3	2
Lactation status at mating	Dry	Dry	Wet	Dry
Average start of mating weight	262	358	334	299
Average start of mating condition (1-5)	2.3	3.7	2.6	3.5
% cycling at start of mating	19%	77%	2%	54%
% cycled at least once by end of mating	56%	100%	30%	79%
% pregnant at end of mating	50%	90%	26%	67%
Estimated established pregnancy rate per cycle	~50%	30-50%	30-70%	40-50%
Numbers				
Mated	186	103	81	218
Pregnant	96	93	21	147
Pre-natal loss	3	3	1	0
Neo-natal loss	7	5	1	7
Post-natal loss	5	1	0	1
Percentages				
Pre-natal loss (of confirmed pregnancies)	3%	3%	5%	0%
Neo-natal loss (of calving cows)	8%	6%	5%	5%
Post-natal loss (of surviving neo-nates)	6%	1%	0%	1%
Total loss (of confirmed pregnancies)	16%	11%	11%	6%
Weaning rate (of confirmed pregnancies)	44%	82%	23%	64%

Table 7. Mating outcome of Composites at Toorak

Start of mating	Dec-02	Dec-03	Dec-03	Dec-03
Age at mating	2	3	3	2
Lactation status at mating	Dry	Dry	Wet	Dry
Average start of mating weight	375	456	408	335
Average start of mating condition (1-5)	3.0	3.1	2.5	2.4
% cycling at start of mating	86%	78%	4%	87%
% cycled at least once by end of mating	98%	100%	92%	99%
% pregnant at end of mating	88%	80%	89%	93%
Estimated established pregnancy rate per cycle	~60%	~40%	~70%	~60%
Numbers				
Mated	160	42	112	181
Pregnant	148	34	100	169
Pre-natal loss	13	6	7	7
Neo-natal loss	19	7	30	65
Post-natal loss	1	0	0	0
Percentages				
Pre-natal loss (of confirmed pregnancies)	9%	18%	7%	4%
Neo-natal loss (of calving cows)	14%	25%	32%	40%
Post-natal loss (of surviving neo-nates)	1%	0%	0%	0
Total loss (of confirmed pregnancies)	22%	38%	37%	43%
Weaning rate (of confirmed pregnancies)	72%	50%	56%	54%

Table 8. Mating outcome of Brahmans at Toorak

Start of mating	Dec-02	Dec-03	Dec-03	Dec-03
Age at mating	2	3	3	2
Lactation status at mating	Dry	Dry	Wet	Dry
Average start of mating weight	336	433	410	320
Average start of mating condition (1-5)	2.7	3.1	2.4	2.4
% cycling at start of mating	54%	83%	8%	43%
% cycled at least once by end of mating	83%	100%	92%	92%
% pregnant at end of mating	63%	88%	85%	86%
Estimated established pregnancy rate per cycle	~40%	~30%	~60%	~70%
Numbers				
Mated	64	22	37	97
Pregnant	43	19	31	84
Pre-natal loss	1	2	1	2
Neo-natal loss	3	8	14	44
Post-natal loss	0	0	0	0
Percentages				
Pre-natal loss (of confirmed pregnancies)	2%	6%	3%	2%
Neo-natal loss (of calving cows)	7%	47%	47%	54%
Post-natal loss (of surviving neo-nates)	0%	0%	0%	0%
Total loss (of confirmed pregnancies)	9%	53%	48%	55%
Weaning rate (of confirmed pregnancies)	61%	41%	43%	39%

Table 9. Number of animals testing positive for reproductive disease within selected heifers from CRC herds

Year Group *	History	n	Pestivirus SNT Ab #	Pestivirus PCR for virus	*Neospora* ELISA Ab	*L* hardjo SA Ab	*L* pomona SA Ab	*L* tarassovi SA Ab
August-September 2003: All herds								
Belmont Brahmans								
No.01	Aborted	3	0	0	3	1/1	1/1	0/1
No.01	Poor doer =	1	0	0	1			
No.01	No CL	1	0	0	0			
No.02	Poor doer	1	0	0				
Belmont Tropical composites								
No.01	Aborted	4	0	0	0	1/1	1/1	0/0
No.01	No CL	1	0	0	0			
No.02	Poor doer	4	0	0				
Brian Pastures Tropical composites								
No.01	Poor doer	4	3	1				
No.02	Poor doer	5	2	3				
Swan's Lagoon Brahmans								
No.01	Poor doer	4	0	0				
No.02	Poor doer	6	2	0				
Toorak Tropical composite								
No.01	Aborted	7	6	1				
No.01	Poor doer	2	1	1				
No.02	Poor doer	2	1	1				
Toorak Brahmans								
No.01	Poor doer	1	1	0				
June 2004: Swan's Lagoon								
01&02	Aborted	8	1		1	5	4	
No.01	Dry non-preg	12	2		1	7	8	
No.02	Cyc non-preg	19	2		5	11	8	
September 2004: Swan's Lagoon								
01&02	Aborted	9				2	4	
No.02	Cyc non-preg	19				6	5	
No.02	Non-preg	7				1	1	
No.01	Non-preg	4				0	0	
No.02	Pregnant	17				2	7	
No.01	Pregnant	6				0	1	

* No.01: Born within 2 months of December 2000; No.02: Born within 2 months of December 2001

= Poor doer – Unthrifty animal with low growth rate

L = *Leptospira interrogans* serovar; Ab = Antibody; SNT = Serum neutralisation test; PCR = Polymerase chain reaction; ELISA = Enzyme-linked immunosorbent assay; SA = Serum agglutination

Commercial herds

Allensleigh 2-year-old heifers

The Allensleigh heifers were relatively small following very poor seasonal conditions. Averages (and range) for weight, height and condition score (5-point scale) were 240 (160-350) kg, 122 (109-135) cm, and 2.5 (1.7-3.3), respectively. If average weight at puberty is 300 kg for these heifers (Fordyce *et al*. 1994), then it was expected that a maximum of 20% (if they were growing) would be cycling at allocation. Only 5% of scanned heifers were cycling at allocation, a reflection of on-going poor seasonal conditions. Brahmans were the tallest, and maintained the best condition ($P<0.05$), but were not heavier than the other genotypes (Figure 3). The Brahman crosses were intermediate for body condition and P8 fat depth ($P<0.05$). The European crosses were consistently in the poorest condition ($P<0.05$). Their P8 fat thickness was well below that of Brahman or Brahman crosses ($P<0.05$).

Most pregnancies occurred in the first 100 days of mating. From this time, growth slowed and condition of heifers started to decline. Final pregnancy rate in July was 73% (Figure 2). An estimated 70% of cycling heifers established pregnancy each 21 days (Figure 4). Only one non-pregnant heifer was cycling in July, and this heifer had been pregnant and aborted. Between April and July, 3 Brahmans and 3 Brahman crosses aborted; one of the Brahmans reconceived. From the small number of animals in the study, it is difficult to ascertain that these abortions were related to either pestivirus or *Neospora caninum*, both of which were prevalent in the herd (Table 10).

Figure 2. Established pregnancies (estimated by foetal ageing) by genotype for Allensleigh 2-year-old heifers in 2004

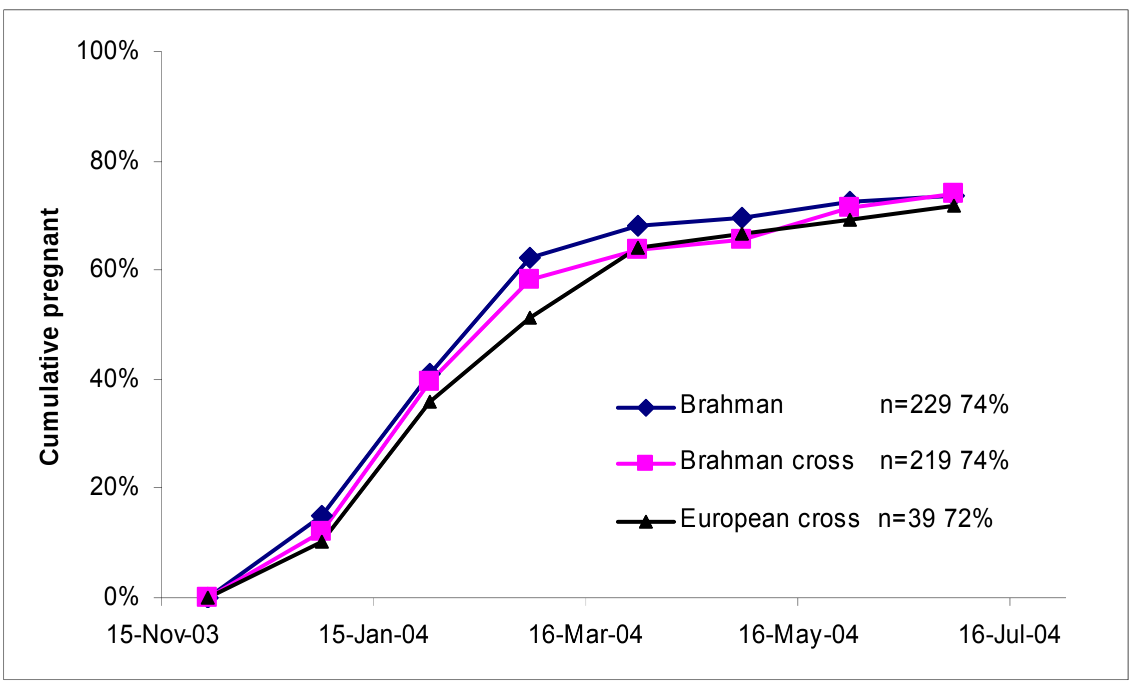


Figure 3. Weight, condition score and height averages for Allensleigh No.02 heifers in 2004

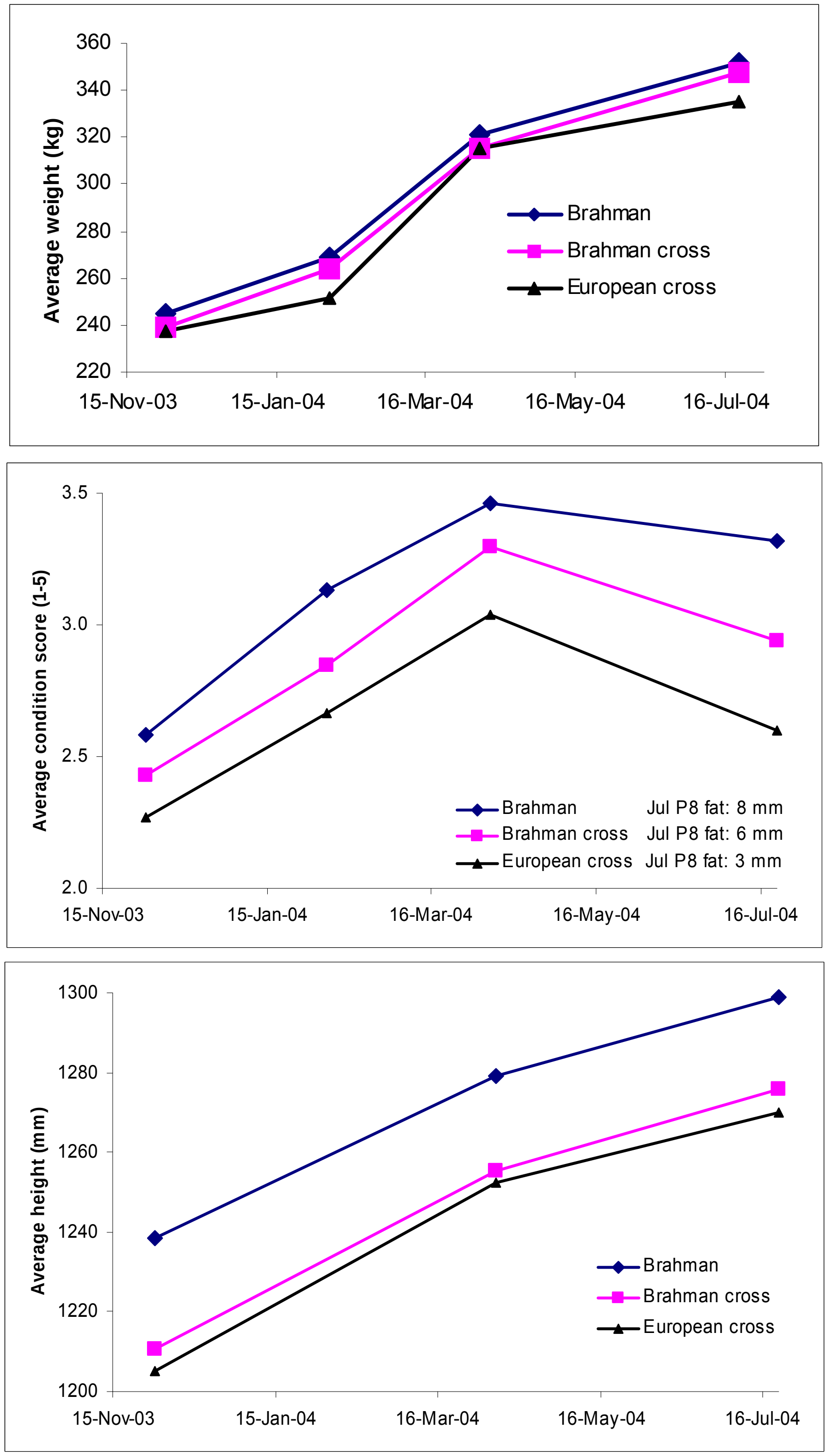
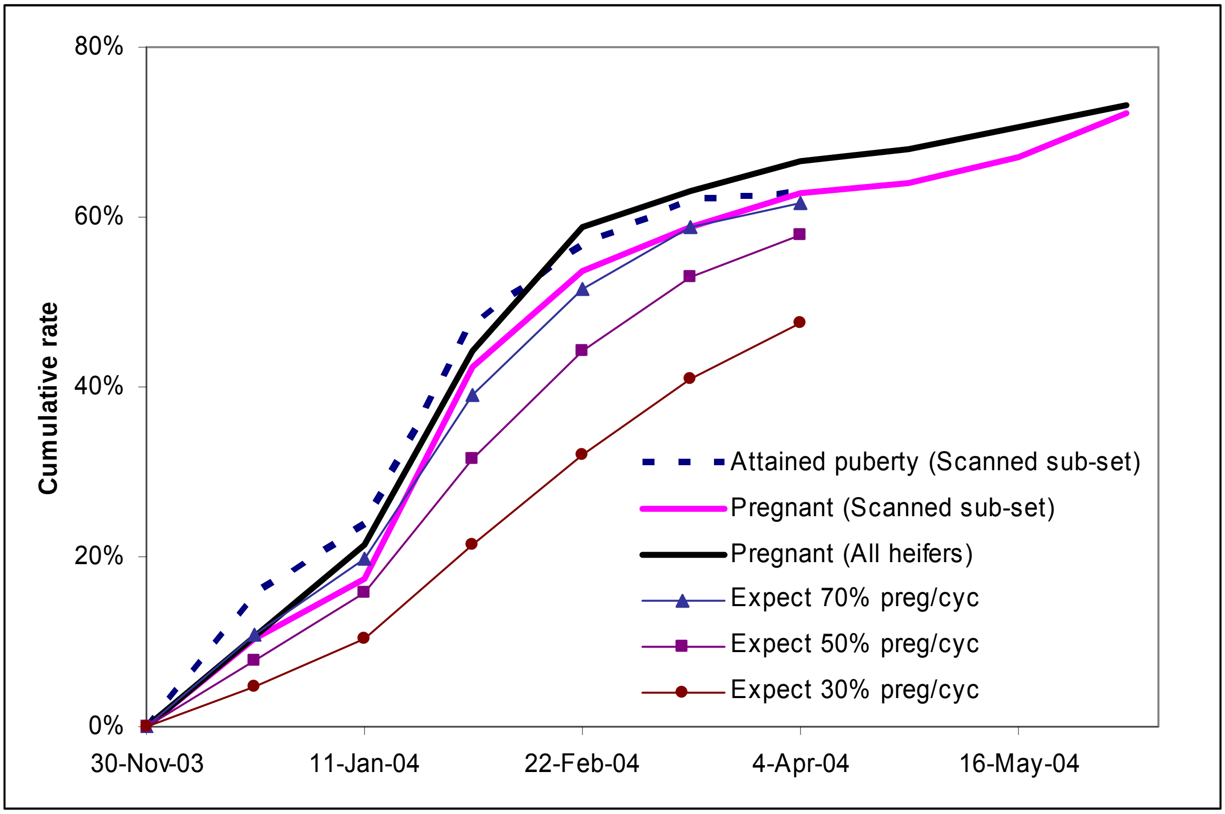


Figure 4. Cycling and pregnancy in Allensleigh heifers in 2004 #



Dotted line indicates estimated percentage of heifers having cycled at least once at that stage of mating. Heavy unbroken lines indicate actual pregnancy rates as determined by foetal ageing. Other lines indicate expected pregnancies with varying pregnancy rate per cycle.

Table 10. Allensleigh heifers positive to pestivirus and Neospora caninum

Class	Bled	Number sampled	Pestivirus *	Neospora #
Pregnant	Pre-mating	10	60%	30%
Empty	Pre-mating	10	60%	20%
	Post-mating	10	70%	20%
Aborted	Pre-mating	4	75%	50%
	Post-abortion	5	80%	60%

* Serum neutralisation test   # Antibody ELISA

Bow Park

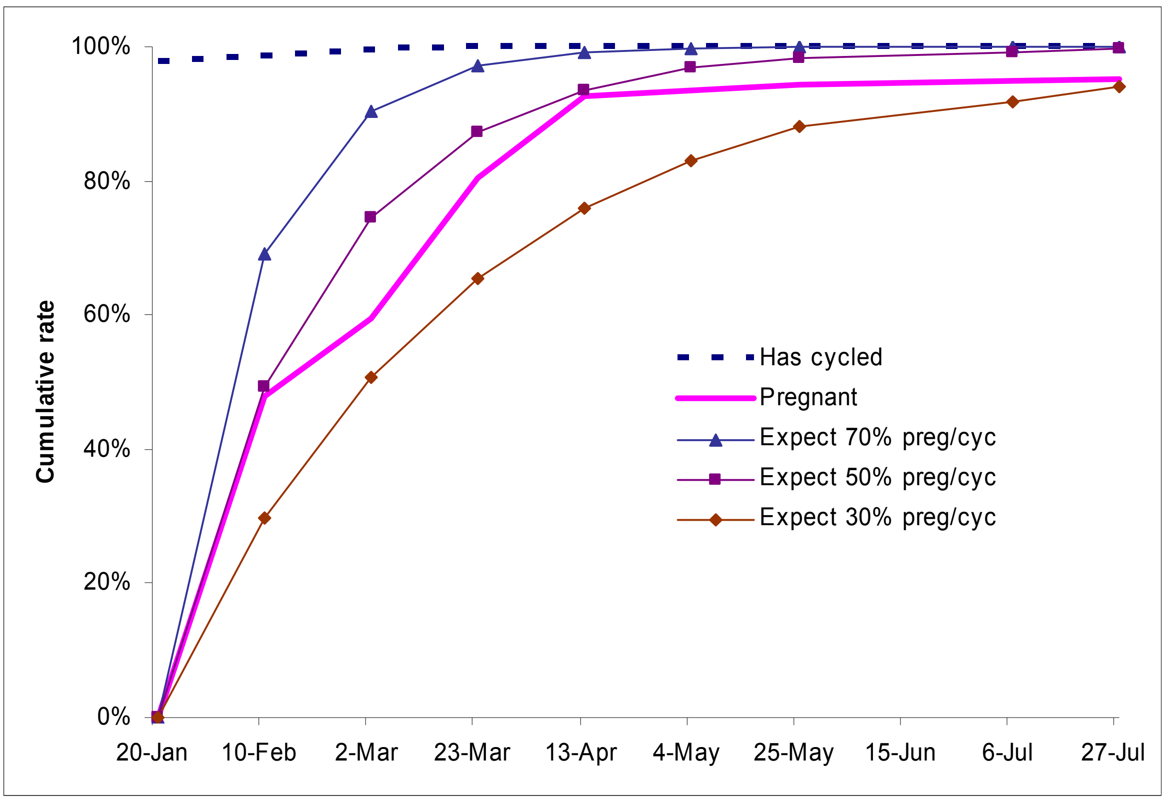
At the initial assessment on 18 March 2004, averages (and ranges) for the Bow Park heifers (2 years of age) were 371 kg (225-498), and 3.7 (2.3-4.7) for weight and condition score (5-point scale), respectively. Average condition score was 3.7 (1.0-4.3) on 09 September at the second and final assessment.

Over 93% of the 230 heifers were either cyclic or pregnant at the 18 March assessment. Only 5 of the heifers appeared to be acyclic. A further 10 had large follicles without CLs, indicating they were most likely about to cycle. By 09 September, 95% of heifers were pregnant, with no abortions from within the group diagnosed pregnant in March.

Pregnancy rate did not plateau for over 100 days (5 x 21-day periods/cycles). It was estimated that fewer than 50% of heifers established pregnancy per cycle (Figure 5.)

Two of the six bulls (2 years of age) in the mating group were found to be infected with *Campylobacter foetus venerealis*, but none were infected with *Tritrichomonas foetus*. Four of 20 (20%) randomly-bled heifers had antibodies to *Neospora caninum*, but no antibodies to pestivirus were detected, despite other age groups on the station having been exposed.

Figure 5. Cycling and pregnancy in Bow Park heifers in 2004 #



Dotted line indicates estimated percentage of heifers having cycled at least once at that stage of mating. Heavy unbroken lines indicate actual pregnancy rates as determined by foetal ageing. Other lines indicate expected pregnancies with varying pregnancy rate per cycle.

In addition to the 230 heifers discussed above, there were 28 heifers in advanced pregnancy in March, courtesy of the neighbour’s visiting bull. Four of these (14%) were non-lactating in September, ie, had experienced calf loss.

Discussion of results from monitor herds

The monitor herds were primarily established to derive levels of pregnancy failure and calf loss in northern herds. The method did not enable us to establish causes of loss except where loss appeared higher than benchmark levels.

With the exception of one herd, the monitor herds were relatively free of infectious diseases, with most losses therefore presumably attributable to non-infectious causes. The cause of high losses have been defined in some cases, eg, hypovitaminosis A was diagnosed for the Toorak herd at Julia Creek where over 40% of calves died within a week of birth. However, across the region there are likely to be many different reasons for losses, including infectious diseases for which efficacious molecular diagnostic tools are only just becoming available. This is highlighted by the possible effects of both campylobacteriosis and pestivirus in delaying established pregnancy in several CRC herds.

The monitor herd data highlights two major areas of loss:

- between cycling and the early embryonic period (ie, days 0-24 of pregnancy). Pregnancy rate per cycle varied between 30% and 70%, with a mode of 60-70%.
- the neo-natal period. Losses varied between 0% and 54%, with a mode of 6%.

In recent times across the dry tropics, from the NT to coastal Queensland, there have been large losses between confirmed pregnancy and weaning reported. In 2004, anecdotal reports indicated losses as high as 40% in large herds (Bruce Hill, *pers. comm*. 2005). Many properties have come to expect high levels of loss, eg, in the vicinity of 20%, especially in first-lactation females. Such losses were evident in only one of our study herds, suggesting that the causes of high commercial loss rates may be:

- factors of low prevalence in the monitor herds, particularly infectious diseases.
- (mal)nutritional factors, as was the cause in one monitor herd.

Of particular interest in our monitoring is that in the absence of significant infectious disease, pregnancy rates per cycle appear to be nearly 10-20% units higher than that accepted as “normal” for intensive beef and dairy production systems throughout the world. That is, extensive production systems appear to offer significant pregnancy rate advantage when oestrus females are mated. International benchmarks for this parameter should not be accepted in north Australia. The corollary is that intensive systems, mostly in temperate regions, may be able to elevate pregnancy rates per cycle by identifying and applying key differences between the systems.

Further perspective on the significance of the loss rates found can be gained from the following section and associate paper.

4.2 Literature review

Literature review synopsis

Factors that impact on the capacity of female beef cattle to conceive, maintain a pregnancy and wean a calf in northern Australia

A synopsis of key aspects of the review is presented here. The review is presented as an attached draft paper for submission to a scientific journal for publication.

The focus of the review is specifically on the ability of cycling female beef cattle to conceive and rear a calf to weaning in north Australia. It does not encompass achieving oestrus, either at puberty or post-partum. Limited research has been conducted in northern Australian on the various components of reproductive losses between cycling and weaning. Therefore, the review draws upon information from international, intensive dairy (main studies) and beef cattle studies to establish possible prevalence levels and causes of losses. The opportunities to minimise losses, thereby improving weaning rates and weaner weights are presented in this synopsis.

The benchmark rate for fertilisation failure appears to be approximately 10% and appears to have relatively-low significance compared to other areas of wastage. If a prevalence significantly higher than 10% is identified, further research may elucidate causes if unknown and practical strategies to ameliorate high rates. However, ability to apply fertilisation failure study techniques under extensive conditions, ie, planned mating, laparoscopy, non-surgical techniques, or slaughter may limit research.

Embryonic loss is a substantial cause of reproductive wastage. Loss of the conceptus before day 45 of gestation usually accounts for 75% of total reproductive loss to weaning, with 75% to 80% of this loss between days 8 and 18 after fertilisation, and about 10-15% around embryo attachment (day 21). New technologies (eg, real-time ultrasound, endocrinological tests, new culture techniques, polymerase chain reaction (PCR) techniques, etc) now offer the opportunity to more easily identify the time and understand and identify the causes (eg, genetic, disease, nutrition, stress, etc) and mechanisms mediating embryonic mortality and to develop strategies to reduce these losses. Methods of diagnosing and managing the known major primary reproductive diseases of campylobacterosis, trichomoniasis, leptospirosis, pestivirus, and neosporosis, which contribute to embryonic, foetal and calf loss, could be developed using these new technologies.

Competence and viability of ova and embryos is established during folliculogenesis. Aspects that may ultimately yield practical strategies to reduce fertilisation failure and embryonic mortality include:
(i) the physiological response to chronic and acute dietary restriction.
(ii) the impact of high environmental temperatures on steroidogenesis.
(iii) modulating (eg, genetically) the number of follicular waves within oestrus cycles.

Sperm attributes impact substantially on fertilisation success and embryo survival. Potential avenues of further research are indicated by studies showing that:
(i) vitamin A deficiency and gossypol adversely affect sperm production, morphology, and function.
(ii) sperm morphology is directly related to conception patterns. The level of genetic variation for this and related traits is unknown.

(iii) compensable and uncompensable semen traits influence both fertilisation success and embryo survival.
(iv) Breed, sire, and sire of dam effects may influence fertilisation failure *versus* embryonic mortality.
(v) sperm chromatin (DNA) structure influences embryonic survival.
(vi) chromosomal abnormalities have been associated with embryo and foetal losses.

Bull behaviour and management influences access of cycling females to fertile bulls, thus ability to fertilise ova. Further developments in this field, and adoption of outcomes in association with bull selection strategies to ensure a high probability of fertility, will enhance fertilisation rates.
The post-insemination inflammatory reaction within the reproductive tract of the cow has a significant influence on spermatozoa and embryo survival. Strategies to manage the impact of this reaction may be developed from understanding its mechanisms. Based on recent work in rodents, studies in cattle might profitably focus on:
(i) cervical and uterine cytokine effects on some or all of the spermatozoa in an ejaculate.
(ii) inflammatory response modulation of the uterine immune system during embryo attachment.
(iii) embryo development and attachment achieved via the inflammatory reaction.

Maternal recognition of pregnancy, with specific emphasis on the cytokine, Interferon-tau (IFN-τ), is central to embryo survival. Embryo losses of 13-15% around the time of maternal recognition of pregnancy (about days 14-19) are probably related to a failure of the anti-luteolytic IFN-τ secretory mechanism. In cattle there are four or five IFN-τ genes that are expressed only in the trophectoderm layer from the time of blastocyst hatching (Days 8-9) until attachment and the specific proteins produced are mediators of this maternal recognition which occurs in the cow around Day 15. Understanding the expression of the IFN-τ genes and their role in maternal recognition and maintenance of pregnancy may provide opportunities to reduce embryonic loss. Specific nutrients may also modulate IFN-τ secretion.

Genetic variation and co-variation exists in and between beef cow and bull reproductive traits. Traits such as puberty, commencement of postpartum oestrus, follicle wave patterns, manifestation of oestrus, luteal competence and level of embryo mortality are under endocrine control which are a result of gene expression at the hypothalamic, pituitary, ovarian or uterine level. Identifying regulatory genes and the mechanisms that trigger their expression may lead to reduced wastage at key stages of reproduction. Many endocrine mechanisms are shared by both males and females, thus providing potential to select in bulls for improved female progeny reproductive rates; this has been demonstrated in limited studies of GnRH secretion in sheep. Differentiation of phenotype class has also been demonstrated in Nellore cattle using random amplified polymorphic DNA (RAPD) markers.

Pre-natal mortality rates beyond day 45 of pregnancy are generally considered to be low in north Australia with sporadic high losses. The primary contributors to sporadic high loss appear to be infectious diseases including pestivirus, leptospirosis, neosporosis, and trichmoniasis. Epidemiological studies will determine appropriate management for these diseases, which includes the need for efficient diagnostic procedures.

Neo-natal mortality rates vary from as low as 3% to over 40% in north Australia. There is a large range of infectious and non-infectious (eg, behavioural, maternal traits) causes. The prevalence of many of factors, and the opportunity to control their impact is poorly understood. There is no reported study of the genetic variation for neo-natal survival.

Vitamin A deficiency following extended dry periods and lack of available green feed can cause substantial neo-natal calf losses. This deficiency was recently identified as the cause of over 40% neo-natal calf mortality on a NW Queensland station. Defining the prevalence of this condition, developing suitable diagnostic methods, and developing effective supplementation and related strategies to ameliorate the deficiency will reduce associated calf wastage in northern Australia.

Dystocia may be a significant cause of neo-natal loss and deaths in young cows in extensive northern Australian herds. Anecdotal reports suggest that yearling mating, ie, to calve at 2 years (often "unplanned" rather than deliberately implemented), especially if combined with the use of large mature size sires or European genotype infused sires in crossbreeding programs, results in dystocia under certain nutritional conditions. Establishing the prevalence of dystocia will facilitate extension of control methods that may also need to be developed specifically for north Australian management situations.

Calf loss beyond a week of birth generally appears low, though sporadic diseases, predation, poor husbandry practices or accidents may elevate loss. It is not clear whether study herds have represented commercial situations where losses could be higher. Inclusion of post-natal loss within studies of foetal and calf loss will further establish prevalence and causes, thus indicating any opportunity or need to develop specific new strategies to overcome such losses.

Reproductive traits in tropical genotypes are repeatable and heritable. *Bos taurus* studies indicate positive genetic correlation between age at puberty and length of lactation anoestrus. A study using tropical cattle reported that heifers selected for high pregnancy rate EBV had a 12% higher pregnancy rate compared to low EBV heifers. The outcome was more earlier-born calves with higher growth and survival, thus a higher-value weaner cohort. This indicates that genetic variation for cow fertility in tropical genotype herds in northern Australia may be high, thus enabling selection to improve overall calf output. Very limited information for tropical Australian genotypes is available to generate multi-breed EBVs and maternal and direct heterosis estimates that may enhance reproductive efficiency, thus genotype improvement in the region. The specific components of reproduction for which genetic variation exists, and the mechanisms of action have not been defined, but are very likely to include aspects of all phases of reproduction.

5 Success in achieving objectives

1. Determine possible causes and level of pregnancy failure and calf loss in northern beef cattle

The literature review (synopsis in Section 4.2; full review as attached draft paper) has identified some of the possible causes of pregnancy failure and calf loss in cattle. Many of these causes have potential direct relevance to north Australian breeding herds. Pregnancy failure and calf loss studied in the 6 herds as part of this project, combined with previous studies in the region, has indicated the importance of infectious diseases, general and specific nutritional deficiencies from before pregnancy through to parturition, and male fertility impacts. In addition to this, genetic influences may be significant and provide opportunity to reduce losses, but in most cases there is insufficient or no data that could be used to develop a practical strategy. Currently, many losses are of unknown cause. Further, where losses are experienced in excess of benchmark levels, it is likely there is more than one significant aetiology.

2. Provide recommendations to reduce current levels of pregnancy failure and calf loss in northern beef cattle

Recommendations to minimise pregnancy failure and calf loss must be manageable within the constraints of resources available to beef cattle businesses in the region. A comprehensive list of practical strategies has been compiled and is presented within Section 7.2.

3. Provide recommendations for research to reduce current levels of pregnancy failure and calf loss in northern beef cattle

Based on the phases of greatest loss and greatest variation in loss, which indicate where the best opportunities to minimise loss are, research recommendations have been developed that are expected to have a high probability of achieving a practical outcome for the north Australian beef industry; ie, application of research outcomes will provide a sound basis for cattle producers to develop and implement strategies that consistently achieve low levels of pregnancy failure and calf loss. These recommendations are presented in Section 7.3.

6 Impact on meat and livestock industry

Losses from mid-pregnancy through to weaning are directly related to weaning rates. Earlier losses have less impact as some occur early enough for cows to re-conceive within the same mating season and rear a calf; this is especially so for failure to conceive and for embryonic mortality. However, the order of losses early in pregnancy is much higher, thus making losses at all stages of similar importance.

A model was developed to assess the impact on calf size due to failure to conceive or rear a calf following conception loss. Figure 6 demonstrates an example where an agent causes embryonic loss to increase by 20%, which is realistic for infectious diseases such as campylobacteriosis. The pattern of calf weights does not seem significant at first glance, but the calculations show a 6% reduction in the weight of calves at weaning with weaning rate only reducing by 2% and average calf weight per cow mated reducing by only 8 kg. For a 1,000-cow herd at a value of $1.75/kg of weaner, the impact is an estimated $14,000 reduction in weaner output.

Modelling an increase in neo-natal mortality rates from 5% to 10%, which represents typical industry situations, shows an almost identical impact on the value of calves weaned as the above-mentioned 20% difference in the established pregnancy rate per cycle (Table 11).

Substantial secondary benefits may also accrue from reducing calf wastage, eg, the opportunity to implement more effective genetic improvement programs.

Economic benefit: Based on only 20% adoption of opportunities developed through recommendations from the project, the direct benefit to beef businesses in tropical Australia is estimated at more than $5M per annum. This estimate is derived from the benefit indicated above being available to 40% of producers and 50% of these implement strategies to achieve the benefits at a cost of half the increase in weaner value increment across the estimated 4.5M breeding-age females in north Australia. Sophisticated modelling processes developed by the CRC for Cattle and Beef Quality indicate that the benefit to the community of improving beef business performance is three times that accruing to producers (Farquharson *et al*. 2003). This indicates an overall potential benefit to north Australia of at least $15M annually.

Welfare of cattle: Applying recommendations from this project may reduce the stress on breeding female cattle, eg, by better timing of calving and weaning, and management to improve growth and survival. The improved animal welfare is a direct benefit to the grazing industry (animal care & production benefits) and the community (animal care).

Reducing regional risk and managing crisis: By application of management that reliably reduces calf wastage, beef businesses will be able to reduce the risk of encountering crisis situations in regional communities, particularly before, during, and after drought.

There is an ever-increasing world-wide demand for beef and co-products. The recommendations from this project will increase the ability of beef businesses to sustain a higher level of output with less fluctuation than currently occurs in the face of seasonal variation. This will be reflected in better opportunities and lower risk for rural business.

Rangeland management: Management that enables fewer animals to achieve the same business targets will improve the opportunity for beef businesses to apply recommended rangeland management practices, eg, spelling. This has the potential to contribute to preserving healthy environments.

Table 11. Modelling the impact of elevated embryonic mortality or neo-natal loss on calf output

Input

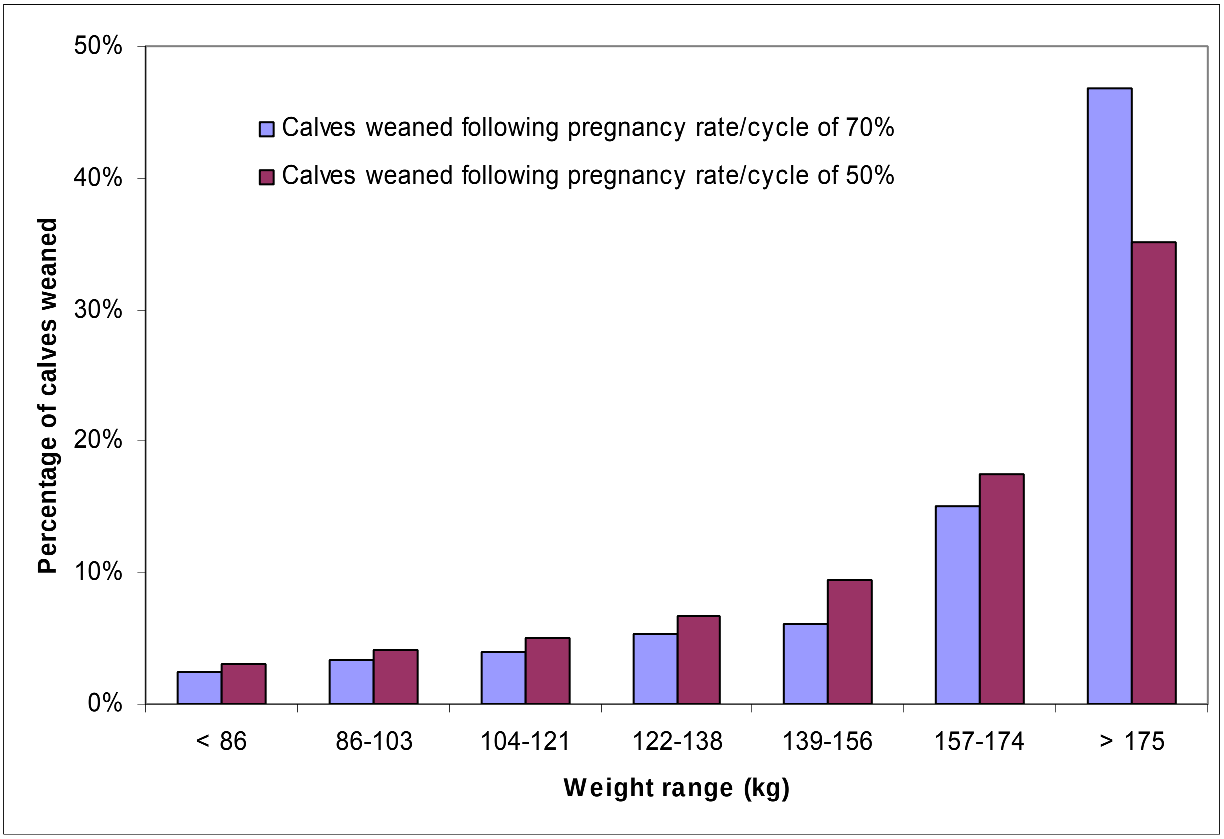
				Day	Cycled
Mating period = 5 months				**Day**	**Cycled**
Immediate re-cycle if fertilisation failure or early embryonic mortality				0	75%
21-day lapse before recycling after later loss				21	78%
Suckling calf growth rate = 0.85 kg/day				42	81%
Weaning after start of mating = Day 510				63	84%
	Benchmark	**High EEM***	**High NNL***	84	87%
Fertlisation failure	10%	10%	10%	105	90%
Early embryonic mortality	20%	40%	20%	126	92%
Late embryonic mortality	5%	5%	5%	147	94%
Foetal mortality	3%	3%	3%	168	96%
Perinatal mortality	5%	5%	10%	189	97%
Post-natal mortality	1%	1%	1%	210	98%

Output

	Benchmark	High EEM	High neo-natal loss
Weaning rate	83%	81%	79%
Average calf weight (kg)	164	158	164
Calf weight weaned/cow mated (kg)	136	128	129
Calf weight distribution at Day 510			
Weight	**Benchmark**	**High EEM**	**High neo-natal loss**
183	47%	35%	44%
165	15%	18%	14%
147	6%	9%	6%
130	5%	7%	5%
112	4%	5%	4%
94	3%	4%	3%
76	2%	3%	2%
58	0%	0%	0%
40	0%	0%	0%
23	0%	0%	0%

* EEM = early embryonic mortality; NNL = neo-natal loss

Figure 6. Estimated impact of an agent that reduces that rate of established pregnancy rate per cycle from 70% to 50%, on weaning weights #



Input: 5 months mating; cumulative rate for cows having cycled increasing from 75% to 95% over mating; suckling calf growth rate of 0.85 kg/day; fertilisation failure 10%; foetal loss 3%; neo-natal loss 5%; post-natal loss 1%; immediate re-cycle after fertilisation failure or early embryonic loss; 21-day lapse before recycling after late embryonic mortality or foetal loss.

7 Conclusions and recommendations

7.1 Conclusions

Reproductive wastage in cycling female cattle prior to day 45 of pregnancy is ill-defined because of the lack of tools to conduct the research. At Swan's Lagoon, pregnancy rates of 60-70% within a 3-week period are usual for cycling cows that are free of significant diseases and mated to fertile bulls (eg, Fordyce and Cooper 1999b). This is supported by observations of a benchmark level of 70% pregnant per cycle in the CRC herds (Section 4.1). Sound research indicates fertilisation failure rates of 10% are expected at each oestrus period (See review paper). Therefore, total embryonic loss is not more than 25% in this situation. This is approximately 10% units lower than the data quoted as "normal levels" in the literature (See review paper).

From the above, and other reported data for north Australia, benchmark levels for reproductive wastage elements are proposed as:

Cow may re-conceive within same mating		*Calf usually lost for that year*	
Fertilisation failure	10%	Pre-natal loss (of confirmed pregnancies)	3%
Early embryonic loss	20%	Neo-natal loss (of calving cows)	5%
Late embryonic loss	5%	Post-natal loss (of surviving neo-nates)	1%

At these levels, cows cycling at an average of 80 days after calving and mated for 3 months are expected to achieve weaning rates of approximately 65% in the following year. This level approaches 75% when mating extends for 5 months, but is only 55% when mated from 63 days, ie, for 3 oestrus cycles. If cows cycle at an average of 60 days post-calving, weaning rates of close to 85% are achievable with 3-month mating.

This data is consistent with the experience at Swan's Lagoon, where a consistent average of 83% of cows mated weaned a calf in the following year over a 15-year period (Fordyce and Cooper 1999a). These cows were mated continuously and experienced some elevated losses between confirmed pregnancy and weaning in some years; in most instances this was related to drought conditions or to increased dingo numbers.

The literature review, reinforced by observations from the monitor herds, indicates that many herds are not achieving the benchmark levels indicated above. It highlights substantial opportunities in northern Australian herds to reduce reproductive wastage, with the most significant opportunities being to:

- increase the rate of established pregnancy per cycle in breeding female cattle, with specific emphasis on early embryonic mortality.

- reduce neo-natal mortality.

Recommended strategies to minimise pregnancy failure and calf loss in northern beef cattle herds, and recommendations for research that have a high probability of producing results that when applied, can significantly increase both weaning rates and weaning weights are presented below.

7.2 Recommendations to minimise pregnancy failure and calf loss in northern beef cattle

1. Select female cattle for future breeding at all ages if they:
    - Rear calves to weaning
    - Do not have phenotypic attributes that may contribute to calf loss, eg, bottle teats, poor maternal temperament

2. Mating management
    - Use bulls identified as fertile by a BBSE prior to initial mating at least
    - Manage time of mating to achieve calving when nutrition is adequate, and when cows and calves are able to tolerate prevailing climatic stresses (temperature extremes, inclement weather)

3. Manage metabolic status
    - Nutrition
        - Ensure adequate feed and water quality, quantity and access.
        - Prevent hypovitaminosis A. Specific practical strategies are yet to be developed and tested, but may include targeted supplementation over the latter half of the usual growing season in years when availability of green feed is limited.
    - Minimise handling stress, especially in the latter half of pregnancy

4. Disease management
    - Diagnose and treat in bulls, if appropriate, prevailing reproductive disease, especially campylobacteriosis and trichomoniasis
    - Use vaccination or allied strategies where significant loss due to a specific disease may occur
        - Leptospirosis. Implement the recommended vaccination program where this disease is known to cause reproductive wastage, or there is a high probability that it may. Commence vaccination in calves at the earliest practical time.
        - Pestivirus. Use strategic sampling of management groups to assess previous exposure and to detect persistently infected (PI) cattle. Vaccinate or use PI cattle in naïve groups.
        - Campylobacteriosis. Vaccinate bulls, starting early in life to establish immunity before homosexual transmission occurs.
        - Clostridial diseases. At marking, 5-in1 (especially to prevent tetanus) and botulism vaccines should be given to suckling calves in areas where these diseases are endemic.

5. Manage dystocia
    - If possible, only mate yearlings that have reached a critical mating weight (breed dependent).
    - Select sires and females with traits indicative of calving ease; eg: use EBVs for calving ease and short gestation length; use older heifers.
    - Ideally, maintain growth of 0.5 kg/day to parturition when yearling-mated heifers are in body condition score 3 to 4 (5-point scale). Alternatives: avoid poor nutrition in mid-pregnancy and excess nutrition in late pregnancy; ensure nutrition in the third trimester of pregnancy does not exceed that in the first trimester.
    - Supervise calving and provide early assistance if required, especially of 2-year-olds, and in areas where high quality nutrition is available in the third trimester.

6. Control predators where there is a risk that these may cause significant calf loss.

7.3 Recommendations for research

Research recommendations	Potential outcome
1. Use reliable R&D methods, including: • Field and applied R&D should generally be conducted where the problems and opportunities exist. • Study of early embryonic mortality (EEM) requires use of techniques that can specifically identify its contribution to reproductive wastage. Real-time ultrasound is a valuable tool to assess oestrus cycling, but not EEM. Oocyte, zygote, and embryo recovery for assessing viability may be suitable tools for EEM study, as may humoral early-pregnancy factors. • Study of neo-natal mortality requires skilled staff who conduct intensive observations where the cattle are located. • Long-term studies may be required for some issues.	Higher security of investments in research to reduce EEM or neo-natal mortality.
2. Quantify variation in the ability of cycling females to achieve pregnancy and then to wean a calf through detailed studies using a range of situations and treatments that enable definition of prevalence of loss and aetiological agents, and efficacy of control measures. Most emphasis should be placed on factors most likely to be significant contributors to reproductive wastage and be manageable, eg, hypovitaminosis A.	Opportunities to implement specific strategies to reduce wastage between cycling and weaning will become more apparent. Extension and adoption of focused messages and effective strategies have a high chance of increasing weaning rates and weights.
3. Using recently-developed research tools (eg, PCR diagnostic methods), study the quantitative impacts, epidemiology and process of infectious diseases affecting reproductive rates, as well as prevention and treatment, with emphasis on leptospirosis, campylobacteriosis, trichomoniasis, neosporosis, and pestivirus infections.	The benefits from control of these known pathogens will be quanitifed. Control strategies will be much more reliable.
4. Replicate northern Australian studies of the prevalence of bulls with less than 50% and 70% normal sperm and the relationships between sperm morphology and calf output in southern Australia and *Bos taurus* bulls - for which this information is currently unavailable.	Enhanced adoption of sperm morphology assessment as a component of a BBSE, which if used to mate fewer genetically-superior bulls, will increase herd genetic merit.

Research recommendations	Potential outcome
5. If DNA Fragmentation Index (DFI) is a repeatable trait with moderate frequency, determine any linkage between it and embryonic survival.	If this is successful, DFI may become a very useful component of BBSE.
6. Quantify losses of both calves and cows due to dystocia in north Australia, and develop and demonstrate practical strategies (eg, nutritional, genetic) to minimise its incidence	Survival of calving 2-year-old cows and their calves will be improved throughout north Australia, with effect across all ages in some high-productivity regions
7. Estimate the genetic variation and opportunity for selection in: • Semen traits and sire and sire of dam effects on embryonic mortality. • The ability of cycling females to rear a calf to weaning: overall, and wastage at all stages of this process.	If suitable indicator traits are identified, ability to use direct and or indirect selection to achieve increased weaning rate and earlier conceptions, thus more and heavier weaners.
8. Increase the understanding of how factors such as fatty acids, urea, energy, progesterone, follicular waves, breed, thermal heat index, chromosomal abnormalities, and stress influence function and viability of ova, embryos, corpora lutea, INF-τ, and the placenta.	Cattle producers will more confidently and accurately apply nutritional, management, and genetic strategies to sustain pregnancy rates per cycle at benchmark levels.
9. Understand the key mechanisms that achieve maternal recognition and support of pregnancy, especially: • Define the cellular and molecular genesis of the post-insemination inflammatory reaction within the cow's reproductive tract and how it modulates sperm function, maternal immunity, and embryo viability • Identify the intra-uterine and or intra-embryonic signals that switch and maintain the genomic and synthetic machinery for timely INF-τ production, thus supporting anti-luteolytic mechanisms	Cattle producers will more confidently and accurately apply nutritional, management, and genetic strategies to sustain pregnancy rates per cycle at benchmark levels.
10. Publish definitions of components of reproduction rate.	Clear understanding by industry participants of reproduction terms, thus increasing the efficiency of communication.

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9 Appendix: Cycling and pregnancy in CRC matings

Legend in all figures:

Dotted line indicates estimated percentage having cycled at least once to that time of mating.
Heavy unbroken line indicates actual pregnancy rates as determined by foetal ageing.
Other lines indicate expected pregnancies with varying pregnancy rate per cycle, as calculated from proportion cycling in each 3-week period.

Figure 7. Cycling and pregnancy for maiden 2-year-old Tropical composite heifers at Belmont in 2003 (n=138)

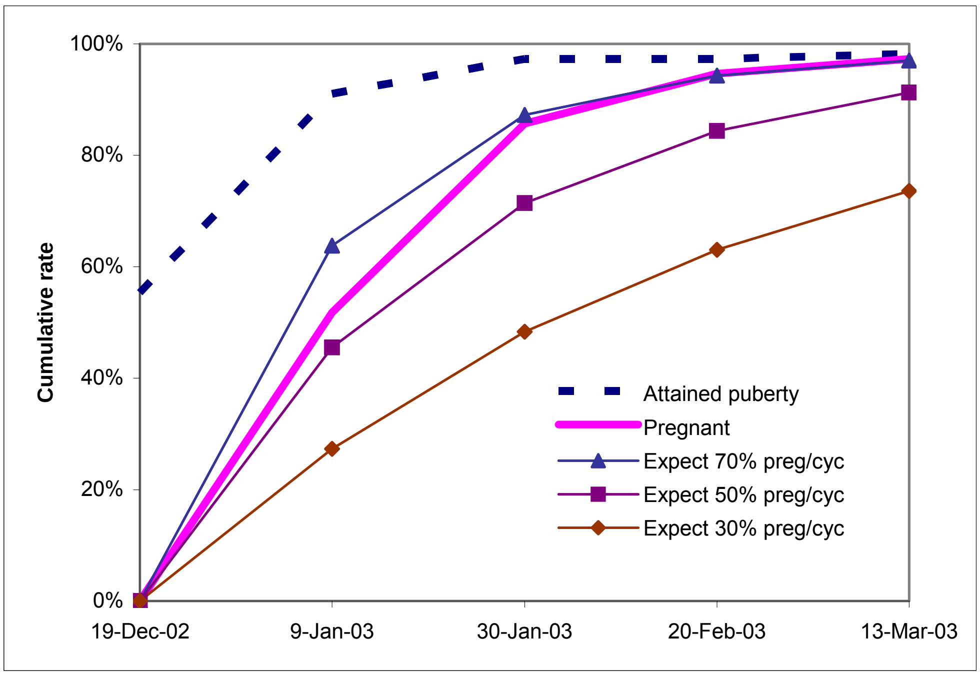

Figure 8. Cycling and pregnancy for non-lactating 3-year-old Tropical composite cows at Belmont in 2004 (n=13)

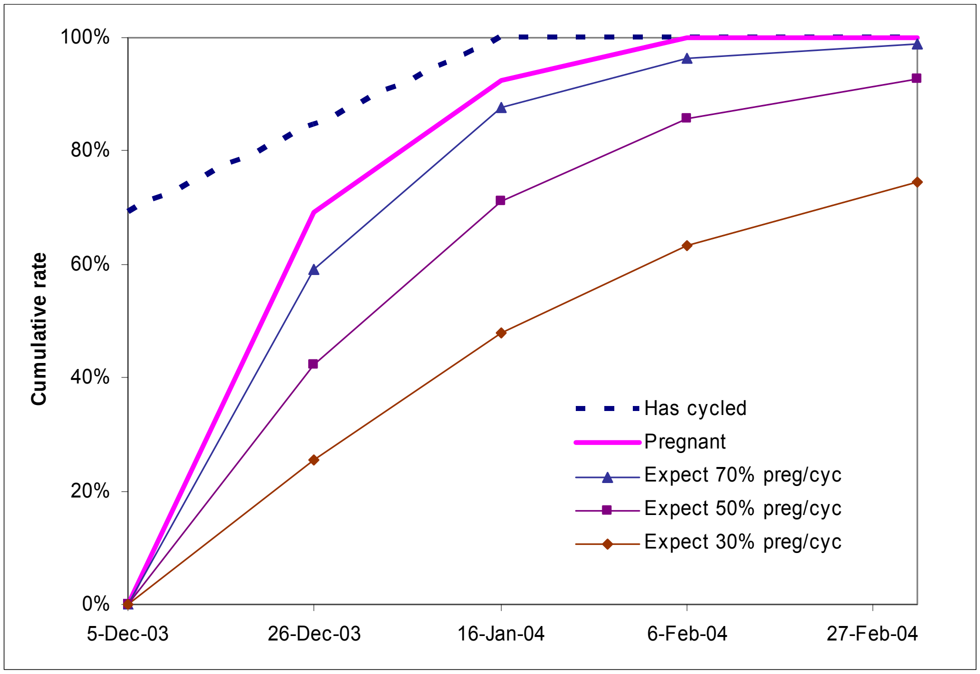

Figure 9. Cycling and pregnancy for lactating 3-year-old Tropical composite cows at Belmont in 2004 (n=97)

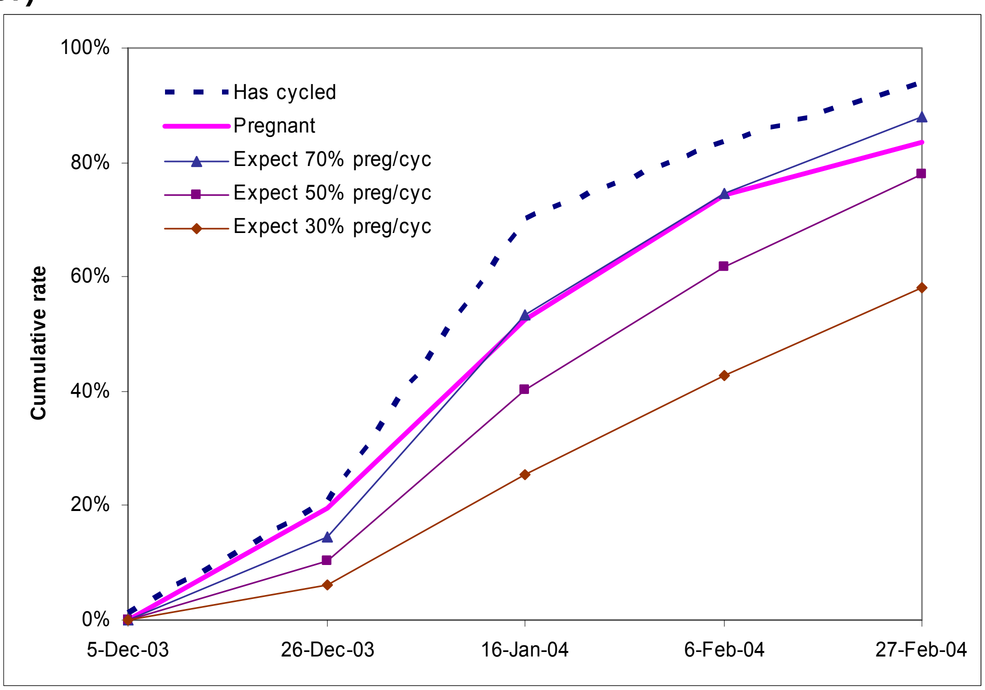

Figure 10. Cycling and pregnancy for maiden 2-year-old Tropical composite heifers at Belmont in 2004 (n=112)

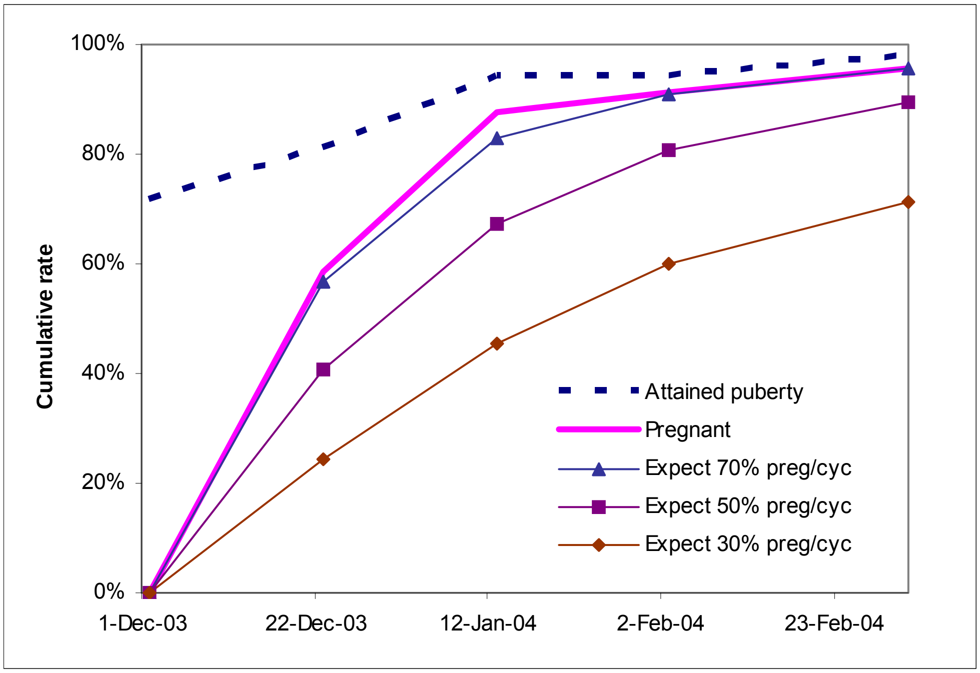

Figure 11. Cycling and pregnancy for maiden 2-year-old Brahman heifers at Belmont in 2003 (n=110)

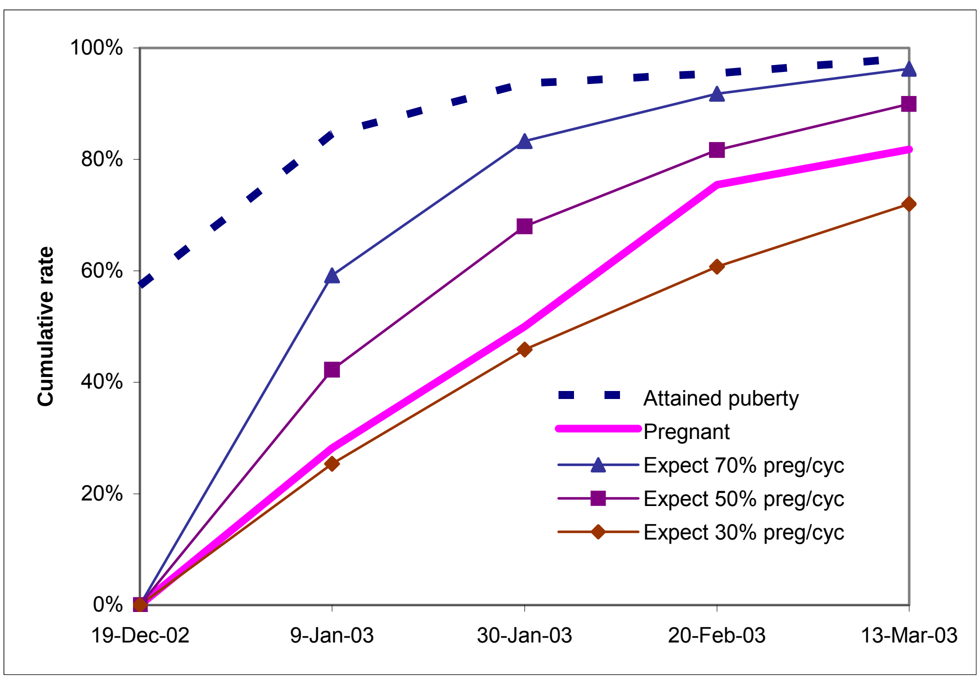

Figure 12. Cycling and pregnancy for non-lactating 3-year-old Brahman cows at Belmont in 2004 (n=35)

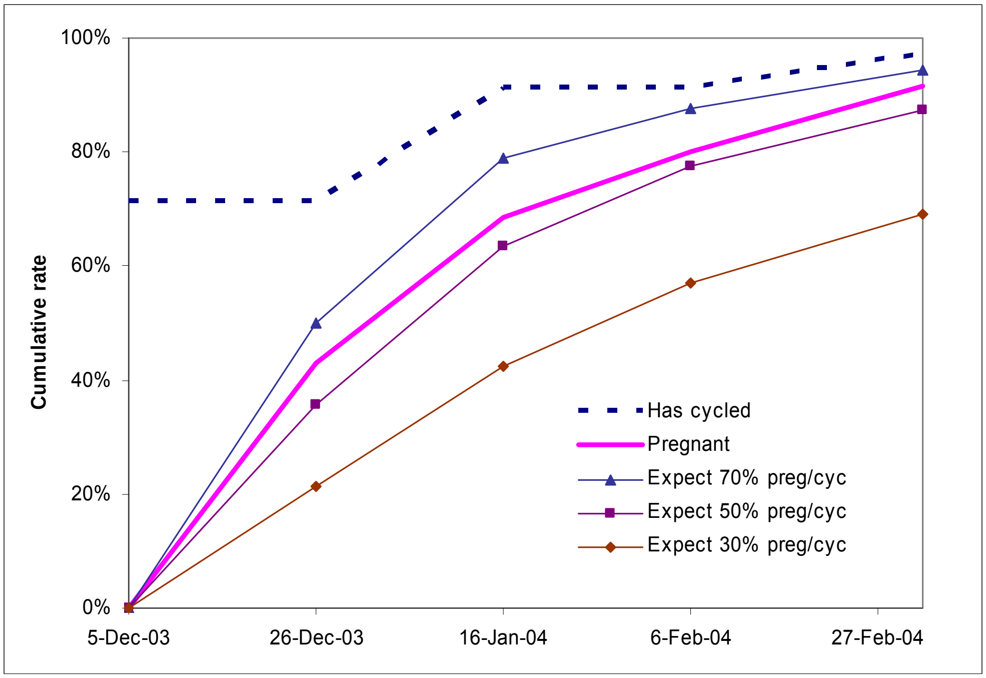

Figure 13. Cycling and pregnancy for lactating 3-year-old Brahman cows at Belmont in 2004 (n=74)

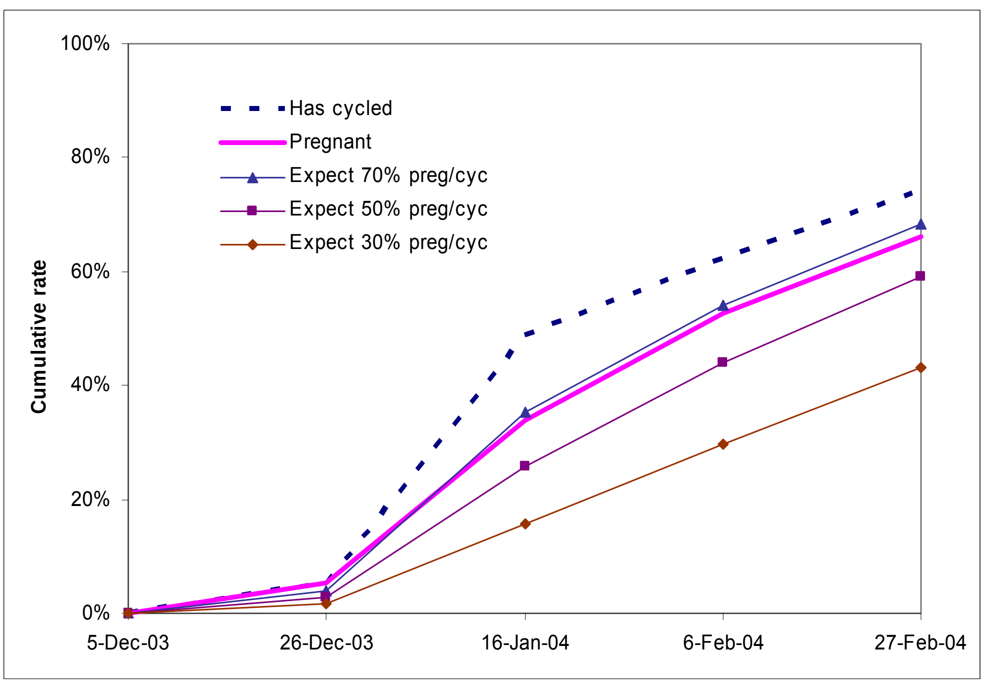

Figure 14. Cycling and pregnancy for maiden 2-year-old Brahman heifers at Belmont in 2004 (n=118)

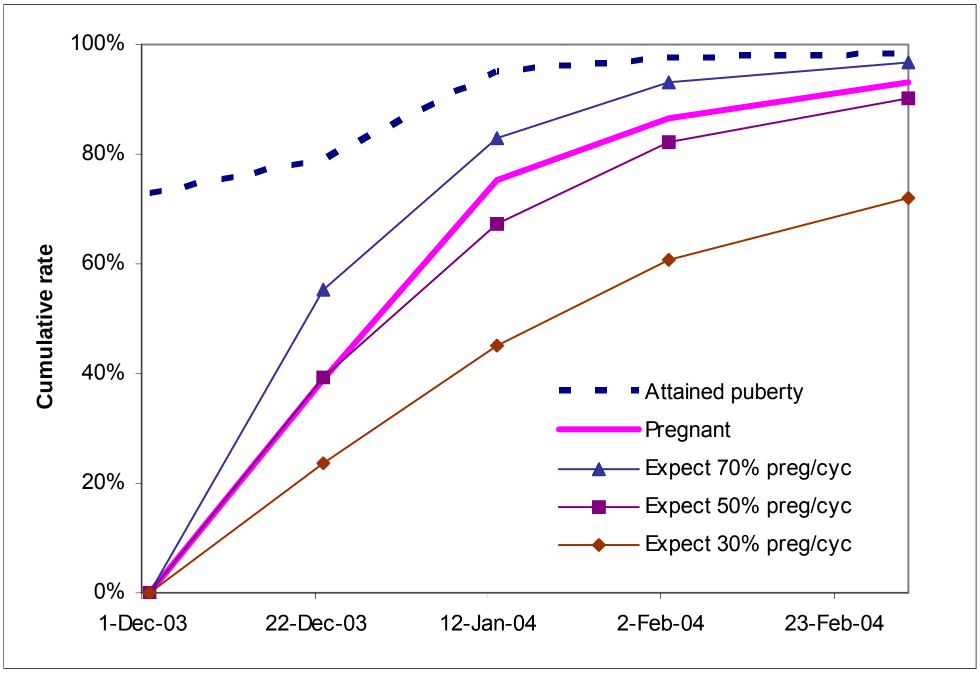

Figure 15. Cycling and pregnancy for maiden 2-year-old Tropical composite heifers at Brian Pastures in 2003 (n=145)

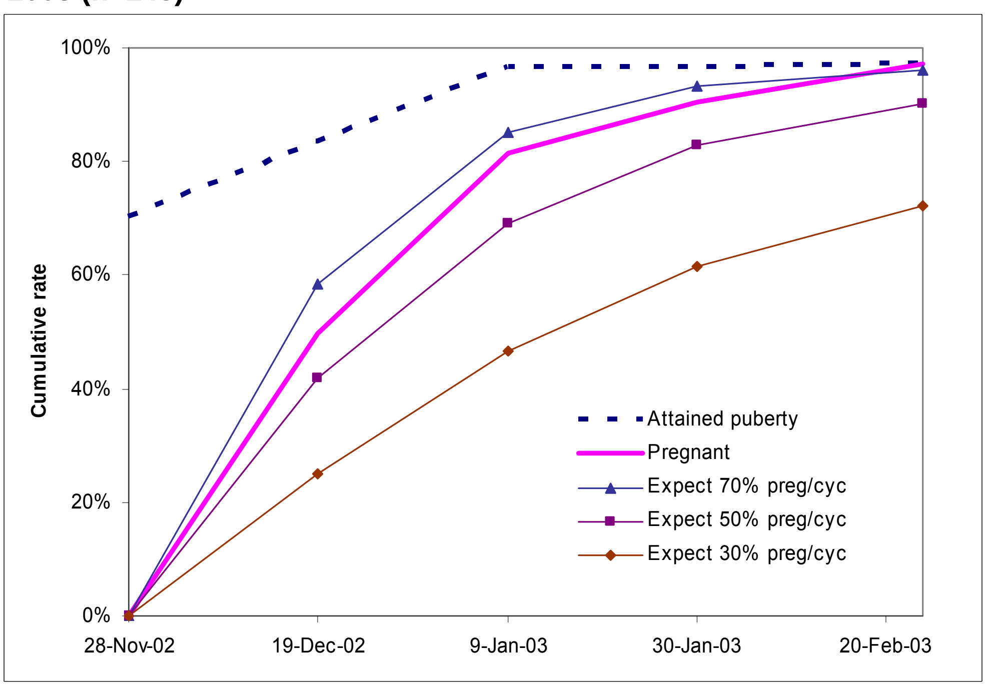

Figure 16. Cycling and pregnancy for non-lactating 3-year-old Tropical composite cows at Brian Pastures in 2004 (n=15)

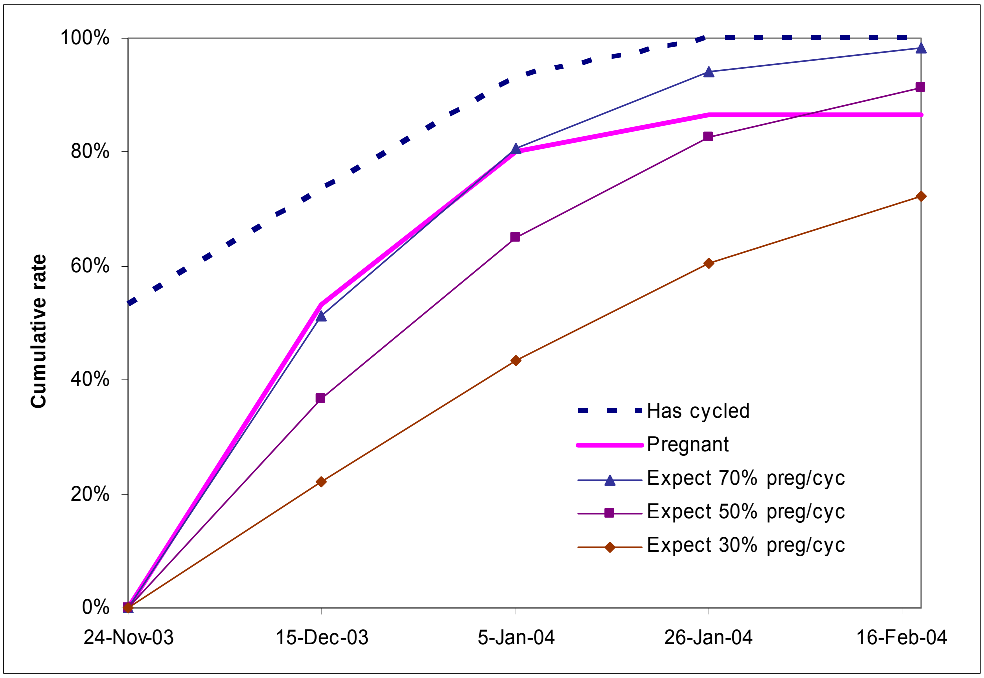

Figure 17. Cycling and pregnancy for lactating 3-year-old Tropical composite cows at Brian Pastures in 2004 (n=125)

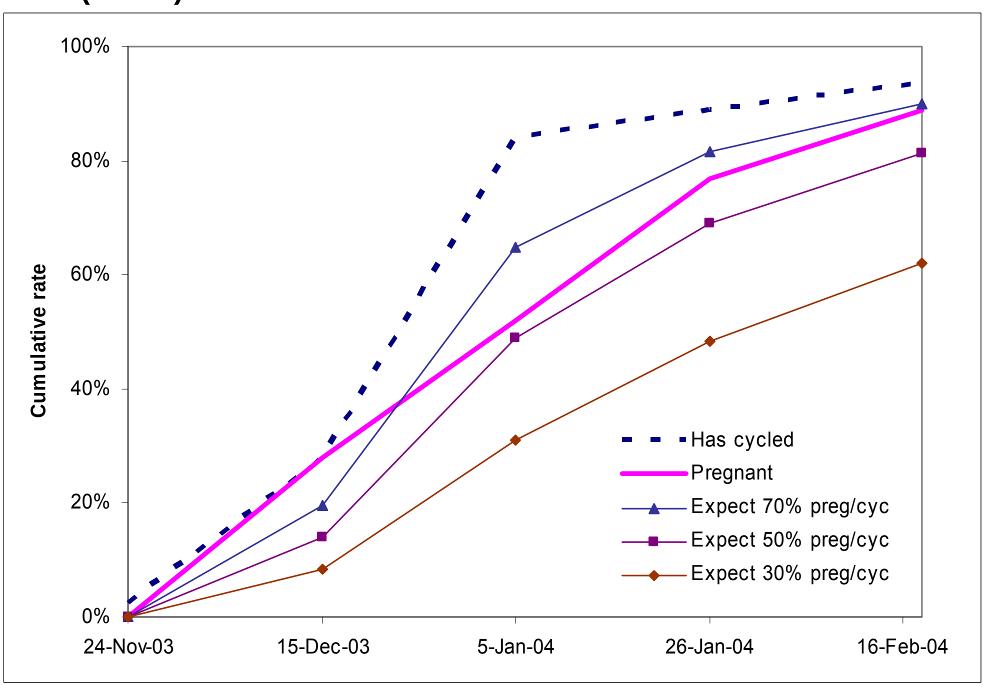

Figure 18. Cycling and pregnancy for maiden 2-year-old Tropical composite heifers at Brain Pastures in 2004 (n=266)

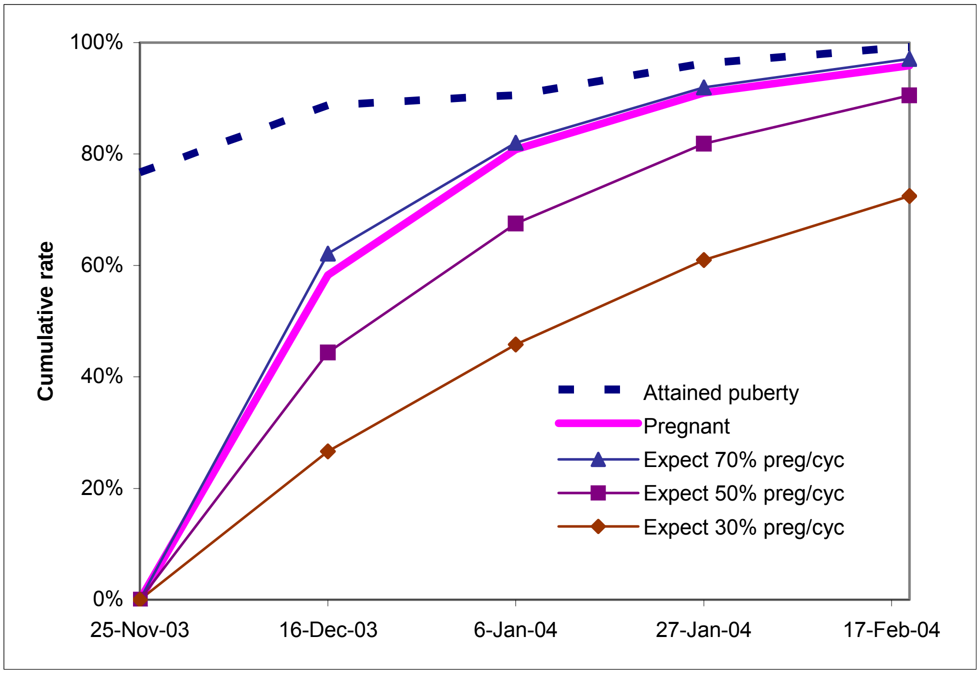

Figure 19. Cycling and pregnancy for maiden 2-year-old Brahman heifers at Swan's Lagoon in 2003 (n=186)

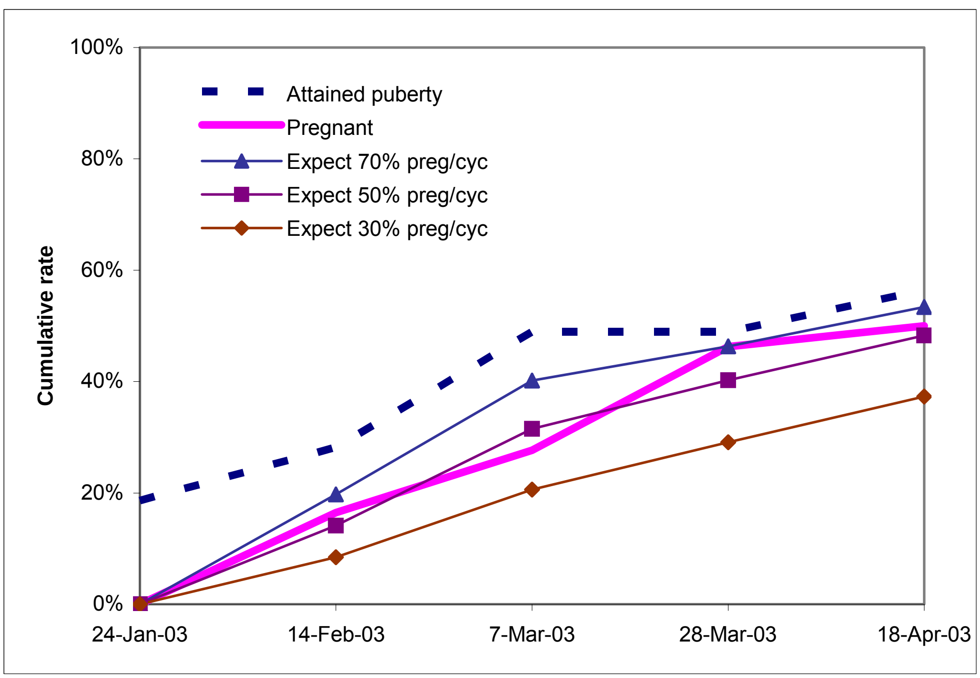

Figure 20. Cycling and pregnancy for non-lactating 3-year-old Brahman cows at Swan's Lagoon in 2004 (n=103)

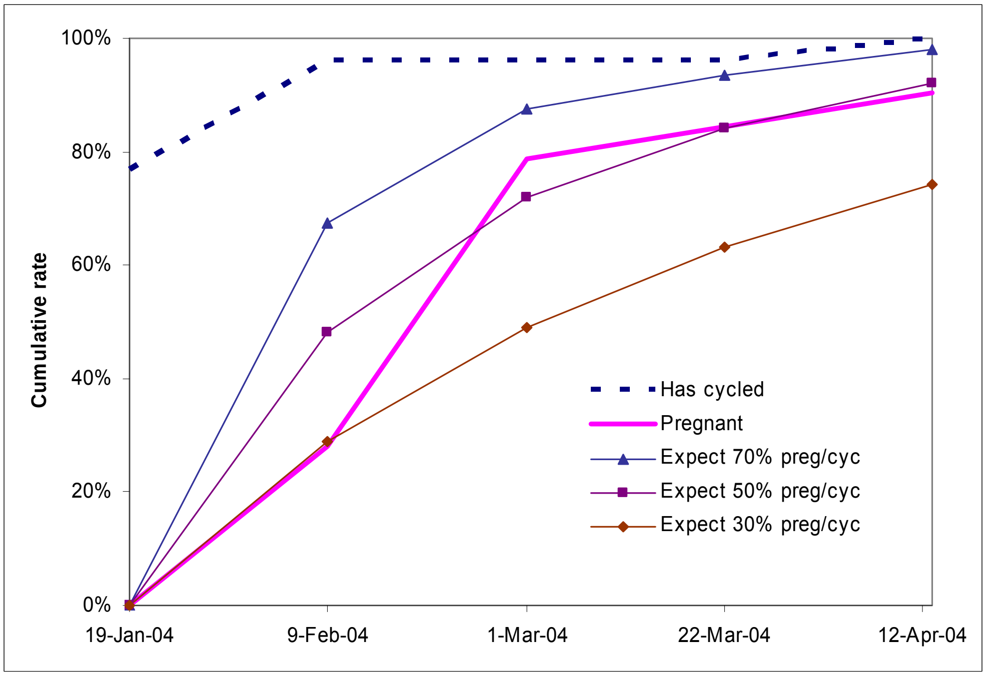

Figure 21. Cycling and pregnancy for lactating 3-year-old Brahman cows at Swan's Lagoon in 2004 (n=81)

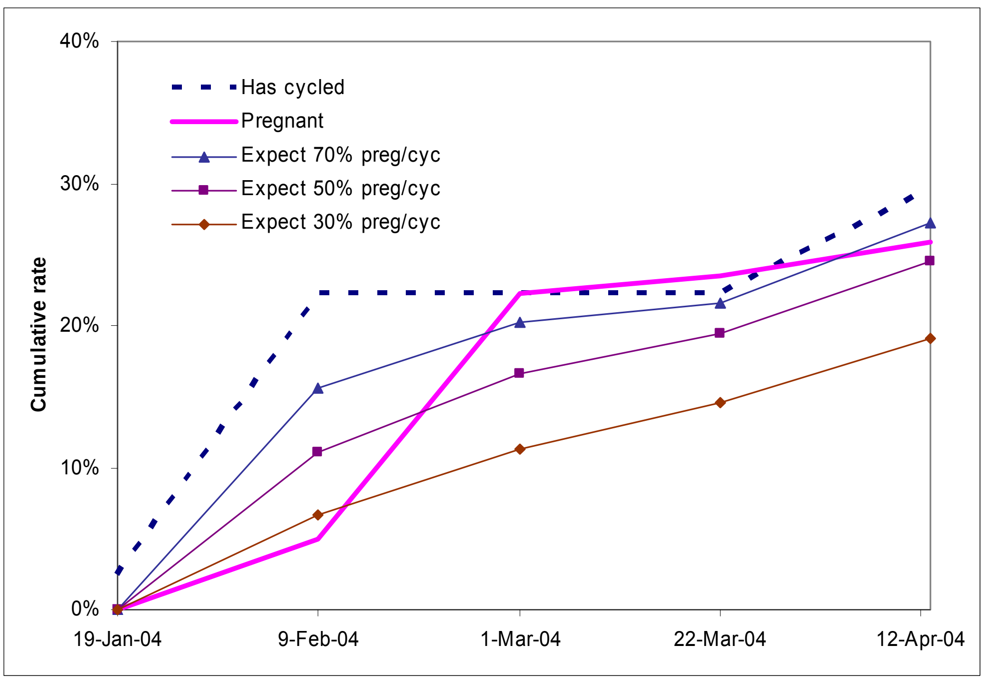

Figure 22. Cycling and pregnancy for maiden 2-year-old Brahman heifers at Swan's Lagoon in 2004 (n=218)

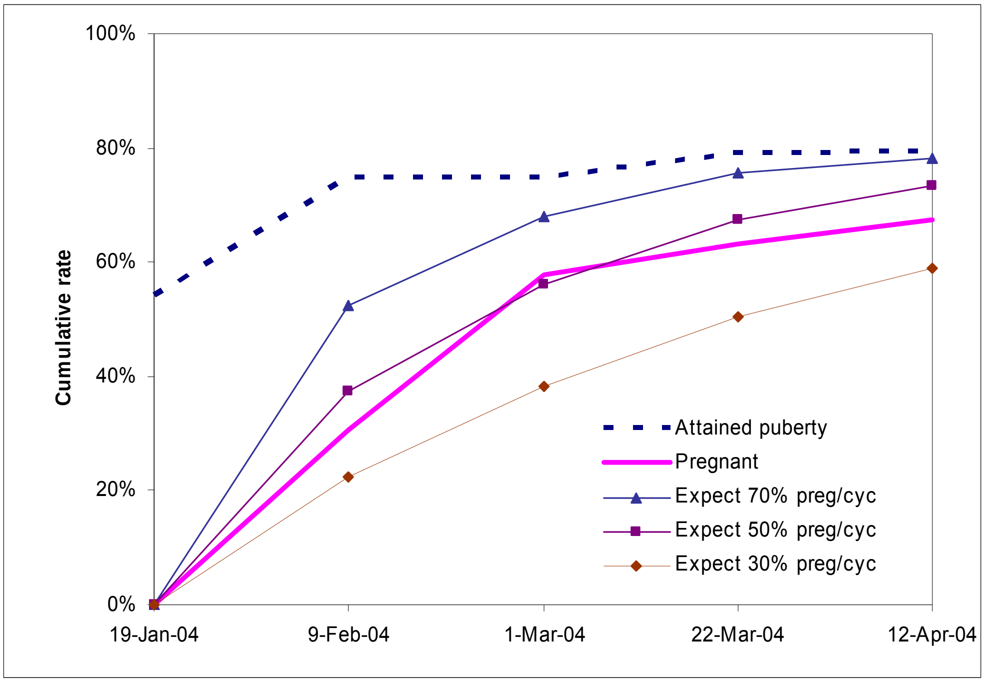

Figure 23. Cycling and pregnancy for maiden 2-year-old Tropical composite heifers at Toorak in 2003 (n=160)

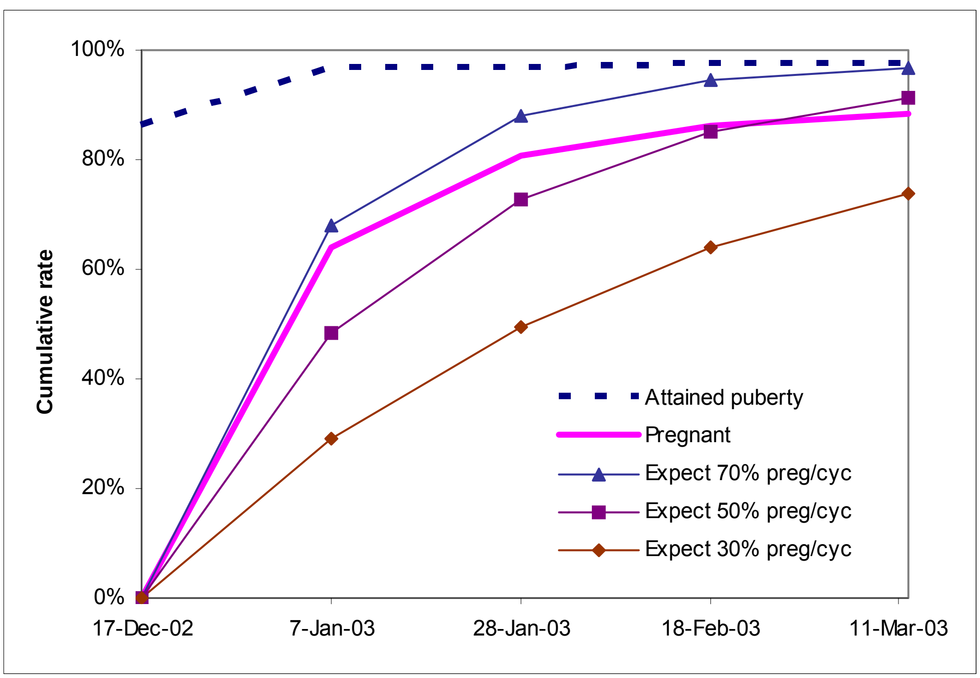

Figure 24. Cycling and pregnancy for non-lactating 3-year-old Tropical composite cows at Toorak in 2004 (n=42)

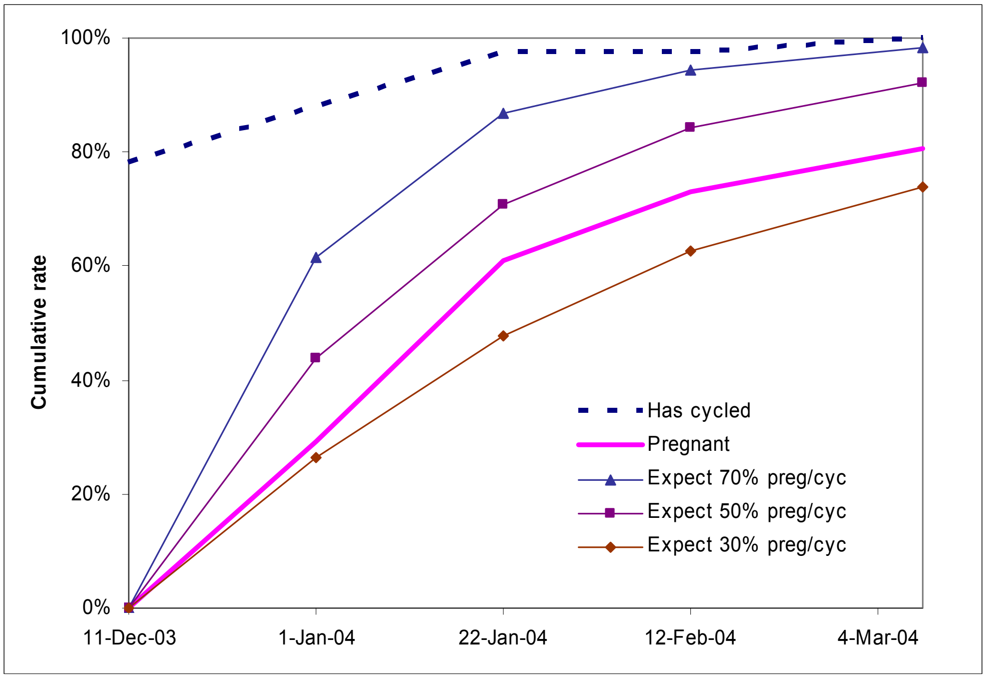

Figure 25. Cycling and pregnancy for lactating 3-year-old Tropical composite cows at Toorak in 2004 (n=110)

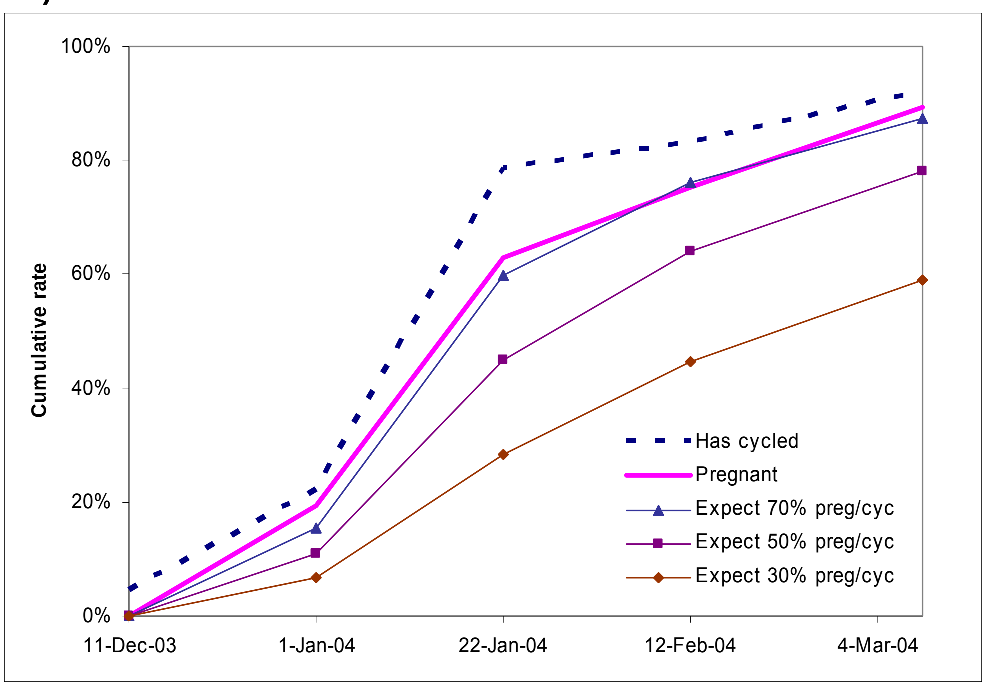

Figure 26. Cycling and pregnancy for maiden 2-year-old Tropical composite heifers at Toorak in 2004 (n=181)

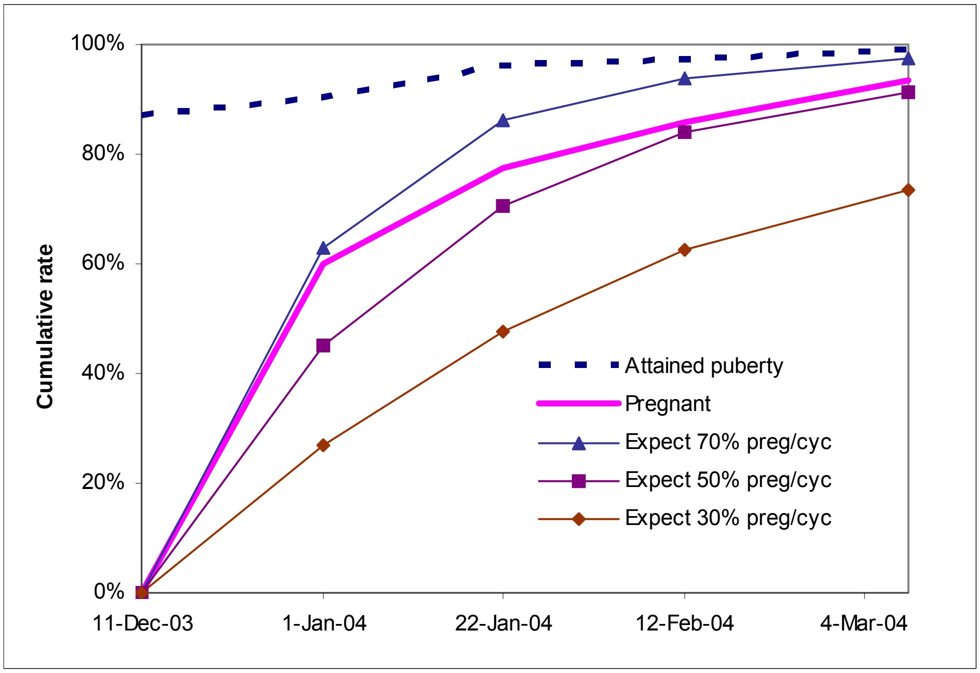

Figure 27. Cycling and pregnancy for maiden 2-year-old Brahman heifers at Toorak in 2003 (n=64)

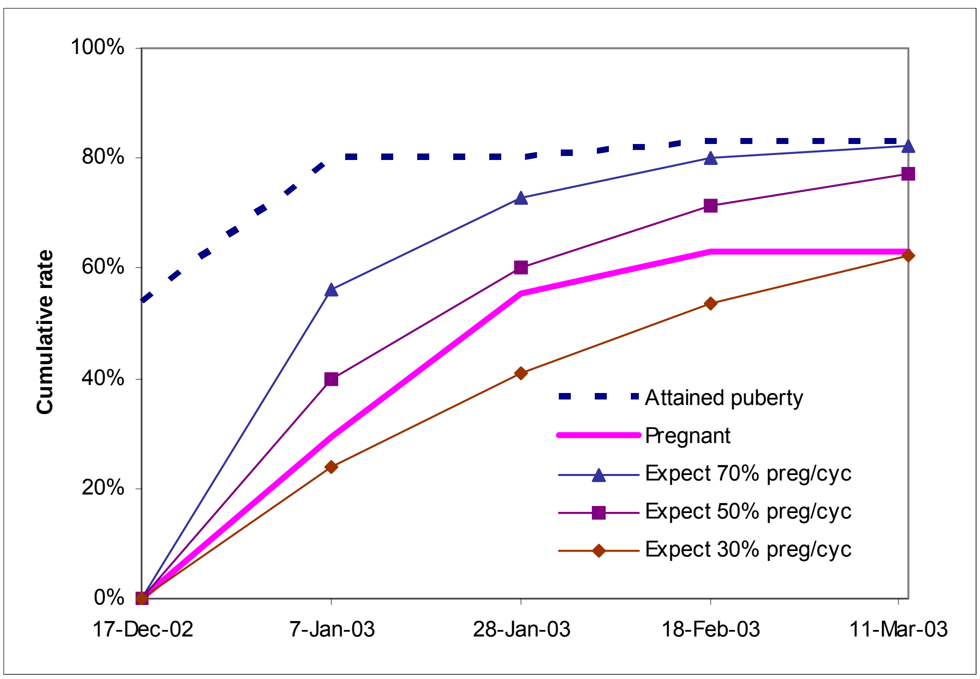

Figure 28. Cycling and pregnancy for non-lactating 3-year-old Brahman cows at Toorak in 2004 (n=22)

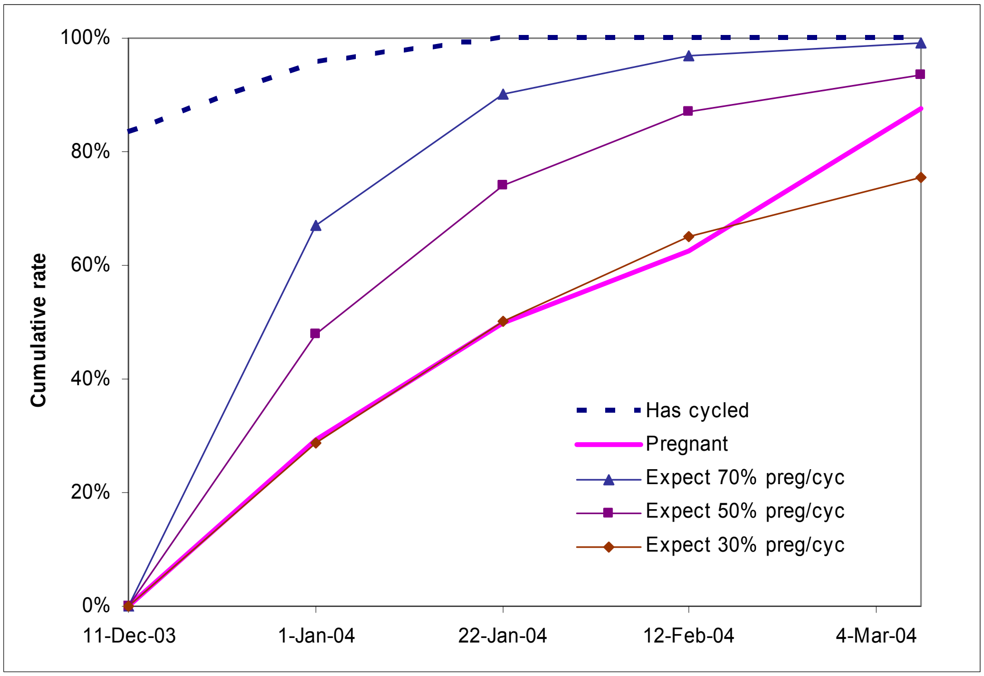

Figure 29. Cycling and pregnancy for lactating 3-year-old Brahman cows at Toorak in 2004 (n=37)

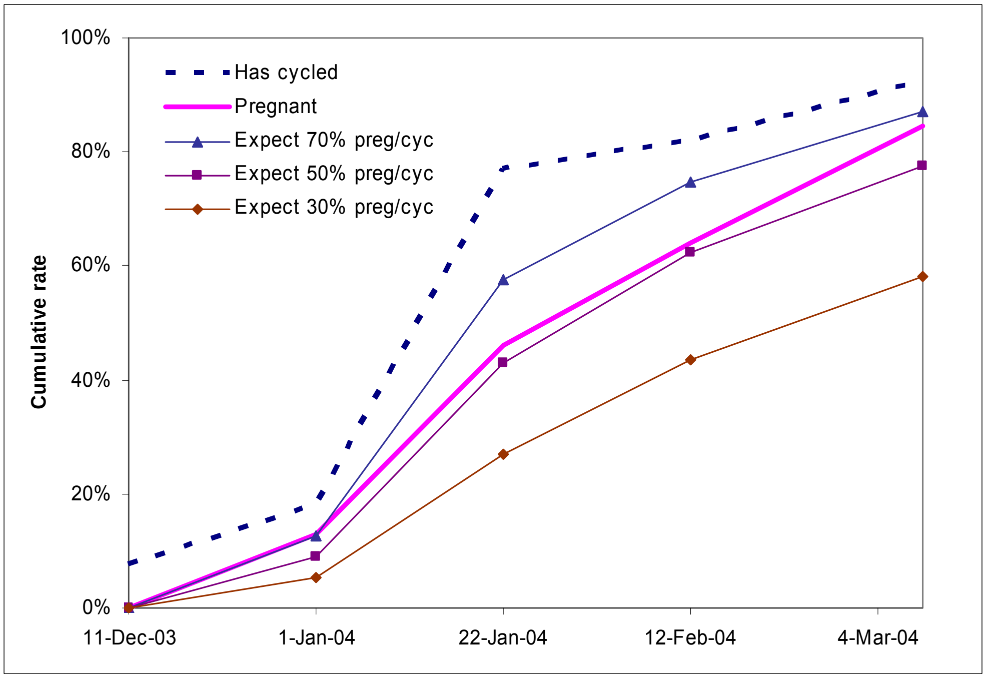

Figure 30. Cycling and pregnancy for maiden 2-year-old Brahman heifers at Toorak in 2004 (n=97)