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Prepared by: Tim Schatz
Northern Territory Department of Resources

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Understanding and improving heifer fertility in the Northern Territory

Abstract

This project established the relationship for both pre joining weight and fat depth (condition) with; pregnancy rates in high grade Brahman maiden heifers (joined both as yearlings and as two year olds) and subsequent re-conception rates in first calf heifers in the Northern Territory. The charts developed showing the likely conception rates from different joining weights will be useful management tools for cattle producers and advisors.

Various management strategies aimed at increasing heifer productivity were researched. It was found that:

Feeding pre partum protein supplements to first calf heifers in the VRD was a reliable method of increasing re-conception rates (by an average of 42%) but was not always cost effective.

- Feeding pre partum protein supplements to first calf heifers grazing fertilised and improved pastures in the Douglas Daly region did not increase re-conception rates.
- Current genotypes of high grade Brahman heifers from NT cattle stations were too late maturing to give high pregnancy rates from yearling mating (the average pregnancy rate was 33%).
- Preliminary economic analysis showed that there was a small positive cost benefit when larger (190-260 kg) Brahman weaner heifers were transported to the Douglas Daly region for yearling mating compared to mating them for the first time as two year olds in the VRD.

Executive summary

While it is known that heavier heifer joining weights ensure higher pregnancy rates, the actual relationship between weight and pregnancy rates had not previously been established for high grade Brahman heifers in the Northern Territory (NT). The aim of this project was to establish this relationship and to apply this knowledge to improve the performance of heifers in northern Australia. Specifically this involved establishing the relationship between;

- joining weight (and fatness) and pregnancy rates in maiden heifers both mated for the first time as two year olds (on native pasture) and as yearlings (on improved pasture)
- pre calving weight (and fatness) and pregnancy rates in first calf heifers that had either been mated for the first time as two year olds (and grazed on native pasture) or as yearlings (and grazed on improved pasture).

All these relationships were found to be significant except for in first calf heifers grazing on improved pasture. Therefore equations were produced that predict the pregnancy rates likely from different:

- Pre joining weights of maiden heifers joined first as two year olds (that grazed native pasture in the Victoria River District (VRD).
- Pre joining weights of maiden heifers joined first as yearlings (that grazed native pasture in the Douglas Daly region).
- Pre joining P8 fat depth of maiden heifers joined first as two year olds (that grazed native pasture in the VRD).
- Pre joining P8 fat depth of maiden heifers joined first as yearlings (that grazed native pasture in the Douglas Daly region).
- Pre calving weights of first calf heifers VRD (that grazed native pasture in the VRD).
- Pre calving P8 fat depths of first calf heifers VRD (that grazed native pasture in the VRD).

Each of these equations was used to produce a chart showing the predicted pregnancy rates from different weights and fat depths. These charts will be useful management tools for cattle producers and advisors. They can be used to:

- Increase awareness of the relationship between joining weight/condition and pregnancy rates, and demonstrate/quantify the benefits that come from increasing joining weights.
- Work out target joining weights for different situations.
- Calculate the return on investment associated with feeding strategies aimed at reaching different target weights (ie work out how many extra pregnancies are likely from increasing joining weight by a certain amount).
- Perform cost benefit analyses to work out the most profitable target joining weights for a property or situation.

- Work out the weight ranges of heifers in which supplementation to achieve target joining weights will be profitable. While it may be quite profitable to supplement some weight ranges of heifers, some heifers will be heavy enough without supplementation and some will be too light to make a target joining weight even with supplementing (and so supplementary feed would be wasted in these cases).

Specific guidelines* for heifer management from these charts are:

a) In extensive areas of the NT where native pastures are grazed:

- When maiden (Brahman) heifers are first joined at two years of age for a period of at least 4 months, heifers with joining weights greater than 250 kg should achieve pregnancy rates of 80% or more. However lighter heifers are likely to conceive towards the end of the joining period and there are significant advantages from early conceptions so a heavier target joining weight of 280 kg is recommended.
- When maiden (Brahman) heifers are first joined at two years of age, heifers with pre joining fat depths at least 2 mm should achieve pregnancy rates of 80% or more.
- A pre calving weight of 460 kg (adjusted for stage of pregnancy or 490 kg unadjusted) is required for re-conception rates of 70% in first calf heifers. Pre calving weights this high are difficult to achieve for first calf heifers grazing native pasture in the NT, and so it is likely that re-conception rates will be lower. A pre calving weight of about 440 kg (unadjusted for stage of pregnancy ie assumes heifers are 7 months pregnant) is required for a 50% re-conception rate.
- A pre calving P8 fat depth of 9.5 mm (equivalent to a condition score of 6.5 on the 1-9 system or 3.5 on the 1-5 system) is required for re-conception rates of 80% in first calf heifers. It is difficult to get heifers in this sort of condition grazing native pasture in normal seasons in the NT, and so it is likely that re-conception rates will be lower.

b) In regard to yearling mating in areas of the NT where higher growth rates can be achieved (eg. from improved pasture in the Douglas Daly region and in good seasons in the Barkly and Alice Springs regions):

- The current genotypes of high grade Brahman heifers on most NT cattle stations are too late maturing to give high pregnancy rates from yearling mating. This study found that only about 1/3 of such heifers conceive from yearling mating (note that higher pregnancy rates can be achieved in heifers from herds that have been selected for fertility).
- A pre joining weight of 335 kg is required to achieve 80% pregnancy rates from commercial genotypes of high grade Brahman heifers mated as yearlings. In the NT it is not common for heifers to reach this weight by 12 months of age and so most yearling mating programs with high grade Brahman heifers will achieve lower pregnancy rates.

In addition to establishing these relationships, several different management strategies aimed at increasing heifer productivity were researched. It was found that:

* *Note that these guidelines are for heifers that have been immunised against botulism, vibriosis and leptospirosis. Not immunising against these diseases may result in lower fertility. Also these guidelines will be most relevant where heifer growth is similar to that which was achieved in this study (although the growth rates in this study are fairly typical for NT cattle properties).*

- Feeding pre partum protein supplements to first calf heifers in the VRD to increase pre calving weight/condition was a reliable method of increasing re-conception rates. Over three years the heifers that were fed pre partum protein supplements had re-conception rates that were an average of 42% higher than heifers that were not given protein supplements. This strategy is likely to apply to most other areas in the NT where beef production systems are based on grazing of native pasture. However despite the large increases in re-conception rates from this strategy, it was not always profitable due to the high on farm cost of protein supplements in the NT. The profitability of such feeding strategies are largely determined by the length of the feeding period (determined by the timing of the start of the wet season) and the cost of supplementary feed. Where the length of the feeding period was not too long and the cost of feed not too high, this strategy was shown to be profitable.
- Feeding pre partum protein supplements to first calf heifers grazing fertilised and improved pastures in the Douglas Daly region did not increase re-conception rates and so was not profitable. It was concluded that first calf heifers at appropriate stocking rates under these conditions gained adequate nutrition from the pasture to achieve good re-conception rates and so there is no benefit from feeding pre partum protein supplements.
- Transporting larger (190-260 kg) Brahman weaner heifers to the Douglas Daly region (where higher growth rates are achieved) for mating as yearlings was more profitable than leaving them in the VRD and mating them as two year olds. However transferring the heifer phase of production to the Douglas Daly displaces other cattle operations there (which may be more profitable) and it is likely that the amount of extra profit from the heifer phase of the production system is not sufficient to justify large scale adoption of this strategy especially where it would require the purchase of another property.

In conclusion this project has been successful in increasing the understanding of the relationship between joining weight/condition and pregnancy rates in high grade Brahman heifers and exploring strategies where this knowledge can be used to improve heifer performance in the NT.

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1 Background

1.1 Heifer fertility in northern Australia

It has been widely documented that the fertility of cattle is lower in northern Australia than in temperate southern Australia (McClure 1973, Rudder *et al*. 1976 and Holroyd *et al*. 1979). This is the result of a number of factors, but the predominant reason is the stressful environmental conditions in northern Australia where seasonal under-nutrition (due to poor pasture quality during the dry season), heat, humidity, parasites and large distances between water and pasture all impact on cattle performance (Entwistle 1983).

These factors have an even bigger impact on the fertility of heifers than mature cows. In northern Australia most heifers are mated for the first time a year later than in southern Australia (Entwistle 1983) and Fordyce (1996) states that pregnancy rates of maiden two year old heifers in the dry tropics are often below 50%. Also re-conception rates in heifers during their first lactation are often very low eg. less than 25% (Sullivan *et al*. 1997; Schatz and Hearnden 2008), and the problem of the low conception rates in lactating first calf heifers is recognised as the biggest area of inefficiency in Northern Australian breeding herds (McLure 1973 and Entwistle 1983).

While there have been many reports of low reproductive performance of heifers in northern Australia, there have also been some reports of very good performance as well, with conception rates exceeding 90% in both maiden (Holroyd *et al*. 1988 and Doogan *et al*. 1991) and first calf heifers (Savage *et al*. 2004). This shows that there is potential for large improvements in heifer performance in northern Australia.

Improvements in heifer performance have the potential to bring about large gains in profitability for northern Australian properties since heifers require about a third of the grazing area available for females on a property (Fordyce 1996). Ridley (1994) calculated that while heifers comprise one third of the animal equivalents of a commercial breeding herd (in the Victoria River District), they only yield an average of 17% of the total calf crop, and that a 40% improvement in heifer productivity would therefore result in a 7% lift in the production of the whole breeding herd. With weaning rates in the adult herd now averaging in excess of 80% in some areas, there do not appear to be many other ways of achieving such a considerable lift in overall productivity.

1.2 The relationship between joining weight/condition and pregnancy rates

It is generally accepted that liveweight/body condition is the major factor influencing the onset of puberty and conception rates of heifers (Entwistle 1983, Reynolds *et al.* 1963, Wiltbank *et al*. 1969, Sparke and Lamond 1968; Joubert 1954).

Several studies have shown that conception rates increase as liveweight at joining increases (Reynolds *et al*. 1971, Goddard *et al*. 1980, Rudder *et al.* 1985, Doogan *et al.* 1991 and Schatz *et al.* 2004a).

O'Rourke et al. (1991) in their study of Brahman cross cattle at Mt Bundey (NT) reported that pregnant heifers weighed 28 kg (or 13kg corrected for the stage of pregnancy) more than non pregnant ones at the end of mating. In first-lactation heifers the conception rates were 14% for heifers lighter than 275kg, 32% for those between 275 and 325kg, and 49% for those >325 kg (at the end of mating).

Jolly et al. (1996) stated that the odds of first calf heifers resuming oestrous cyclicity within 6 weeks after calving increased about 3-fold for every 20 kg increase in liveweight at weaning (in heifers that are >270 kg) and length of post partum anoestrus interval (PPAI) increased by a factor of 1.2 for every half unit decrease in body condition score (using the 1 to 9 system).

Dixon (1998) summarised data from *Bos indicus* cross cattle in northern Australia (and two African data sets) and stated that the effects of liveweight on fertility were more important in lighter cows than heavier ones. He concluded that for cows lighter than 340 kg a 5% increase in pregnancy rate might be expected for each 10 kg increase in weight achieved by improved nutrition prior to mating. For cows >340 kg the response is more likely to be a 3% increase.

Reports in the literature indicate that it is the actual weight and condition at calving/joining that is important, rather than the weight changes that have led to reaching that weight/condition (Richards *et al.* 1986, Whittier *et al.* 1988, De Rouen *et al.* 1994, Dixon *et al.* 1997b and Morrison *et al.* 1999). Where heifers/cows are in good condition at calving their conception rates are not affected much by moderate weight changes either before or after calving (Corah *et al.* 1975; Dunn and Kaltenbach 1980), however large weight losses after calving can reduce conception rates (Rakestraw 1986) and this is common in first calf heifers in northern Australia (Entwistle 1983).

Since there is such a strong relationship between liveweight and reproductive rates it should be possible to define this relationship in terms of a formula or regression equation. Lamond (1970) in his review states “it seems that, for any particular breed in a particular location under a specified system of management, a model can be developed to depict likely consequences of changes in level of nutrition on fertility.” There have been a number of models developed to predict conception rates from joining weights but none are directly relevant to high grade Brahman heifers on extensive properties in the NT. The aim of this project was to meet this need. Following is a review of a number of the models that have been developed and an evaluation of how they may or may not be applicable to NT Brahman heifers.

It should be noted that the methodology varied between studies and that weights were collected at different stages. It is usually quite simple to collect joining weights for maiden heifers, however it is much more difficult in first calf heifers and in practise a pre-calving weight is often used instead of a joining weight (especially under extensive conditions in Northern Australia). The reason for this is that mustering and weighing heifers that have recently calved or are just about to calve can increase the rate of calf loss (and so managers do not like to do it). If heifers are not weighed before calving it is difficult to find suitable time after calving, since a group of heifers usually calve over a period of several months and this usually occurs during the wet season in northern Australia when mustering is difficult. Therefore a pre-calving weight is usually used instead of a joining weight for first calf heifers and this is a more practical measure for use by cattle managers. Some studies have found a strong relationship between the weight of heifers at the time when their calves are weaned and the proportion of heifers that have re-conceived (O'Rourke *et al.* (1991); Schatz and Hearnden 2008) and this avoids mustering heifers during calving.

King (1968) developed a model for dairy cows in which a regression equation predicted pregnancy rate (using artificial insemination) from change in liveweight. While this demonstrates the principles of relating conception rate to liveweight, this model is likely to have little relevance to Brahman maiden and first calf heifers under extensive conditions in the NT. This is also the case with other models that were developed for different genotypes in other countries: Meaker (1975) produced an equation that can be used to determine the joining liveweight required to achieve high conception rates in Africander lactating cows in South Africa. In the USA Dunn and Kaltenbach (1980) showed that for each 1 kg decrease in pre-calving body weight, there was a 0.5% decrease in multiparous Hereford cows that show oestrus by 60 days post partum and that PPAI was increased by 1 day for each 5 kg of pre partum weight loss in first calf Hereford and Angus heifers.

Rudder *et al.* (1985) stated that there are few reports of relationships between joining liveweight and reproductive rates in tropically adapted genotypes. They described these relationships for Brahman crossbred cattle (up to 50% *Bos taurus*) in central Queensland (Qld) and gave regression equations for yearling mated heifers and cows of various ages.

While useful for crossbred animals in central Qld, the predictive equations produced by Rudder *et al.* (1985) are not that relevant to Brahman heifers on extensive properties in the NT as their equations were produced from different genotypes (up to 50% *Bos taurus*) under less harsh conditions and on a relatively small property (*Panicum* pasture near Rockhampton Qld where the stocking rate was 3.2- 4.3 ha per breeder). As a result their equations give considerably higher estimates of conception rates than what has been reported by other research in the harsher areas of northern Australia for the corresponding weights (see Figure 1).

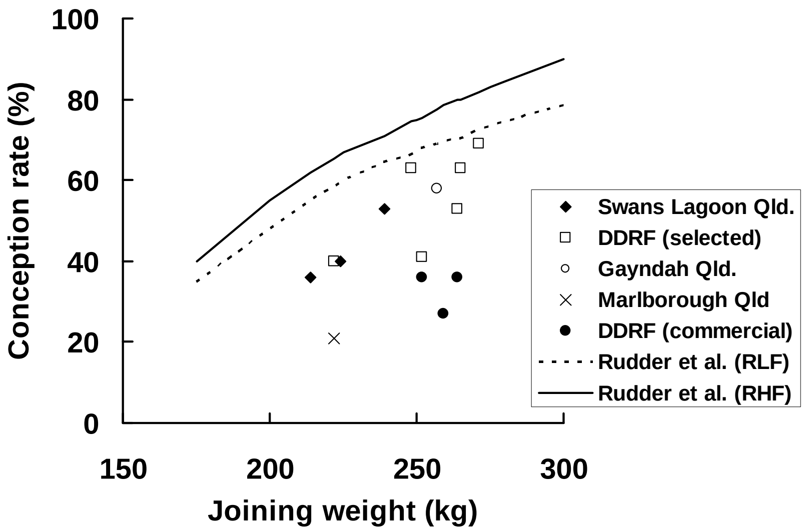

Figure 1. Comparison of conception rates of yearling mated heifers with those predicted by Rudder *et al*. (1985)

The data in figure 1 is sourced from; Swans Lagoon - Fordyce et al. (1992-4), DDRF selected-Jayawardhana et al. (1999), Gayndah – Gulbransen (1994), Marlborough – Loxton and Holroyd (1996a), DDRF commercial – this project
Rudder et al. (1985) – RLF = relatively low fertility genotype and RHF = relatively high fertility genotype.

Figure 1 shows that the Rudder *et al.* (1985) equations overestimate the conception rates for heifers mated as yearlings in northern Australia, especially at the lighter weights. The Rudder *et al.* (1985) equations are also not relevant to the majority of extensive properties in the NT since most are not able to achieve the growth rates required to successfully join heifers for the first time as yearlings.

Doogan *et al.* (1991) studied the relationship between liveweight at the start of mating (SOMW) and conception rates for *Bos indicus* x Shorthorn cross maiden heifers (½ and ¾ Brahman and Sahiwal) first joined at 2 years of age. They found that the response to increased liveweight was curvilinear with a point of inflection around 250 kg. They produced the following equations for the regression of SOMW on conception rate with very high R^2 values.

1st back cross heifers (¾ Brahman or ¾ Sahiwal cross Shorthorn)
CR = -430.5 + 3.346 SOMW – 0.0053 SOMW2   (R2 = 0.94)

F2 et seq. heifers (57.5% Brahman and Sahiwal cross Shorthorn)
CR = -227.1 + 2.056 SOMW – 0.0034 SOMW2   (R2 = 0.98)

These equations are shown diagrammatically in Figure 2.

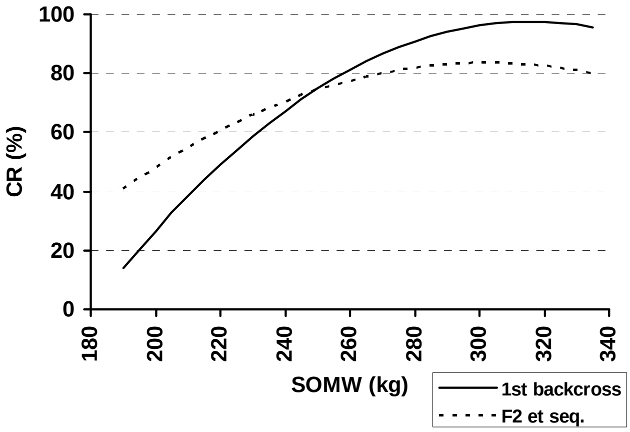

Figure 2. The effect of SOMW on conception rates of two genotypes of maiden heifers in north Queensland

The genotypes studied in Doogan *et al.* (1991) are different to high grade Brahmans and the type of model used is no longer considered to be the appropriate method for analysing this type of data. The model used to produce the F2 *et seq.* line in figure 2 seems to have a limit on conception rate around 84% which is unlikely to actually be the case for heifers that are 57.5% *Bos indicus* cross (ie it would be possible to get conception rates higher than 84% at the higher joining weights but the type of model fitted doesn't allow for it).

Bakry (1981) generated a model to predict pregnancy rate from weight (in January), age and a year effect using data from Droughtmaster cows in North Queensland. Weight was found to have a significant effect on pregnancy rate in non-lactating cows but not in lactating cows and the author believed that this was due to the unreliability of the weight data that was used in the analysis. Also the data came from mature cows and the model required too much information to have a practical use in the extensive NT cattle industry.

Dixon (1998) reviewed work on predicting conception rates from joining weights in tropical cattle. Using data from *Bos indicus* cross cattle in northern Australia and two African data sets he derived equations that showed that increases in liveweight cause larger increases in fertility in lighter cows than heavier cows. He found that in most cases the data was best described by two linear relationships where:

- in cows lighter than 340 kg at mating there was an increase in pregnancy rate by about 5% for each additional 10 kg increase in liveweight.
- in cows heavier than 340 kg at mating there was an increase in pregnancy rate by about 3% for each additional 10 kg increase in liveweight.

Dixon (1998) also produced a relationship between joining weight and subsequent pregnancy rate for first calf heifers from the data of Goddard *et al.* (1980). However this was from a small data set with Droughtmaster cattle, and the highest pregnancy percentage was only 50% (and it would be useful to know the relationship beyond this).

Anderson (1990) reported data collected over a number of years from the mating of 3 year old first calf heifers at Swans Lagoon and Fletcherview in north Queensland. The breeds used were characterised as 1/2 or 3/4 *Bos indicus* made up of various combinations and generations of Brahman, Sahiwal, Africander, Shorthorn and Hereford. Although the data was not presented in this way, when regression analysis is performed on all the average start of mating weights and the subsequent conception rates, an equation with an R^2 of 0.875 is produced (Figure 3). It would be possible to use this equation to produce a chart showing the likely mating outcomes from mating heifers at different weights (see Figure 3) but again there are some limitations in applying this data directly to high grade Brahman heifers in the NT. As well as the genotype differences, linear regression is not the correct method of analysis as the relationship between liveweight and conception rates is unlikely to be linear over the full range of liveweights. A wider range of data is required to produce an equation that more accurately describes this relationship over it's full range (the maximum average joining weight was 375kg at Swans Lagoon and 402kg at Fletcherview).

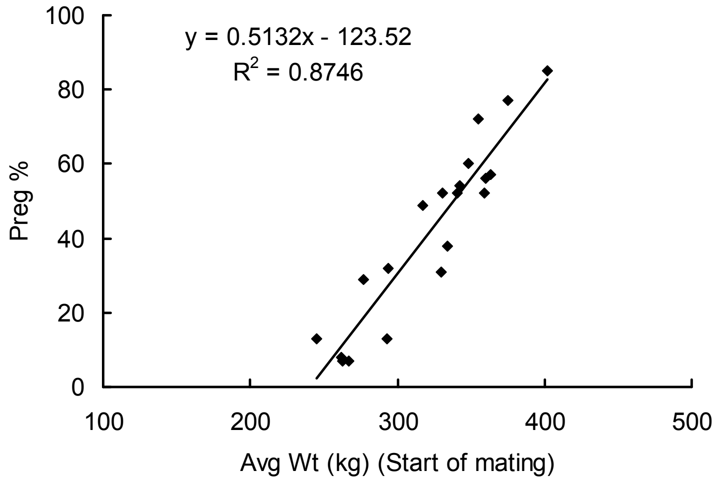

Figure 3. The relationship between weight and conception rates for ½ and ¾ *Bos indicus* cross 1st calf heifers (3 y.o) in north Qld (data sourced from Anderson 1990)

Also each data point in Figure 3 is an average joining weight for a year group of heifers and so different joining weights are due to seasonal effects. Cattle managers would be interested to know the effect of weight differences brought about through management eg. supplementation.

O'Rourke *et al.* (1991) found no predictive relationship for conception rate in first lactation heifers at Mt Bundey (NT) but found that there was a strong relationship (P<0.01) between liveweight after mating (ie at the time when their calves were weaned) and the conception rate that had occurred during the previous mating period. However conception rates were only given for 3 classes of first lactation heifers (< 275 kg = 14%, 275-325 kg = 32%, and > 325 kg = 49%) and the highest conception rate given was 49%. Again it would be useful for cattle managers aiming to achieve higher conception rates in first lactation heifers for this relationship to be described in more detail and over a wider range (ie higher than 49%).

Schatz and Hearnden (2008) also found a strong relationship between pregnancy rates in first lactation heifers and their weight at the time when their calves were weaned (WR1). This relationship was generated using data from 11 different properties in the NT and each data point represented the average weight of a group of first lactation heifers and the pregnancy rate of that group. Again while this was not a predictive relationship as weight was recorded after the mating period, it does show that weight during the mating period has a strong effect on re-conception rates in first lactation heifers.

While weight and BCS can be used to predict conception rates it should be noted that there will always be some inaccuracy in the predictions as growth rates of heifers during joining vary, and weight and BCS are not the only factors affecting pregnancy rate. Pregnancy rate in lactating first calf heifers is determined by the proportion of heifers whose PPAI is short enough to have re-conceived by the end of mating and there are a number of factors that influence PPAI length. Short *et al.* (1990) state that "a degree of caution should be exercised when interpreting simple correlation and regression relationships between BCS and post partum interval (and hence re-conception rates) since both of these variables are physiological responses in a system in which the relationships may not be cause and effect but co-generated.

Establishing the relationship between joining (or pre-calving) weight and conception rates for Brahman maiden and first calf heifers over its full range in the NT would be a useful resource for cattle managers. The aim of this project was to do this and produce simple charts showing joining weights and corresponding expected conception rates could be a used by producers to identify the most profitable target joining weights for their situation. They are in the best position to decide how to reach the target weights on their property.

1.3 Yearling mating of Brahman heifers in northern Australia

Most properties in northern Australia try to keep their young heifers segregated from bulls until the start of their first mating period. This is usually timed to coincide with the start of the wet season and is roughly either 12 or 24 months after the majority of the heifers were born. Most heifers on northern Australian properties are mated for the first time as “two year olds” (Bortolussi *et al.* 2005) although some properties practice “yearling mating”. It should be noted that both these terms are quite general and somewhat misleading as not all heifers are 24 months of age (in the case of 2 year old joining) or 12 months of age (in the case of yearling mating) at the start of joining, but that there is a range around these ages.

Usually in northern Australia the term “yearling mated” is used to describe heifers that are mated in the first wet season after weaning. Weaning usually occurs throughout the dry season months (from May to October) on northern Australian properties (Bortolussi *et al.* 2005), and where yearling mating is practiced, weaner heifers that look like they may be heavy enough by the end of the year are selected for “yearling mating”. In practice these are usually the oldest weaner heifers and, especially where heifers come from continuously mated herds they may be older than 12 months and usually range from 12 to 18 months of age at the start of joining.

Heifers are generally joined when it is considered that they are likely to reach puberty before the end of the joining period, and at a time when the calves conceived from that joining are likely to be born just before the period when pasture quality and quantity are at their best (Fordyce 1990). Obviously the younger heifers start breeding, the greater their potential lifetime calf production will be. However the ability to successfully join heifers as yearlings (around 12 months of age) depends on the growth rates that are possible on each property, as the critical weights for puberty need to have been reached by joining for yearling mating to be successful.

Pregnancy rates from the first ovulation when puberty is reached are lower than in subsequent cycles (Byerly *et al.* 1987). At least two fertile cycles are required to achieve pregnancy rates of 90% and so to achieve good conception rates in maiden heifers they should reach puberty by such time that they will have at least reached their third ovulation before the end of joining (Fordyce 2006). It is important that heifers have reached weights sufficient to give them a high probability of conceiving early in the first mating period as heifers that conceive early will then calve early. This has been found to increase their likelihood of re-conception and as a result heifers that conceive early during their first joining period have been found to wean more kilograms of calf over their lifetime (Lesmeister *et al.* 1973).

Since weight has the largest influence on age at puberty (Entwistle 1983), the growth rates that can be achieved on a property largely determine the age at which heifers are joined for the first time there. “Yearling mating” can be considered where growth rates are sufficient for heifers to reach the critical target joining weight (usually around 270 kg) by about 12 months of age.

It should be noted that most properties in northern Australia do not achieve sufficient growth rates for yearling mating, and that even where maiden heifers are first joined at two years of age that it is not uncommon for a proportion of heifers to have failed to reach adequate joining weights resulting in low conception rates in maiden heifers (Goddard *et al.* 1980; Schatz and Hearnden 2008). This is a result of inadequate nutrition between weaning and joining and can usually be overcome through adequate supplementation programs and appropriate stocking rates.

The fact that Brahman heifers reach puberty later than *Bos taurus* heifers (Warnick *et al.* 1956, Reynolds 1967, and Randel 2005) means that they are usually less suitable for yearling mating. Hearnshaw *et al.* (1994) found that only 9% of pure Brahmans in their study had reached puberty by 22 months of age, and Randel (1994) states that Brahman and Brahman-based heifers reach puberty at too old an age to routinely calve at 2 years of age (ie for successful yearling mating). This is especially the case in many parts of northern Australia where nutrition is often limiting, however high conception rates can be achieved from yearling mating of Brahman cattle under favourable conditions especially in Brahman genotypes that have been selected for fertility. Schatz *et al.* (in press) reported a pregnancy rate of 79% in one year group of high grade Brahman heifers that came from a herd that had been highly selected for fertility and had been mated as yearlings.

Substantial gains can be made through mating replacement heifers for the first time as yearlings, if they can meet target weights at their first and second joinings. Lifetime breeder calf output is increased which improves the breeding herd efficiency (Donaldson 1968, Morris 1980 and Fordyce *et al.* 1994). Fordyce *et al.* (1994) states that yearling mating in northern Australia can increase lifetime breeder output by 0.3 to 0.5 calves which is a 5-10% increase in the annual herd branding rate (assumes a base branding rate of 75%). Yearling mating is also a way of identifying heifers that are inherently more fertile and will produce more calves over their lifetime (Lesmeister *et al.* 1973 and Morris 1980). Age at puberty in Brahman heifers is also quite highly heritable (0.57) (Johnston *et al.* 2009) and so the use of yearling mating in a selection program is likely to produce an earlier maturing line of animals over time (Schatz *et al.* in press).

However Short *et al.* (1990) state that yearling mating may not be a viable management practice on properties where some or all of the following factors apply; low pasture quality and quantity, slow-maturing genotypes and less intensive management systems. These factors occur to some extent on most properties in northern Australia. The success of yearling mating depends largely on whether the heifers have reached puberty by joining. Obviously if a heifer has not yet reached puberty by the end of the joining period it won’t be pregnant. Studies have shown that conception rates are correlated with the number of heifers exhibiting oestrus early in the breeding season (Short and Bellows 1971). High conception rates in yearling heifers can only be expected from heifers that have reached the critical weights required for puberty. The critical weight for yearling mating is considered to be around 275 kg by the start of joining (Rudder *et al* 1995).

Entwistle (1983) states that in southern Australia, the question of whether to mate heifers as yearlings or two year olds is decided by the producer’s ability to achieve critical minimum target joining weights. The same principle holds for northern Australia although in the past it has been assumed that heifers in northern Australia will not make the target joining weights as yearlings, and so most heifers are traditionally mated (intentionally) for the first time as two year olds (Oxley *et al.* 2004). However, there are some regions within the NT where adequate growth occurs to make yearling mating a possibility. One such area is the Douglas Daly region with it’s fertile soils, improved pastures and high and reliable rainfall. Schatz *et al.* (2004) found that on average heifers will put on 65 kg between weaning and the start of mating on the first of January at DDRF and so heifers weighing 200 kg or more at weaning should be suitable for yearling mating there. One aspect of this project was to determine the profitability of a management strategy that involves transporting Brahman heifers from commercial properties in areas of the NT where heifers are traditionally first mated as two year olds to the Douglas Daly region and mating them as yearlings.

1.4 Pre partum supplementation of first calf heifers

Since conception rates increase with joining weight in first calf heifers (Rudder et al. 1985 and Anderson 1990) it follows that increasing the joining weight of heifers through improved nutrition should result an increase in the number of calves weaned and a corresponding increase in profit, although much depends on the cost of the improved nutrition.

Reports in the literature indicate that while there can be effects from both pre and post partum weight change (Wettemann *et al.* 1982; Rutter and Randel 1984) that body condition at calving has by far the biggest effect on subsequent re-conception rates in lactating first calf heifers (Wettemann *et al.* 1986; Short *et al.* 1990) and that where heifers/cows are in good condition at calving their conception rates are not affected much by moderate weight changes either before or after calving (Corah *et al.* 1975; Dunn and Kaltenbach 1980). It has also been shown that cows need to have greater body reserves to re-initiate cycling than to maintain it (Leow *et al.* 1988 and Wettemann 1994). From this it follows that since most heifers in northern Australia experience limiting nutrition through the dry season leading up to calving, that supplementation will be most beneficial when it is used to increase body condition at calving rather than to try to build body condition back up after calving.

While weight loss post partum has been found to reduce conception rates (Rakestraw et al. 1986), the effects of post partum supplementation have been variable. Some studies have found that supplementation of first calf heifers post partum does increase conception rates when heifers are in poor condition (Spitzer et al. 1995 and Lalman et al. 2000), and other studies have found no improvement in fertility following post partum supplementation (Lishman et al. 1984, McSweeny et al. 1993, Marston et al. 1995 and Dixon et al. 1996a). Generally where heifers are in adequate condition at calving, post partum supplementation has little effect on re-conception rates (Richards et al. 1986).

The responses to pre partum supplementation have also been variable but have generally been more successful than post partum supplementation in increasing conception rates (McSweeny *et al.* 1993, Marston *et al.* 1995 and Fordyce 1996). In their review Monteil and Ahuja (2005) state that in beef cows, pre partum nutrition reflected by BCS at calving is a greater determinant on the length of post partum anoestrus than post partum nutrition is. Pre partum supplementation is also more practical and efficient than post partum supplementation in northern Australia as heifers and cows usually calve during the wet season and the wet conditions can make implementing supplementation programs with high protein and energy supplements difficult. Feeding these sort of supplements post partum is also less efficient as calves eat the supplement and the on-farm costs of supplementary feeds are usually very high in northern Australia.

In studies done in northern Australia, Dixon *et al.* (1997a and b) and Siebert *et al.* (1976) found no increase in joining weight or conception rates following supplementation in the pre-calving dry season in years where there was rain and hence green pick in the dry season. Siebert *et al.* (1976) did get a response to supplementation with cottonseed meal in a dry year. Dixon *et al.* (1996b) reported a significant increase in pregnancy rates from feeding a cottonseed meal and urea based dry lick in the dry season. Fordyce *et al.* (1997) state that their results indicate that 42-54 days of dry season supplementation of late-pregnant *Bos indicus* cross cows grazing poor quality native pasture can, in some years, significantly improve subsequent fertility, particularly in cows rearing their first calf.

Entwistle *et al.* (1994) state that “spike feeding” (a strategy of feeding a high quality supplement for about 50 days starting 6-8 weeks before calving) heifers in the first pregnancy (ie pre partum supplementation) will increase pregnancy rates by an average of about 15% and up to 25% in good seasons, although there may be no response in very poor seasons.

Where pre partum supplementation has not caused an improvement in subsequent re-conception rates, it has been because the supplementation did not result in the fed group being heavier at joining (eg Dixon *et al.* 1997a and 1997b). The challenge for a manager who wishes to increase the fertility of first calf heifers through increasing their joining weight is to find a method of reliably and cost effectively increasing the joining weight. The response from feeding supplements has been variable in achieving this, especially where there is a late break to the season. In these situations supplementary feeding probably has to be continued right up to the break in the season to maintain the increased weight and thus get a response in fertility (Fordyce *et al.* 1996).

Supplementary feeding is not widely practised on extensive NT cattle stations (Oxley *et al.* 2004) due mostly to the high cost of transport. While it seems that good pasture due to good seasons has been more effective in producing higher re-conception rates in first calf heifers (Anderson 1990 and Dixon 1997a), it would still be advantageous to be able to increase joining weight through management rather than relying totally on favourable seasons. This can be achieved either through supplementary feeding or through the use of better quality pasture and/or lower stocking rates. Areas in the NT where high growth rates and joining weights can be achieved are on the Barkly Tableland (Savage *et al.* 2004), the Douglas Daly region (Schatz *et al.* 2007) as well as in the Alice Springs district in good seasons (after a rainfall events).

Grazing *Leucaena* has been one method proposed to achieve higher joining weights on extensive properties in northern Australia. Steers grazing *Leucaena* at Meadowbank in north Queensland have gained 0.84 kg/head/day over the dry season (from late June to November 1997) (Meadowbank PDS Annual Report 1999). Petty *et al.* (1998) reported dry season gains in heifers grazing *Leucaena* in the Ord of 0.71 kg/day. Similar performance from heifers in the dry season prior to their first calving would see them attain the high weights conducive for high re-mating conception rates at their second joining.

There have been reports of *Leucaena* depressing the fertility of cows (Jones *et al.* 1989) but the authors of this study stated that they expected that the problems would be overcome through inoculation with DHP degrading bacteria. It is now thought that cattle that possess the bacteria have no problems with fertility (Raymond Jones *pers. comm*.).

From the reports in literature cited above it seems that the most reliable way of increasing re-conception rates through the use of supplementation in northern Australia is by supplementing them through the late dry season prior to first calving. It also seems to be important to continue the supplementation until the season breaks and green grass is available other wise much of the benefit of the supplementation can be lost. Therefore this was the strategy undertaken in this research.

1.5 Terminology

Throughout this document, the term heifer is used to refer to replacement breeders up until the time that they have weaned their first calf (and should be pregnant with their second).

Heifers being mated for the first time are called maiden heifers. From diagnosis of their first pregnancy until the weaning of their first calf they are referred to as first calf heifers.

The terms “mating” and “joining” (as in “mating period” and “joining period”) are assumed to mean the same thing and are sometimes used interchangeably.

The term “target joining weight” refers to the targeted average weight of heifers at the start of joining. The term “critical weight for first conception” refers to the average weight at which heifers first conceive.

Victoria River Research Station is referred by the acronym VRRS and the Douglas Daly Research Farm by DDRF.

Several abbreviations are used for the measurements that were recorded. These are:

Wn Wt = weaning weight

PJ Wt = pre joining weight

PJ Fat = pre joining P8 fat depth (mm)

EJ Wt = end of joining weight

PC Wt = pre calving weight

PC Fat = pre calving P8 fat depth (mm)

WR1 Wt = weaning round 1 weight.
A superscript letter C (ie ^{C}) shows where a weight has been corrected for stage of pregnancy, or growth has been calculated from corrected weights.

The age group of heifers is denoted by the use of the symbol for number (#) and the year that they were weaned in. Therefore heifers weaned in 2004 are referred to as #4 heifers, heifers weaned in 2005 are referred to as #5 heifers etc.

2 Project objectives

The objectives of this project are (by December 2009) to:

1. Establish the relationships between conception rate and:
   - body weight,
   - condition score, and
   - P8 measurement

   For maiden heifers in the Northern Territory joined over two consecutive pregnancies. Relationships will be established for heifers first mated as yearlings and as two year olds.

2. Create simple management tools that show the expected conception rates for heifers of a particular age, weight, condition score and P8 measurement at their first two joinings.

3. Demonstrate and document the heifer body weights, subsequent fertility and costs incurred under high and low input management systems in the NT.

3 Methodology

The methodology is described for each objective separately.

3.1 Establishing the relationship between weight, condition and fatness in Brahman heifers in the NT

A brief summary of the methodology of this aspect of the project is given here and then the work at each of the research sites is described in more detail in sections 3.1.1 and 3.1.2.

Brief summary: Three year groups of about 100 Brahman maiden heifers were joined at Victoria River Research Station (VRRS) at 2 years of age, and at Douglas Daly Research Farm (DDRF) as yearlings.) At both sites, the heifers that conceived were split into two treatment groups. One group (CON) grazed pasture as normal in the pre-calving dry season, while the other (HN = high nutrition) was managed (fed a protein supplement) with the aim of gaining about an extra 50 kg before calving. The intention was to produce heifers with a range of weights/body conditions at their second joining.

The data produced was then used to generate models that describe the relationship between weight/condition and pregnancy rates, and that predict pregnancy rates from joining weights and body condition/fatness of maiden and first calf heifers. These models were then used to produce charts for use by cattle managers and advisors showing the conception rates that would be expected from mating maiden and first calf heifers at different weights and fatnesses.

3.1.1 Heifers first mated as 2 year olds at VRRS

The Victoria River Research Station (VRRS) is in the Victoria River District (VRD) about 220 km south west of Katherine, NT (16^{o}7' S and 130^{o}57' E). The climate, soils and pastures have been described by Sullivan and O'Rourke (1997) but a brief summary is that the climate is hot with a strongly seasonal rainfall pattern and that the pastures are native species predominantly *Chrysopogon fallax*, *Iseilema* spp., *Enneapogon* spp. *Heteropogon contortus and Sehima nervosum*.

Like most parts of the NT, the year is considered to consist of two seasons known as the wet season and the dry season. The wet season (usually from November to March) is characterised by high temperatures and humidity, and around 90% of the annual rainfall (737 mm) falls in these months (Table 1 – BOM 2009). The dry season (usually from April to October) is characterised by almost no rainfall, lower humidity and lower temperatures although the average daily maximum is normally still around 30^{o} (Table 1). Most mustering and stock work is done during the dry season and like most properties in the region, VRRS performs two mustering rounds at which weaning and husbandry practises are performed; the first weaning round muster (WR1) is at the start of the dry season (usually in May or early June) and the second round muster (WR2) is at the end of the dry season (usually in late September or October).

Table 1. Climate data for VRRS

	Mean maximum temp. (°C)	Mean minimum temp. (°C)	Average Rainfall (mm)	2005 Rainfall (mm)	2006 Rainfall (mm)	2007 Rainfall (mm)	2008 Rainfall (mm)	2009 Rainfall (mm)
Jan	35.9	25.0	168.8	206	267.2	134.4	104	451.4
Feb	35.6	24.7	199.6	164.5	46	35.6	575.7	462
Mar	35.6	23.3	128.5	129.9	414.1	299.5	32.2	14
Apr	35.5	20.6	23.7	0	319.6	0	0	0.6
May	32.6	15.9	4.4	0	0	12.8	0	0
Jun	29.8	13.1	4.0	0	0	102.6	0	0
Jul	30.3	12.2	2.6	0.5	0.4	0	0	
Aug	32.7	13.8	0.1	0	0	0	0	
Sep	36.8	19.8	3.6	4.3	0	0	1.4	
Oct	38.7	23.7	25.7	63.8	0	47.7	0.7	
Nov	39.0	25.0	57.4	67.9	17	15.8	109.9	
Dec	37.4	25.3	139.3	151.6	62	125.8	335.8	
Total	34.9	20.2	737.4	788.5	1126.3	774.2	1159.7	

Data sourced from BOM website (BOM 2009). Average rainfall is for the period 1970 to 2009. Mean monthly maximum and minimum temperatures are for the period 1996 to 2009. Monthly rainfall records are shown for the years relevant to this project.

Each year (in 2004, 2005 and 2006) at the first weaning round (WR1) at VRRS, a weaning weight (referred to as Wn Wt in this report) was recorded for about 110 Brahman weaner heifers and they were segregated from the rest the herd and placed in a heifer paddock to grow out until they were ready for joining at approximately 2 years of age. During this time the heifers were given inorganic supplements ad libitum and were weighed twice a year. The supplements used were a “loose mix” of 50% salt, 20% urea, 20% kynophos and 10% gran-am in the dry season and 50% salt, 35% kynophos and 15% gran am in the wet season. From weaning until the end of their first joining period the heifers were stocked at rate of approximately 18 per km^2.

All heifers were given Vibrovax™ vaccinations (once prior to first joining as two year olds) and 7 in 1™ vaccinations (twice; one at weaning and another several months later) to protect against infection with vibriosis and leptospirosis.

Prior to being mated for the first time at around 2 years of age, the heifers were weighed and their fat depth at the P8 site was measured ultrasonically. These measurements were taken in November and are called pre joining weight (PJ Wt) and pre joining fat depth (PJ Fat) in this report.

Bulls were introduced to the heifers in mid December and mating continued until the end of March when the bulls were removed from the paddocks. Young bulls that had been fertility tested were used. The heifers were pregnancy tested (manual palpation per rectum) and weighed (end of joining weight = EJ Wt) about 2 months after the bulls were removed and real time ultrasound was used to confirm pregnancy diagnosis’ if necessary (with early pregnancies).

Following pregnancy diagnosis in May/June the pregnant heifers were allocated (randomly and stratified for pregnancy status and weight) to one of two treatments– high nutrition (HN), or control (CON). These two groups grazed in very similar paddocks that were adjacent to each other (they had previously been one paddock but were split into two at the start of the project for this purpose). Both paddocks were stocked at a rate of around 10 heifers per km^2. The CON group was given the dry season inorganic supplement (described earlier) and conditions were the same for the HN except that they were also given a protein supplement over the latter part of the dry season leading up to calving.

A description of the protein supplement used in the HN treatment in each year is as follows;

1) #4 heifers (first mated from December 2005 to March 2006). From 17/7/06 to 18/12/06 the HN heifers were fed AustAsia Hipro pellets (28% crude protein) twice weekly at a rate of 2.27 kg/hd/day (or 0.58 % of liveweight).
2) #5 heifers (first mated from December 2006 to March 2007). From 30/7/07 to 16/11/07 the HN heifers were fed copra meal (22% crude protein) twice weekly at a rate of 1.62 kg/hd/day (or 0.4 % of liveweight).
3) # 6 heifers (first mated from December 2007 to March 2008). From 11/8/08 to 17/11/08 the HN heifers were fed copra meal twice weekly at a rate of 1.62 kg/hd/day (or 0.4 % of liveweight).

The reason that the AustAsia live export pellets were used in the first year and copra meal was used in the other years was that it was originally intended to use the AustAsia pellets in all years, but they were not available after the first year of the study (the company stopped importing them). Feeding continued up until the “season broke” ie rain resulted in green pasture being available. This occurred at different times each year which is why feeding finished on different dates.

A pre calving weight (PC Wt) and fat depth (PC Fat) were recorded in September. This was timed to be as close as possible to the start of calving without having to muster heifers that were just about to calve or had recently calved.

In 2008 the ultrasound machine used to measure fat depth broke down on the day that the cattle were mustered and so PC Fat could not be recorded in that year.

Since feeding continued past the date on which the PC Wt was recorded (until the break in the season) it was not possible to accurately determine the full benefit of the HN treatment in each year in terms of extra weight gain.

The heifers calved over the wet season and bulls were re-introduced in late December and remained with the heifers from this point onwards. The heifers were mustered in May and the calves were weaned (WR1). At this time lactation status was recorded to determine whether each heifer had successfully raised a calf to weaning or if calf loss had occurred. Weight (WR1 Wt) and fatness (WR1 Fat) at weaning were recorded and pregnancy status was determined by manual palpation per rectum and real time ultrasonography.

All weights were recorded after a 12 hours without feed or water ie the animals were mustered to the yards, fasted over night and weighed the next morning. Weights recorded when heifers were pregnant (ie pre calving and at WR1) were corrected for the stage of pregnancy, using the technique described by O’Rourke *et al.* (1991a), before statistical analysis.

Statistical analysis
The relationship between pregnancy rate and each of the following variables; PJ Wt, PJ Fat, PC Wt and PC Fat, for each of the data sets was assessed with generalised linear models using binomial errors and a logit link function (McCullagh & Nelder 1989). For each the data comprised a number of year groups (all managed similarly) so year class was also fitted as a covariate. In all cases the interaction with year was not significant ($p > 0.01$) so the final fit was determined for the pooled year class data. To assess the fit, an analogue of the R^2 measure used for linear models was calculated using a squared residuals fit of proportion pregnant in size-classes to predicted values of the regression obtained from the generalised linear model (Mittlbock 2002).

3.1.2 Heifers first mated as yearlings at DDRF

The Douglas Daly Research Farm (DDRF) is located approximately 220 km south of Darwin (NT) at the northern end of the Daly Basin (13°50' S, 131°11' E). The climate is fairly similar to that at VRRS except that it is more tropical ie the rainfall is higher, the wet season tends to start earlier and the humidity is usually higher. The average annual rainfall from 1968 to 2009 was 1233 mm (BOM 2009). The average daily maximum temperature is greater than 30°C all year round but the months between April and August are cooler and less humid (Table 2).

Table 2. Climate data for DDRF

	Mean maximum temp. (°C)	Mean minimum temp. (°C)	Average Rainfall (mm)	2004 Rainfall (mm)	2005 Rainfall (mm)	2006 Rainfall (mm)	2007 Rainfall (mm)	2008 Rainfall (mm)	2009 Rainfall (mm)
Jan	33.6	23.8	274.4	237.8	435.8	338	196.2	374.2	345.8
Feb	33.1	23.7	291.1	494.4	167.2	236.2	144.8	680.2	400
Mar	33.7	23	231	157.6	154	312.6	359.6	415.2	68
Apr	34.7	20.3	47.2	21.4	4.2	410.4	0.6	3.4	0
May	33.2	16.3	8.3	31.8	0	0	13.8	0	0
Jun	31.2	13.6	2.5	0.8	0	0	4.6	0	0
Jul	31.6	12.3	2.8	0	0	0	0	0	
Aug	33.5	14.2	1.3	0	0	0	21.4	0	
Sep	36.6	18.6	4.4	0	0.2	0.2	6.4	14.2	
Oct	37.5	22.3	35.9	4.4	115	0	6.2	0	
Nov	36.8	23.5	117.6	107.6	247.2	47	149.8	96.8	
Dec	35	23.6	204.3	126.6	228	350.6	308.8	251	
Total	34.2	19.8	1233.6	1182.4	1351.6	1695	1212.2	1835	

Data sourced from BOM website (BOM 2009). Average rainfall is for the period 1968 to 2009. Mean monthly maximum and minimum temperatures are for the period 1968 to 2009. Monthly rainfall records are shown for the years relevant to this project.

The main difference between the farming systems in the Douglas Daly area and the VRD is that properties in the Douglas Daly tend to be smaller, more highly intensified and have established improved pastures. This came about under what was known as the ADMA scheme where small properties where set up for the purpose of cropping and mixed farming, as the fertile soils and high and reliable rainfall made the district suitable for this type of farming. However over time most properties reverted back to cattle grazing but with improved pasture and some hay production

The soil type in the paddocks which were used for this project was a Blain soil type which has been described by Lucas *et al.* (1987) as a sandy red earth. It is a fertile soil and suitable for improved pastures although the surface crusts and so some species (eg. Buffel grass) require cultivation for establishment.

The pasture in the experimental paddocks was almost exclusively Buffel grass (*Cenchrus ciliaris* cv. Gayndah) apart from some invading weeds and small amounts of Sabi grass (*Urochloa mosambicensis*). The Buffel pasture was established in 1988 on recently cleared bush. It received an annual dressing of 70 kg/ha of superphosphate and trace elements (Cu, Mo and Zn) every 3 years. The paddocks are spot sprayed for weeds using glyphosate and 2,4 Damine in the early to mid wet season.

The heifers were stocked at a rate of 1.3 per Ha in the first year they were at DDRF (until after their first joining) and then at 1.1 per Ha for the next year (from after their first joining until after their 2nd joining).

As well as establishing the relationship between joining weight/fatness and conception rates in Brahman heifers first joined as yearlings, the purpose of the work at DDRF was to determine the viability of a management system in which Brahman heifers from more extensive properties in other regions of the NT are transported to DDRF and joined there as yearlings.

Each year over 4 years (2004 to 2007) groups of about 100 high grade Brahman weaner heifers weighing between 195 kg and 260 kg were purchased from a NT commercial property (a different property each year) and transported to DDRF. Heifers weighing more than 195 kg were selected, as Schatz *et al.* (2004) found that it can be expected that on average heifers will grow about 65 kg from weaning (in the middle of the year) to the start of mating on the first of January at DDRF. From this it was decided that heifers weighing less than 195 kg at weaning would be unlikely to conceive when mated as yearlings and so only heifers weighing >195 kg were selected for this work. Heifers weighing more than 260 kg were not selected as they could not be considered to be “yearlings” (they were probably older and had missed being mustered the previous year).

These heifers proved difficult to purchase as they were considered by managers to be the best of their weaner heifers and in most cases it was difficult to find managers who were willing to sell them. As a result in some years the purchase of heifers could not be arranged until later in the year than originally intended. In 2005 and 2007 heifers were not transported to DDRF until the start of November (although they had been weaned several months earlier on the properties they had been purchased from). The heifers were transported to DDRF in early September in the other years.

On arrival at DDRF all heifers were weighed and vaccinated with Vibrovax^{TM} and 7 in 1^{TM} to protect against infection with vibriosis and leptospirosis. A second injection of each vaccine was given 6 weeks later. Heifers had *ad libitum* access to Uramol^{TM} lick blocks in the dry season and Phosrite^{TM} blocks in the wet season.

Each year some heifers from VRRS that had been weaned at the second round (WR2) the previous year and transported to DDRF were added to the purchased heifers to try to increase the number of pregnant heifers available for first calf heifer studies. These heifers were not included in the yearling mating studies as they were about 6 months older than the heifers purchased from the commercial properties.

Heifers grazed in paddocks that were almost entirely Buffel grass at a rate of 1.3 per Ha up until the start of mating in late December. A pre joining weight (PJ Wt) and fat depth (PJ Fat) measurement was recorded in mid December and young bulls that had been fertility tested were introduced to the heifers in late December and remained with them until the end of March. The heifers were pregnancy tested (manual palpation per rectum) at the end of joining and real time ultrasound was used to confirm pregnancy diagnosis' with early pregnancies.

The ovaries of non pregnant heifers were ultrasonically scanned for the presence of a corpus luteum (CL) at the end of the joining period. The reason for the ovary scanning was to determine whether non pregnant heifers had reached puberty (and were cycling). Two scans were performed 10 days apart as this timing allows for heifers being at different stages of their estrous cycle. If a heifer is cycling then a CL should be present on an ovary at one of the scans if they are done 10 days apart. If no CL is detected at either of the scans then the heifer is not cycling (and in the case of yearling heifers is unlikely to have reached puberty). Non pregnant heifers were held in a separate paddock for an additional two months and then preg tested again to confirm that they had not conceived right at the end of joining.

All pregnant heifers were allocated (randomly and stratified for pregnancy status and weight) to one of two treatments– high nutrition (HN), or control (CON). The CON group grazed pasture with continuous access to lick blocks while the HN group was managed with the aim that they would gain an extra 50 kg each over the pre calving dry season. In the first year the HN group grazed a crop stubble for a period and were given good quality hay. In subsequent years the HN groups grazed in buffel paddocks for the entire time but were also given a protein supplement over the latter part of the dry season leading up to calving.

A description of the HN treatment in each year is as follows;

1) #4 heifers (mated from late December 2004 to 31/3/05). Heifers grazed a crop stubble for a month from 06/07/05 and were then moved to Buffel grass pasture and regularly given bales of good quality hay up until 29/9/05.
2) #5 heifers (mated from late December 2005 to 31/3/06). From 15/8/06 to 6/11/06 heifers were given a ration (fed twice a week) of 1.2 kg/head/day cracked sorghum and 0.28 kg/head/day copra meal.
3) #6 heifers (mated from late December 2006 to 31/3/07). From 1/8/07 until 12/11/07 the heifers were fed (twice weekly) 1.43 kg/hd/day of copra meal.
4) #7 heifers (mated from late December 2007 to 31/3/08). From 15/8/07 until 21/11/0807 the heifers were fed (twice weekly) 1.43 kg/hd/day of copra meal.

A pre calving weight (PC Wt) and fat depth (PC Fat) were recorded in mid to late September but HN treatment feeding continued until the season broke and green grass became available (in November).

At the end of the feeding period for the HN treatment each year all the heifers were put into one (Buffel pasture) paddock to calve and be joined for the second time. Bulls were re-introduced in late December and remained with the heifers until early May. The heifers were checked regularly during the calving period and date of calving was recorded.

All heifers were mustered in early May and the calves were weaned (WR1). At this time lactation status was recorded to determine whether each heifer had successfully raised a calf to weaning or if calf loss had occurred. Weight (WR1 Wt) and fatness (WR1 Fat) at weaning were recorded and pregnancy status at WR1 was determined by manual palpation per rectum and real time ultrasonography.

Weights recorded when heifers were pregnant (ie pre calving and at WR1) were corrected for the stage of pregnancy using the process described by O'Rourke *et al.* (1991a).

Statistical analysis

The relationship between pregnancy rate and each of the following variables; PJ Wt, PJ Fat, PC Wt and PC Fat, for each of the data sets was assessed with generalised linear models using binomial errors and a logit link function (McCullagh & Nelder 1989). For each the data comprised a number of year groups (all managed similarly) so year class was also fitted as a covariate. In all cases the interaction with year was not significant ($p > 0.01$) so the final fit was determined for the pooled year class data. To assess the fit, an analogue of the R^2 measure used for linear models was calculated using a squared residuals fit of proportion pregnant in size-classes to predicted values of the regression obtained from the generalised linear model (Mittlbock 2002).

3.2 Creating management tools for heifer target mating weights and conditions

The data collected in this project was used to produce equations that predict the conception rates that are likely for heifers mated at different weights and fatnesses for;

3.2.1 - Maiden heifers first joined as two year olds in the VRD district (grazing native pasture).

3.2.2 - First calf heifers first joined as two year olds in the VRD district (grazing native pasture).

3.2.3 - Maiden heifers first joined as yearlings in the Douglas Daly District (grazing improved pasture).

3.2.4 - First calf heifers first joined as yearlings in the Douglas Daly District (grazing improved pasture).

These models were then used to create charts that show the expected pregnancy rates from different weights and fatness. These charts can be used by managers and extension officers to;

- Perform cost benefit analyses to work out the most profitable target joining weights for a property.
- Work out target joining weights for different situations.
- Calculate the return on investment associated with feeding strategies aimed at reaching different target weights.
- Work out the weight range of heifers in which supplementation to achieve target joining weights will be profitable (ie some heifers will be heavy enough anyway and some will be too light to make a target joining weight even with supplementing).

3.3 Demonstrating the costs and benefits of high and low input management systems for heifers in the NT

Most heifers are joined for the first time at two years of age on extensive NT cattle properties (Oxley *et al.* 2004 and Bortolussi *et al.* 2005) and other than being segregated from other cattle until their first joining, their management is usually fairly similar to the rest of the breeder herd. This project investigated costs and benefits of three other strategies. These were;

3.3.1 – Feeding protein supplements to first calf heifers during the dry season prior to calving in the VRD.

3.3.2 – Transporting Brahman weaner heifers to the Douglas Daly region for yearling mating.

3.3.3 - Feeding protein supplements to first calf heifers during the dry season prior to calving in the Douglas Daly region.

In each case the costs (feed, transport etc.) were compared to the benefits (higher pregnancy rates) to determine the potential of each strategy to increase profitability.

The methodology of each study is as follows:

3.3.1 Feeding protein supplements to first calf heifers during the dry season prior to calving in the VRD.

The management of the heifers involved in this study has been described in detail in section 3.1.1. In summary, 3 year groups of heifers (#4's, #5's and #6's) were used in the study at VRRS. Each year at the end of their maiden joining (as 2 year olds) the heifers which had conceived were allocated (randomly and stratified for pregnancy status and weight) into two treatment groups – high nutrition (HN), or control (CON).

These two groups grazed in very similar paddocks that were adjacent to each other (they had previously been one paddock but were split into two at the start of the project for this purpose). Both paddocks were stocked at a rate of around 10 heifers per km^2. The CON group was given a dry season inorganic supplement (described in section 3.1.1) and conditions were the same for the HN except that they were also given a protein supplement over the latter part of the dry season leading up to calving.

A description of the HN treatment in each year is as follows;

- #4 heifers. From 17/7/06 to 18/12/06 the HN heifers were fed AustAsia Hipro pellets (28% crude protein) twice weekly at a rate of 2.27 kg/hd/day (or 0.58 % of liveweight).
- #5 heifers. From 30/7/07 to 16/11/07 the HN heifers were fed copra meal (22% crude protein) twice weekly at a rate of 1.62 kg/hd/day (or 0.4 % of liveweight).
- #6 heifers. From 11/8/08 to 17/11/08 the HN heifers were fed copra meal twice weekly at a rate of 1.62 kg/hd/day (or 0.4 % of liveweight).

At the start of this work it was intended to use the Hipro pellets in each year but they ceased being imported after the first year and so this was not possible. Also in the 3rd year it was decided to try to reduce the amount of time that the protein supplement was fed for to see if the profitability of the strategy could be increased. As a result feeding started later in that year.

The heifers calved from September to January and bulls were put with the heifers from mid December and remained with them from this point onwards. Calves were weaned at the first weaning round muster (WR1) in May/June and the heifers were weighed and lactation status and pregnancy diagnosis was recorded at this time.

Statistical Analysis: Data were analysed with binomial proportion tests (Snedecor and Cochran 1989) determine if the underlying proportions of pregnancies were equal in each group (HN vs CON).

The profitability of feeding protein meal to first calf heifers at VRRS prior to the first calving was assessed by comparing the value of the extra weaners produced to the cost of supplement fed.

3.3.2 Transporting Brahman weaner heifers to the Douglas Daly region for yearling mating

The management of the heifers involved in this study has been described in detail in section 3.1.2. In summary, Brahman weaner heifers weighing between 195 and 260 kg were purchased from NT commercial properties (a different property each year for 4 years) and transported to DDRF to be mated as yearlings (ie a year earlier than they would normally be mated).

Heifers weighing more than 195 kg were selected as Schatz *et al.* (2004) found that it can be expected that on average heifers will grow about 65 kg from weaning in the middle of the year to the start of mating (on the first of January) at DDRF. From this it was decided that heifers weighing less than 195 kg at weaning would be unlikely to conceive when mated as yearlings and so only heifers weighing >195 kg were selected for this work. Heifers weighing more than 260 kg were not selected as they could not be considered to be "yearlings" but were probably older and had not been mustered the previous year.

These heifers proved difficult to purchase as they were considered by managers to be the "lead" (best) of their weaner heifers in most cases, and it was difficult to find managers who were willing to sell them. As a result in some years the purchase of heifers could not be arranged until later in the year than originally intended. In 2005 and 2007 heifers were not transported to DDRF until the start of November (although they had been weaned several months earlier). The heifers were transported to DDRF in early September in the other years. About 100 heifers were purchased each year.

On arrival at DDRF all heifers were weighed and vaccinated with Vibrovax™ and 7 in 1™ to protect against infection with vibriosis and leptospirosis. A second injection of each vaccine was given 6 weeks later. Heifers had ad libitum access to Uramol™ lick blocks in the dry season and Phosrite™ blocks in the wet season.

Heifers grazed in paddocks that were almost entirely Buffel grass at a rate of 1.3 per hectare up until the start of mating in late December. A pre joining weight (PJ Wt) and fat depth (PJ Fat) measurement was recorded in mid December and young bulls that had been fertility tested were introduced to the heifers in late December and remained with them until the end of March. The heifers were pregnancy tested (manual palpation per rectum) at the end of joining and real time ultrasound was used to confirm pregnancy diagnosis' with early pregnancies. The ovaries of non pregnant heifers were ultrasonically scanned for the presence of a CL to determine whether they had reached puberty and commenced cycling (see section 3.1.2).

The reason for the ovary scanning was to determine if non pregnant heifers had reached puberty and were cycling. The timing of scans allows for heifers being at different stages of their cycle. If a heifer is cycling then a CL should be present on an ovary at one of the scans if they are done 10 days apart. Non pregnant heifers were held in a separate paddock for an additional two months and then preg tested again to confirm that they had not conceived right at the end of joining.

The profitability of this strategy was then assessed by comparing the transport costs to the value of the extra calves produced through yearling mating.

3.3.3 Feeding protein supplements to first calf heifers during the dry season prior to calving in the Douglas Daly region

The management of the heifers involved in this study has been described in detail in section 3.1.2. In summary: Each year (with 4 year groups) about 100 Brahman weaners were purchased from an NT commercial property (a different property each year) and transported to DDRF where they were mated as yearlings. Also, each year about 40 Brahman heifers that were about 6 months older were also mated with the yearlings to increase the number of pregnant heifers available for first calf heifer studies. These were heifers that had been weaned at the second round the previous year at VRRS and transported to DDRF. It was necessary to use these extra heifers as the pregnancy rates from yearling mating were too low (average = 33%) to give sufficient numbers for first calf heifer studies.

Following the maiden joining, all pregnant heifers were allocated (randomly and stratified for pregnancy status and weight) to one of two treatments– high nutrition (HN), or control (CON). The CON group grazed pasture with access to lick blocks while the HN group was managed with the aim that they would gain approximately an extra 50 kg each over the pre calving dry season. In the first year The HN group grazed a crop stubble for a period and were given good quality hay. In subsequent years the HN groups grazed in buffel paddocks for the entire time but were also given a protein supplement over the latter part of the dry season leading up to calving.

A description of the HN treatment in each year is as follows;

1) #4 heifers (mated from late December 2004 to 31/3/05) Heifers grazed a crop stubble for a month from 06/07/05 and were then moved to Buffel grass pasture and regularly given bales of good quality hay up until 29/9/05.
2) #5 heifers (mated from late December 2005 to 31/3/06). From 15/8/06 to 6/11/06 heifers were given a ration (twice a week) of 1.2 kg/head/day cracked sorghum and 0.28 kg/head/day copra meal.
3) #6 heifers (mated from late December 2006 to 31/3/07). From 1/8/07 until 12/11/07 the heifers were fed (twice weekly) 1.43 kg/hd/day of copra meal.
4) #7 heifers (mated from late December 2007 to 31/3/08). From 15/8/07 until 21/11/0807 the heifers were fed (twice weekly) 1.43 kg/hd/day of copra meal.

Pre calving weight (PC Wt) and fat depth (PC Fat) were recorded in mid to late September but HN treatment feeding continued until the season broke and green grass became available (in November) and so the full benefit (in terms of extra weight gain) from the HN treatment could not be assessed.

At the end of the feeding period for the HN treatment each year all the heifers were put into one (Buffel pasture) paddock to calve and be joined for the second time. Bulls were re-introduced in late December and remained with the heifers until early May. The heifers were checked regularly during the calving period and date of calving was recorded.

All heifers were mustered in early May and the calves were weaned (WR1). At this time lactation status was recorded to determine whether each heifer had successfully raised a calf to weaning or if calf loss had occurred. Weight (WR1 Wt) and fatness (WR1 Fat) at the time of weaning were recorded and pregnancy status at WR1 was determined by manual palpation per rectum and real time ultrasonography.

Statistical Analysis: Data were analysed with binomial proportion tests (Snedecor and Cochran 1989) determine if the underlying proportions of pregnancies were equal in each group (HN vs CON).

The profitability of this management system was assessed by comparing the costs (supplement) to the benefits (extra weaners produced).

4 Results and discussion

The results and discussion are presented for each objective separately.

4.1 Establishing the relationship between weight, condition, fatness and fertility in Brahman heifers in the NT

The relationship between weight and pregnancy rates was established. Initially it was also planned to establish the relationship of two measures that are used to assess body reserves (ie condition score and P8 fat depth) with pregnancy rates. However as the project progressed it became clear that it was not going to be possible to use condition score as a predictor of pregnancy rate in young heifers as they were all in a very narrow range of condition scores at time when the pre joining measurements were recorded (most were score 5 on the 1-9 system). The narrow range of condition scores meant that it was not possible to use the data to produce models predicting pregnancy rates from condition score. Condition score is a more useful method of assessing body reserves in older females where the effect of lactation can result in large differences in condition, however in younger heifers that have not had a calf there is usually not much of a range in body condition (especially where appropriate stocking rates have been used). For this reason and because condition scoring has been found to be quite an inaccurate method of assessing body reserves (Schatz and Ridley 2002), it was decided to use fat depth at the P8 site as the criteria for assessing body reserves. Therefore P8 fat depth was the measure of body reserves that was assessed for its relationship with pregnancy rate and its potential to be used to predict pregnancy rates.

The results for each section are presented separately here;

4.1.1 Heifers first mated as 2 year olds at VRRS

The results for maiden heifers and first calf heifers at VRRS are presented separately here;

4.1.1.1 Maiden heifers - VRRS

The general performance measures for maiden heifers are presented in Table 3. It shows that although the growth in the 18 months from weaning to joining was not high (average = 105 kg) that sufficient joining weights were reached for high conception rates (average = 87%) to be achieved. The fact that good growth occurred during the joining period (average = 110 kg) meant that the average weight at the end of joining was greater than 390 kg in each year and this resulted in most heifers reaching sufficient weights during the joining period for high conception rates to be achieved.

Table 3. Average weights and weight gains at for VRRS maiden heifers from weaning until the end of their first joining period

Year Group	Wn Wt (kg)	Growth: Weaning to joining (kg)	PJ Wt (kg)	EJ Wt (kg)	Growth: over joining period (kg)	Avg Wt at 1st conception (kg)	Pregnancy rate
# 4	180	89	277	396	119	332.1	90%
# 5	174	118	293	403	110	352.5	83%
# 6	187	111	288	390	102	332.5	88%
Average	179.5	105.4	285.5	395.7	110	337.7	87%

Wn Wt = weaning weight, PJ Wt = pre joining weight, EJ Wt = end of joining weight
Note: some animals did not have weaning weights recorded and so the average pre joining weight (PJ Wt) is not equal to the sum of the average weaning weight and the growth from weaning to joining (as the growth over this period could not be calculated for all animals).

Growth over the joining period and the subsequent pregnancy rate were slightly higher in #4 heifers than the other year groups. This is likely to be because the 2005/06 wet season (when the #4 heifers were joined) was a very good one for growth. 64mm of rain fell in October 2005 and 1330 mm was received between then and May 2006. This was considerably more than was received in the following two wet seasons. The 2006/07 wet season was started by 17mm of rain in November 2007 and 562 mm fell between then and the following May. The 2007/08 wet season was started by 47mm of rain in October 2007 and 901 mm fell between then and May 2008 (see Table 1).

The relationship between joining weight and pregnancy rate in maiden heifers

The data from the 3 year groups of heifers was used to determine the relationship between PJ Wt and pregnancy rates in maiden heifers (that had been joined first as 2 year olds at VRRS) at the end of the four month joining period.

PJ Wt was found to have highly significant effect ($P < 0.0001$) on pregnancy rate (see figure 4). Since year did not have a significant effect ($P = 0.1978$) on pregnancy rate and there was a very weakly significant interaction between year and PJ Wt ($P = 0.0465$), data from all years was pooled to produce an equation that predicts pregnancy rate from PJ Wt.

The equation for this model is:

Predicted pregnancy rate = $e^{\theta} / (1+e^{\theta})$, where $\theta = -5.193 + 0.026$ PJ Wt

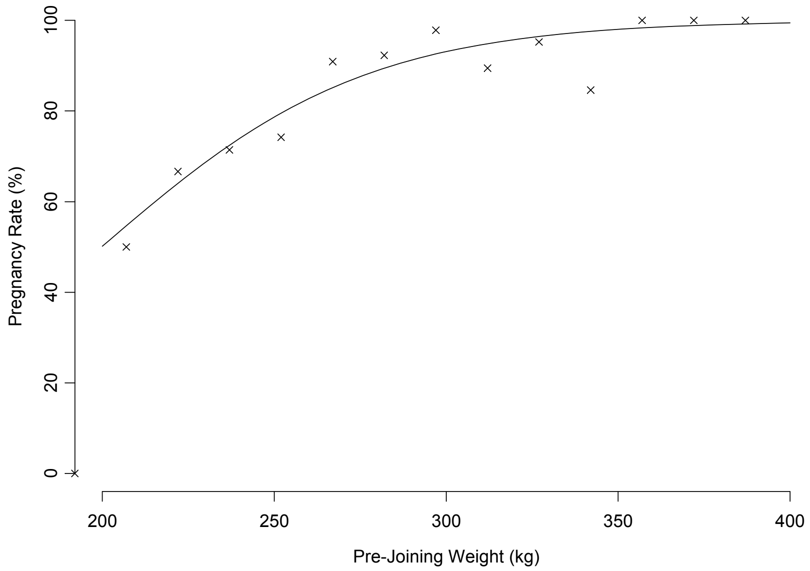

Figure 4. The effect of pre joining weight on pregnancy rates in maiden heifers (joined for the first time as 2 year olds and for a period of 4 months at VRRS). R^2 = 0.7580

This equation was used to produce a table showing the pregnancy rates predicted from different pre joining weights and the increase in pregnancy rate associated with each 10 kg increase in PJ Wt (see Table 4). Table 4 also shows that there is roughly a 5% increase in predicted pregnancy rate for each 10 kg increase in PJ Wt up until an 80% pregnancy rate is reached at around 253 kg, and then past this point the rate of increase in pregnancy rate is much smaller.

Table 4. Predicted maiden heifer pregnancy rates at different pre joining weights (after a 4 month joining period) and the predicted increase in pregnancy rate for each 10kg increase in pre joining weight (PJ Wt)

PJ Wt (kg)	Predicted Pregnancy rate	Increase in pregnancy rate per 10 kg increase in PJ Wt
200	50%	
210	57%	6.5%
220	63%	6.3%
230	69%	5.8%
240	74%	5.3%
250	79%	4.7%
260	83%	4.0%
270	86%	3.4%
280	89%	2.8%
290	91%	2.3%
300	93%	1.9%
310	95%	1.5%
320	96%	1.2%
330	97%	0.9%
340	97%	0.7%
350	98%	0.6%

The estimates of pregnancy rates using the equation produced in this study (and shown in Table 4) are relevant to properties which have high grade Brahman cattle, mate their heifers for the first time at 2 years of age, get similar growth over the joining period (eg. 0.593 kg/day) and can measure pre joining weight in November. This is typical for most properties in northern parts of the NT.

Approximately 76% of the variation in pregnancy rate can be predicted by PJ Wt (R^2=0.7580, p<0.0001). Other studies (eg Rudder *et al.* 1985; Doogan *et al.* 1991) have produced equations predicting pregnancy rate from PJ Wt in *Bos indicus* cross maiden heifers in north Queensland with higher R^2 estimates (>0.9) than this study, however the reason for this was largely due to the method of analysis used. These studies used normal approximation models that also return R^2 estimates of greater than 0.9 when fitted to the data from this study. However these models use mean estimates for size classes as predictors of conception rate and as such do not account for the observed variation in pregnancy rate at the individual level (estimated using binomial models).

The model produced in this study is highly significant and can be used with confidence to predict pregnancy rate for 2 year old maiden Brahman heifers from pre joining weights recorded in November. The equation predicts an 80% pregnancy rate from heifers weighing 253 kg in November prior to joining. This is consistent with the findings of Fordyce *et al.* (1996b) who after studying 6 year groups of (5/8 Brahman) heifers concluded that heifers that reach 250kg by the start of mating at two years of age should achieve at least 80% conception rates.

However some other similar studies have found that a higher PJ Wt (of around 270 kg) is required for such a conception rate. To achieve conception rates of 80%, Rudder *et al.* (1985) found that a pre joining weight of 275 kg was required and Doogan *et al.* (1991) indicated that the target weight should be 270 kg. Probable reasons for the higher PJ Wt's cited in these studies are that the heifers in the Rudder *et al.* (1985) study were a year younger at their maiden joining (ie they were mated as yearlings) and heifers younger than 14 months of age usually reach puberty at heavier weights than older ones (Fordyce 2006). In the Doogan *et al.* (1991) study the joining period was for about 100 days starting in mid to late January, and pre joining weight was recorded in January which was several months later than the pre joining weights were recorded in this study. The heifers in this study grew considerably between the time when their PJ Wt was recorded (in November) and January, therefore their joining weights would have been higher, and more similar to the Doogan *et al* (1991) study if they had been recorded in January. In the NT, the wet season has usually commenced by January and commercial properties are unlikely to record joining weights at this time. Also joining would have already commenced on most properties. A more practical time to measure pre joining weights of maiden heifers on NT properties is in the late dry season (eg. November) as was done in this study.

It should be noted that this equation will only predict pregnancy rates accurately when growth following the measurement of the pre joining weight is similar to that which occurred with the heifers in this study (ie the average growth between the PJ Wt in November and the EJ Wt in the following May was 110 kg [or 0.593 kg/day over 186 days]). Obviously if heifers grow less than this during the joining period then lower pregnancy rates would be expected from the same pre joining weights as the heifers would reach lower weights during the mating period. The growth that occurred over the joining period in this study is typical for maiden heifers on NT properties if inorganic supplements are given and stocking rates are conservative.

The relationship between pre joining P8 fat depth and pregnancy rate of maiden heifers

PJ Fat was found to have highly significant effect (P = 0.0007) on pregnancy rate (see figure 5). Year did not have a significant effect (P = 0.5512) on pregnancy rate and there was no interaction between year and PJ Fat (P = 0.0812), so the data from all years was pooled and used to produce an equation to predict pregnancy rate from PJ Fat.

The equation for this model is:

Predicted pregnancy rate = $e^{\theta} /(1+e^{\theta})$, where $\theta = 0.630 + 0.429$ PJ Fat

Approximately 72% of the variation in pregnancy rate can be predicted by PJ Fat (R^2=0.7216, p=0.0016).

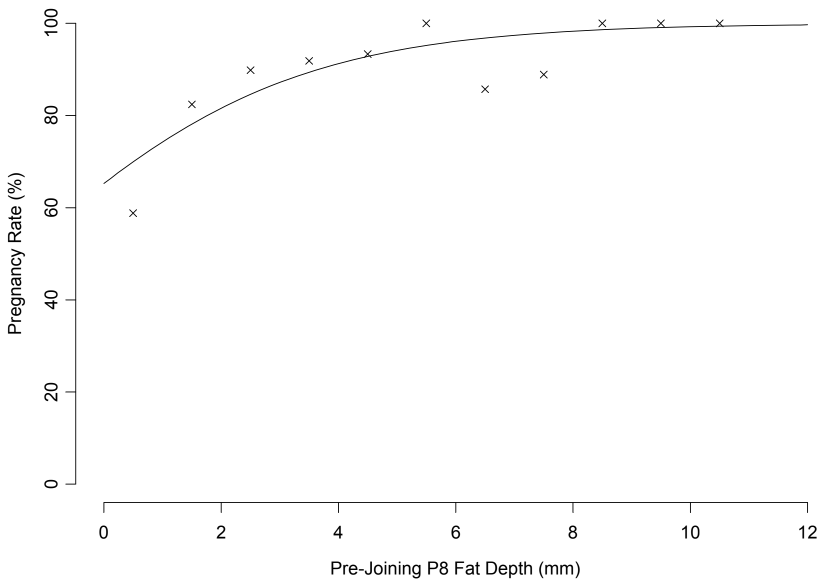

Figure 5. The effect of pre joining P8 fat depth on pregnancy rates in maiden heifers (joined for the first time as 2 year olds at VRRS). R^2 = 0.7216

This equation was used to produce a table showing the pregnancy rates predicted from different pre joining fat depths and the predicted increase in pregnancy rate from each 1 mm increase in pre calving P8 fat depth (Table 5). Table 5 shows that the rate of increase in predicted pregnancy rate for a 1 mm increase in PJ Fat declines as PJ Fat increases. Only small increases in pregnancy rate are predicted to occur for each 1mm increase in PJ Fat past 6mm.

Table 5. Predicted maiden heifer pregnancy rates at different pre joining P8 fat depths (PJ Fat) after a 4 month joining period, and the predicted increase in pregnancy rate for each 1mm increase in PJ Fat

Pre joining P8 fat depth (mm)	Predicted Pregnancy rate	Predicted increase in pregnancy rate for each 1mm increase in PJ Fat
0	65%	
1	74%	9.0%
2	82%	7.3%
3	87%	5.6%
4	91%	4.1%
5	94%	2.9%
6	96%	2.0%
7	97%	1.3%
8	98%	0.9%
9	99%	0.6%
10	99%	0.4%

The equation predicts that 2 year old maiden heifers with PJ Fat >1 mm should achieve pregnancy rates of at least 80% (see Table 5). As with PJ Wt, these predictions rely on there being similar growth rates to those that were achieved by the heifers in this study (ie 0.593 kg/day). Where heifers grow less during the joining period, the pregnancy rates achieved may be lower than this equation predicts.

4.1.1.2 First calf heifers - VRRS

Calf loss between pregnancy diagnosis and weaning was 8% in #4 heifers, 14% in #5 heifers, 18% #6 heifers and averaged 14% over the three year groups (Table 6). This rate of calf loss is actually quite low for first calf heifers eg. Schatz and Hearnden (2008) found that the average rate of calf loss in first calf heifers on NT properties was 22%.

Table 6. Calf Loss between pregnancy diagnosis and weaning in first calf heifers at VRRS

Year group	Treatment	N Weaned	N Lost	N Total	Calf Loss
# 4	HN	38	4	42	10%
	CON	38	3	41	7%
	Total	76	7	83	8%
# 5	HN	29	6	35	17%
	CON	32	4	36	11%
	Total	61	10	71	14%
# 6	HN	34	7	41	17%
	CON	33	8	41	20%
	Total	67	15	82	18%
All years	HN	101	17	118	14%
	CON	103	15	118	13%
	Total	204	32	236	14%*

= Average calf loss.

The calf loss reduced the number of heifers whose data could be used in analysing the relationship between PC Wt and re-conception rates and also resulted in the number of animals in each treatment being unequal.

Measures of the performance of first calf heifers are shown in Table 7. The effects of the treatments are examined in more detail in section 4.3. This data shows that re-conception rates in first calf heifers that were not given a protein supplement prior to calving (CON) were low (average = 23%). This is consistent with the findings of Schatz and Hearnden (2008) who found that re-conception rates in lactating first calf heifers on NT cattle stations are often low (<20%). Re-conception rates were significantly higher ($P<0.0001$) in heifers that were given a protein supplement prior to calving (HN). Over the 3 year groups re-conception rates were an average of 42% higher in the HN groups than the CON groups. The differences between the HN and CON treatments were highly significant in each year ($P<0.0001$ in #5 and #6 heifers and $P=0.0004$ in #4 heifers) and over all years ($P<0.0001$).

Table 7. Performance of first calf heifers at VRRS

Year weaned	Treatment	EJ Wt^{C} (kg)	PC Wt^{C} (kg)	Growth^{C} EJ - PC (kg)	WR1 Wt^{C} (kg)	Growth^{C} PC - WR1 (kg)	N	Re-conc. Rate
2004	HN	389.1	424.7	37.2	386.1	-38.3	38	82%
	CON	391.0	400.0	8.4	363.6	-33.8	38	39%
2005	HN	402.7	415.1	12.3	361.0	-54.1	30	63%
	CON	401.1	399.3	-1.8	346.2	-53.0	32	9%
2006	HN	385.7	394.9	8.9	352.9	-42.0	31	45%
	CON	380.9	368.3	-11.4	342.6	-26.1	33	18%
All years	HN	392.1	411.3	19.4	368.2	-44.7	99	65%
	CON	390.9	389.8	-1.2	351.5	-37.8	103	23%

EJ Wt = end of joining weight, PC Wt = pre calving weight, WR1 Wt = weaning round 1 weight.
^{C} denotes where weight is corrected for stage of pregnancy or growth has been calculated from weights that have been corrected for stage of pregnancy.
*3 animals escaped from the HN paddock at during the 2006 wet season. As a result their data could be used in the analysis of the effect of weight on pregnancy rate but not for the effect of nutritional treatment.

The aim of the HN treatment was to increase growth between the end of joining (EJ) and pre calving (PC) measurements, to ensure that some heifers reached the higher weight ranges and to increase the range of pre calving weights. Having heifers in a wide range of weight ranges is beneficial in producing an equation that describes the relationship between pre calving weight and re-conception rates. Table 7 shows that Growth^{C} EJ - PC was higher in the HN treatments with each year group of heifers. The extra growth in the HN heifers was approximately 29 kg in the #4 heifers, 14 kg in the #5 heifers, and 20 kg in the #6 heifers and this resulted in higher re-conception rates in HN heifers in each of the years. It should be noted that the full extent of the extra growth due to the HN treatments could not be measured as feeding continued after the date when PC Wt was recorded.

The relationship between pre calving weight and pregnancy rate of first calf heifers

PC Wt^{C} had a highly significant effect (P=0.0002) on pregnancy rates in lactating first calf heifers at the time their calves were weaned (WR1) (see figure 6). Both year (P=0.0079) and nutrition treatment (P<0.0001) had a significant effect on mean pregnancy rate, but since there was no significant effect when year (P=0.3608) and nutrition treatment (P=0.2519) were adjusted for PC Wt^{C}, the data for all years was pooled to produce an equation that predicts pregnancy rate from PC Wt^{C}.

The equation for this (binomial) model is:

Predicted pregnancy rate = $e^{\theta} / (1+e^{\theta})$, where $\theta = -5.661 + 0.013$ PC Wt^{C}

Approximately 81% of the variation in pregnancy rate can be predicted by PC Wt^{C} (R^2=0.8127, p=0.0001).

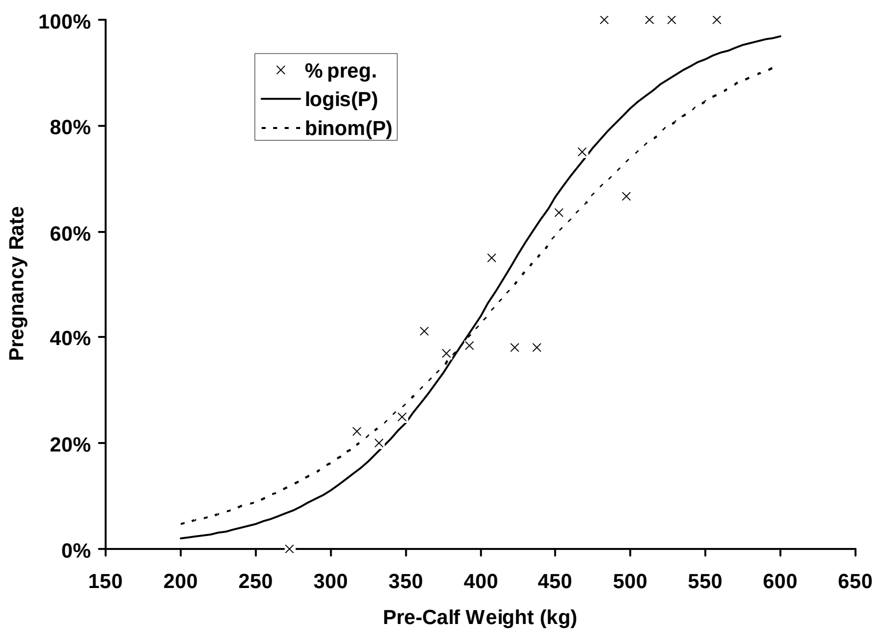

Figure 6. The effect of pre calving weight (corrected for stage of pregnancy) on pregnancy rates in lactating first calf heifers at VRRS (both binomial and logistic models). (Each data point represents the pregnancy rate of a 15 kg weight range of PC Wt^C)

The majority of the data for the heifers were in the middle pre calving weight ranges (84% of heifers had PC Wt^C's between 340-360 kg). The fact that there were fewer animals in the upper and lower weight ranges meant that (in the binomial model) these data points had less influence on the relationship than the data points in the middle weight ranges where there were greater numbers of heifers in each weight range. As a result confidence in the tail ends of the curve is lower and this is the likely reason for why the binomial curve in figure 6 appears to over-estimate pregnancy rates at the lower PC Wt^C's and under-estimate pregnancy rates at the higher PC Wt^C's.

To overcome the over-estimation of pregnancy rates at the lower PC Wt^C's and under-estimation at higher PC Wt^C's, a logistic was fitted to the data (the pregnancy rates for the mean of each weight range). This allows each PC Wt^C range to have equal influence on the relationship and overcomes the problem of low numbers of heifers in the higher and lower ranges. This produced the relationship shown in figure 6, which has an R^2 of 0.8627 and appears to fit the data better than the binomial model.

The equation for the logistic model is;

Predicted pregnancy rate = $e^{\theta} / (1+e^{\theta})$, where $\theta = -7.593 + 0.018$ PC Wt^C (R^2 of 0.8627).

Both equations (binomial and logistic) were used to produce a table showing the pregnancy rates predicted from different pre calving weights and the increase in pregnancy rate associated with each 10 kg increase in PC Wt^C (Table 8). Even though it is more technically correct to use the binomial model, the pregnancy rates predicted by the logistic model are more likely to be accurate in practise (in the experience of the author and in comparison to the findings of Schatz and Hearnden 2008), especially at the higher and lower PC Wt^C ranges.

Table 8. Predicted pregnancy rates at different pre calving weights (corrected for stage of pregnancy) and the predicted increase in pregnancy rate for each 10kg increase in PC Wt^C

PC WT^C (kg)	Binomial model		Logistic model*	
	Predicted Pregnancy %	Increase in pregnancy rate per 10 kg increase in PC Wt^C	Predicted Pregnancy %	Increase in pregnancy rate per 10 kg increase in PC Wt^C
250	9		5	
260	10	1.2	6	0.9
270	11	1.3	7	1.1
280	13	1.4	8	1.3
290	14	1.6	10	1.5
300	16	1.7	11	1.7
310	18	1.9	13	2.0
320	20	2.1	15	2.2
330	22	2.2	18	2.5
340	25	2.4	21	2.9
350	27	2.6	24	3.2
360	30	2.7	28	3.5
370	33	2.9	31	3.8
380	36	3.0	35	4.1
390	39	3.1	40	4.3
400	42	3.2	44	4.5
410	46	3.3	49	4.6
420	49.	3.3	53	4.6
430	52.	3.3	58	4.5
440	56	3.3	62	4.4
450	59	3.3	67	4.2
460	62	3.2	70	4.0
470	65	3.1	74	3.7
480	68	3.0	78	3.4
490	71	2.8	81	3.0
500	74	2.7	83	2.7
510	76	2.5	86	2.4
520	79	2.3	88	2.1
530	81	2.2	90	1.8
540	83	2.0	91	1.6
550	85	1.8	93	1.4

**The predictions of pregnancy rate using the logistic model are likely to be more accurate than the predictions from the binomial model.*

Note- The weights in Table 6 are corrected for the stage of pregnancy and so this needs to be taken into account when using these figures. These weights were recorded in September and since most maiden heifers are joined from December and the peak calving time for first calf heifers is usually in November/December, then on average first calf heifers would be around 7 months pregnant in September. According to O'Rourke et al. (1991a) the weight of a 7 month old pregnancy is 26 kg and a 7.5 month old pregnancy weighs 32 kg. Therefore adding 30 kg (using a round figure which is approximately the weight of a 7.3 month old pregnancy) to pre calving weights that have been adjusted for stage of pregnancy, is a way of converting corrected weights to weights that have not been corrected for stage of pregnancy. The weights are presented in this way in Table 20 (in section 4.2.2).

It should be noted that these relationships are calculated from data in which heifers lost around 45 kg during their lactation (ie PC Wt – WR1 Wt) (see Table 7). The amount of weight that heifers lose between calving and weaning is likely to affect their re-conception rates (Rakestraw 1986); lower re-conception rates would be expected when heifers lose more weight than occurred in this study, and higher re-conception rates when heifers lose less weight.

Table 8 and figure 6 show that the rate of increase in predicted pregnancy rate is highest for PC Wt^C's between 350 kg and 490 kg, and that outside of this weight range, the rate of increase in pregnancy rate is less for each 10 kg increase in PC Wt^C. For PC Wt^C's between 380 and 460 kg, the predicted pregnancy rate increases by between 4% and 4.6% (average = 4.4 %) for each 10 kg increase in PC Wt^C. This is fairly similar to the findings of Dixon (1998) who reviewed several data sets from North Queensland and found increases in first calf heifer re-conception rate of between 3% and 8% (average = 4.8%) for each 10 kg increase in liveweight.

The pregnancy rate often used as a target in beef production is 80%. Table 8 shows that a PC Wt^C of 490 kg is required for a re-conception rate of 80% (this equates to an unadjusted weight of approximately 520 kg for 7 month pregnant heifers). Pre calving weights this high are very difficult to achieve in the NT and so re-conception rates in first calf heifers are usually considerably lower (Schatz and Hearnden 2008). This is in agreement with Anderson (1990) who analysed the data from several herds of Brahman cross first calf heifers and stated that the results show the difficulty of achieving a target re-conception rate of 80% in first lactation heifers in the harsh conditions of northern Australia. Rudder *et al.* (1985) stated that the target joining weight required for high conception rates from first calf heifers was 375 kg, but this figure was calculated from data from crossbred heifers (up to 50% *Bos taurus*) in central Queensland and so is not that applicable to high grade Brahmans in the NT.

Goddard *et al.* (1980) found that re-conception rates in Droughtmaster first calf heifers (in north Queensland) increased in a curvilinear response to liveweight but that they plateaued at 50% for heifers weighing > 440 kg. Table 8 predicts a similar pregnancy rate for heifers of this weight as it shows that a PC Wt^C of about 410 kg (equivalent to 440 kg unadjusted for pregnancy) is required for a re-conception rate of 50% (Table 8). These results are similar to those of O'Neil (1995) who reported a 50% re-conception rate from high grade Brahman heifers with an average weight of 416kg. There have been few studies that report re-conception rates for high grade Brahman heifers in northern Australia, but some studies with *Bos indicus* cross heifers have found that this level of fertility can be achieved from lower weights, eg. Anderson (1990) reported an average re-conception rate of 52% from an average liveweight of 341 kg at the start of mating in North Queensland. While this is a higher re-conception rate from this weight than is predicted by Table 8, it should be noted that the Anderson (1990) study was with cross bred heifers which are likely to have higher fertility than high grade Brahmans (O'Neill *et al.* 1997), and also that the predictions from Table 8 are fairly consistent with the findings from the recent heifer performance recording on NT commercial properties that was a part of MLA project NBP.344 (Schatz [in press]). This study produced an equation that shows the likely pregnancy rate from different first calf heifer weights at the time when their calves are weaned (WR1). This equation calculates that a WR1 weight of 390 kg is required for a re-conception rate of 50%. This can be converted to a PC Wt of 430kg since the average weight loss on the properties in the study between the recording of pre-calving and WR1 weights was 40kg. While there were few reports of high re-conception rates on NT properties in this study, specific examples from the study of the high weights required to achieve high re-conception rates in first calf heifers in the NT are: (i) A re-conception rate of 76% was recorded from a herd of Composite heifers on the Barkly Tableland with an average weight of 497 kg prior to calving and 421 kg at WR1. (ii) A re-conception rate of 68% was recorded from a herd of Santa Gertrudis heifers on the same property with an average weight of 484 kg prior to calving and 416 kg at WR1. These weights and corresponding re-conception rates are consistent with the pregnancy rates predicted from these pre calving weights in Table 8.

There are few published reports of re-conception rates from high grade Brahman first calf heifers in Northern Australia where joining weights were high enough to give high re-conception rates. As a result it is difficult to find reports with which to compare the predicted pregnancy rates from the higher weight ranges in Table 8. This study differs from most other previous studies conducted in northern Australia in that the pre calving supplementation allowed re-conception rates to be calculated for Brahman first calf heifers in the higher pre calving weight ranges (eg. 450 - 550 kg [see figure 6]). This allows pregnancy rates to be predicted over the whole range of pre-calving heifer weights compared to other studies where data was only collected in the lower to moderate ranges.

The relationship between pre calving fat depth and pregnancy rate of first calf heifers

PC Fat had a highly significant ($P<0.0001$) effect on pregnancy rates in lactating first calf heifers (see figure 7). Year ($P=0.0075$) and nutrition treatment ($P=0.0001$) also had significant effects on pregnancy rates. The interaction between PC Fat and year was not significant ($P=0.7009$) when treatment was included as a factor, but the interaction between PC Fat and treatment was significant ($P=0.0229$) when year was included as a factor. Therefore the data for both nutritional treatments could not be pooled and separate predictive equations were produced for each nutrition treatment.

The equation for the HN model is:

Predicted pregnancy rate = $e^{\theta} / (1+e^{\theta})$, where $\theta = -4.5035 + 0.6373$ PC Fat

Approximately 95% of the variation in pregnancy rate (in HN heifers) can be predicted by PC Fat ($R^2=0.9510$, $p<0.0001$). Figure 7 shows that the fit of the model to the data was highly significant.

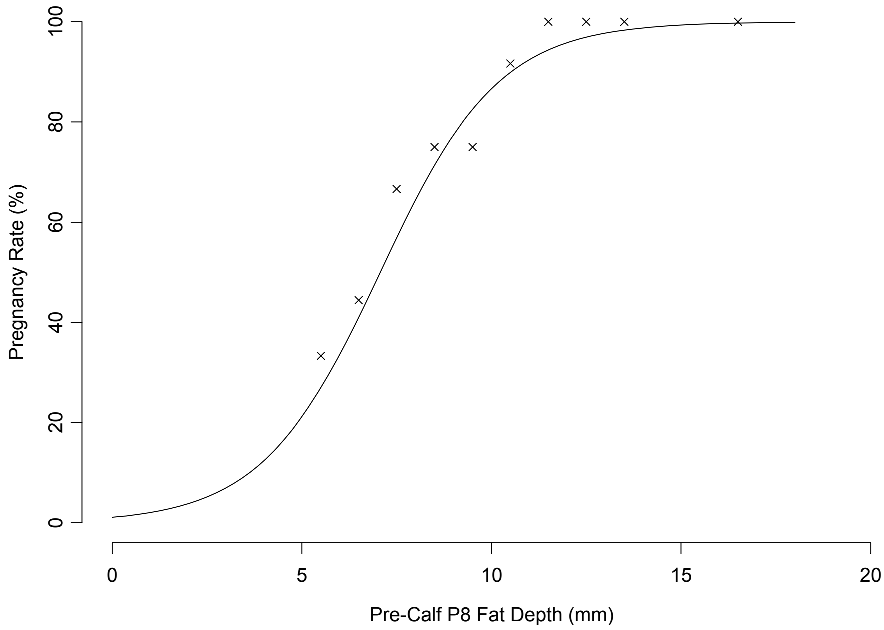

Figure 7. The effect of pre calving P8 fat depth on pregnancy rates in first calf heifers at VRRS. (R^2=0.9510, p<0.0001)

The HN equation for predicting pregnancy rate from pre calving fat depth was used to produce Table 9, which shows the predicted pregnancy rate for first calf heifers at different pre calving fat depths.

Table 9. Predicted pregnancy rates at different pre calving P8 fat depths (PC Fat) and the predicted increase in pregnancy rate for each 1 mm increase in PC Fat for first calf heifers at VRRS in the HN treatment (ie fed a protein supplement in the late dry season prior to calving)

Pre calving P8 fat depth (mm)	Predicted pregnancy rate	Increase in pregnancy rate per 1 mm increase PC Fat
1	2%	
2	4%	2%
3	7%	3%
4	12%	5%
5	21%	9%
6	34%	13%
7	49%	15%
8	64%	16%
9	77%	13%
10	87%	10%
11	92%	5%
12	96%	4%
13	98%	2%
14	99%	1%
15	99%	

Table 9 shows that re-conception rates increase by >10% for each 1mm increase in PC Fat between pre calving fatnesses of 5 to 10 mm and that outside of this range the increases in re-conception rate for each 1 mm increase in PC Fat are smaller. Table 9 and figure 7 show that a pre calving P8 fat depth of 9.5 mm is required to achieve a 80% re-conception rate and that increasing PC Fat above 10 mm results in very little extra increase in re-conception rate. A P8 fat depth of 9.5 mm is approximately equivalent to a BCS of 6.5 on the 1-9 system (*pers. obs*.) or 3.5 on the 1-5 system (Fordyce *et al.* 2008), and so a target pre calving BCS of 6.5 would be required if re-conception rates of around 80% are desired.

As mentioned previously the data from the HN and CON treatments had to be analysed separately as there was a significant interaction between PC Fat and treatment (P=0.0229) when year was included as a factor.

The equation for the CON model is:

Predicted pregnancy rate = $e^{\theta} / (1+e^{\theta})$,   where $\theta = -1.9108 + 0.1119$ PC Fat

The CON equation was not a significant fit to the data (P=0.3560) and so it cannot be used to predict pregnancy rate from PC Fat. Therefore predictive tables were not produced for this treatment. It should be noted though that the predictive tables are more likely to be used in circumstances where pre partum supplementary feeding is going to be practised (eg. to assess the profitability of such strategies) and that Table 9 applies to these situations.

4.1.2 Heifers first mated as yearlings at DDRF

The results for maiden heifers and first calf heifers at DDRF are presented separately here;

4.1.2.1 Maiden heifers - DDRF

The general performance measures for maiden heifers mated as yearlings at DDRF are presented in Table 10. It shows that the growth from weaning to joining averaged 35 kg for the 4 year groups of heifers. It is likely that growth would have been higher if the animals could have been transported to DDRF earlier in the year but this was not possible as it took longer than expected to find stations that had the type of heifers required (high grade Brahman weaner heifers weighing195 – 260 kg and that had not missed being weaned the previous year) and were willing to sell them.

Table 10. The performance of Brahman maiden heifers mated as yearlings at DDRF (the figures are averages for each year group)

Year weaned	N	Wn Wt (kg)	PJ Wt (kg)	EJ Wt (kg)	Growth: Weaning to PJ (kg)	Growth: during joining period (kg)	Avg Wt at 1st Conception (kg)	Pregnancy rate
# 4	110	216	259	319	49.2	59.9	309.5	27%
# 5	92	220	252	332	31.9	73.0	333.2	36%
# 6	98	233	265	350	31.1	68.7	300.1	36%
# 7	91	228	251	320	24.7	69.0	308.3	35%
Total	391	224.0	256.9	330.1	34.9	67.3	315.7	33%

The #4 heifers had slightly lower conception rates compared the other year groups. This is likely to be because they came from a property that used control mating and so were slightly younger on average than the heifers from the other year groups which came from continuously mated herds. The heifers from the continuously mated herds were all weaned at the 1st round but some had been branded as small calves at the 2nd round the previous year (and returned to their dams) which shows that they are slightly older.

Over all the average weight at the end of the joining period (EJ) was 330 kg and the low pregnancy rates achieved (average = 33%) suggest that most heifers were not fertile by this age and weight. In a recent large study of 1007 Brahman heifers by the Beef CRC it was found that the average weight and age at puberty in Brahman heifers was 334 kg and 24.7 months (Johnston *et al.* 2009). There have been a number of other reports in literature of average weights and ages of Brahman heifers at puberty (see Table 11)

Table 11. Reported age and weight at puberty of Brahman heifers

Age at puberty (days)	Weight at puberty (kg)	Source
690		Reynolds (1967)
590		Plasse *et al.* (1968)
481	246	Post and Reich (1980)
429	323	Cundiff *et al.* (1986)
602	321	Warnick *et al.* (1991)
	315	Fordyce *et al.* (1996)
592 (age at 1st conception)	366	Chase *et al.* (1997b)
735	299	Rodrigues *et al.* (1999)
415	347 (Approx.)	Cundiff (2005)
751	334	Johnston *et al.* (2009)
587	*319*	*Average of all studies above*

When the figures reported in all the studies in Table 11 are averaged, the average age and weight at puberty is 587 days (19.3 months) and 319 kg. From this it is likely that many of the heifers in this study had not reached puberty by the end of the joining period since many weighed less than 319 kg at this time. This was confirmed by the results of the ovary ultrasound scanning that showed that most non pregnant heifers were not cycling at the end of joining (Table 12). Also the average weight of those heifers that did conceive from yearling mating in this study was 316 kg (Table 10) and from the EJ Wts in Table 10 it is evident that many of the heifers that failed to conceive during the joining periods did not reach these weights.

The average weight at first conception in maiden heifers mated as yearlings at DDRF (316 kg) and as 2 year olds at VRRS (338 kg [from Table 3]) in this study are both likely to be biased to due the way that the heifers were managed. The actual critical weight for first conception is likely to be somewhere between these two figures (and similar to the average weight at puberty measured by Johnston *et al.* [2009]). The figure from the DDRF study of yearlings is likely to be biased as joining finished before most heifers reached their critical weight for first conception, and since the average weight at first conception was only calculated from heifers that did conceive during the joining period, it is likely to include a higher proportion of earlier maturing heifers than if joining had continued until all heifers were pregnant. Also the average weight at first conception calculated for the 2 year old maiden heifers at VRRS is likely to be too high since some heifers would have conceived earlier and at lighter weights if bulls had been present before the start of joining as 2 year olds. A more appropriate way of measuring average weight at first conception would have been to leave bulls with heifers continuously from the start of joining as yearlings (but this was not the purpose of this study).

Table 12. Results of ovary scanning and pre-testing at the end of joining to determine pregnancy status and whether heifers were cycling

Year group	Number	% Pregnant	% Not pregnant and not cycling	% not pregnant but with a CL present
# 4	110	27%	68%	5%
# 5	92	36%	59%	5%
# 6	98	36%	61%	3%
# 7	91	35%	62%	3%

Ultrasound scanning of the ovaries of non-pregnant heifers was conducted to determine if a CL was present. If there was no CL present at either scan (performed 10 days apart) then it is safe to say that the heifer is not cycling. In yearling Brahman heifers the most likely reason for why they would not be cycling is that they have not reached puberty yet.

These results suggest that high grade Brahman heifers are too late maturing for high pregnancy rates to result from yearling mating when grazing pasture in the NT.

The relationship between joining weight and pregnancy rate of yearling mated maiden heifers

PJ Wt was found to have highly significant effect ($P<0.00001$) on pregnancy rate (see figure 8). Year did not have a significant effect ($P = 0.$) on pregnancy rate and there was not a significant interaction between year and PJ Wt ($P = 0.2960$) so the data from all years was pooled and used to produce an equation to predict pregnancy rate from PJ Wt (recorded in December).

The equation for this model is:

Predicted pregnancy rate = $e^{\theta} /(1+e^{\theta})$, where $\theta = -7.404 + 0.026$ PJ Wt

Approximately 80% of the variation in pregnancy rate can be predicted by PJ Fat ($R^2=0.7978$, $p<0.00001$). This gives good confidence in using this equation to predict pregnancy rates from pre joining weights in yearling mated Brahman heifers.

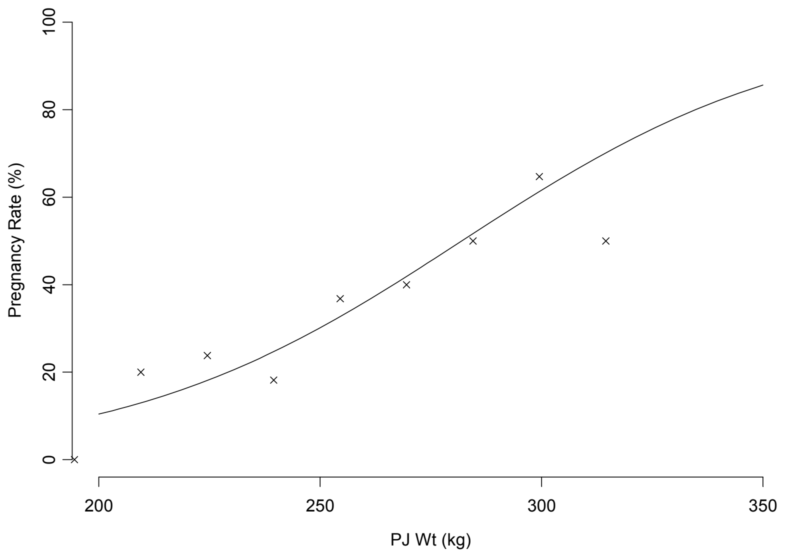

Figure 8. The effect of pre joining weight on pregnancy rates in maiden heifers (joined for the first time as yearlings at DDRF). R^2 = 0.7978

This equation was used to produce a table showing the pregnancy rates predicted from different pre joining weights and the increase in pregnancy rate associated with each 10 kg increase in PJ Wt (Table 13). Table 13 shows that the rate of increase in predicted pregnancy rate for a 10 kg increase in PJ Wt, increases as PJ Wt increases from 200 kg to 290 kg and then decreases after that. The predicted pregnancy rate increases by more than 5% for each 10 kg increase in PJ Wt for PJ Wt's between 250 - 320 kg.

Table 13. Predicted pregnancy rates at different pre joining weights and the predicted increase in pregnancy rate for each 10kg increase in PJ Wt

PJ Wt (kg)	Predicted Pregnancy rate	Increase in pregnancy rate per 10 kg increase in PJ Wt
200	10%	
210	13%	2.7%
220	16%	3.3%
230	20%	3.9%
240	25%	4.6%
250	30%	5.2%
260	36%	5.8%
270	42%	6.2%
280	49%	6.5%
290	55%	6.5%
300	62%	6.4%
310	68%	6.0%
320	73%	5.5%
330	78%	4.9%
340	82%	4.2%
350	86%	3.5%

Note that PJ Wt was recorded in December for the heifers in this study. Mustering and weighing cattle at this time of year is much more feasible in the Douglas Daly region than on the larger extensive properties in other regions of the NT.

There are very few published reports of pregnancy rates with corresponding joining weights for high grade Brahman heifers mated as yearlings in northern Australia with which to compare the predicted weights from Table 13. Jayawardhana (1999) reported a conception rate of 25% for one year group of Brahman heifers with an average joining weight of 217 kg. This is slightly higher fertility than is predicted by Table 13, but the herd that this report is from has been highly selected for fertility and has been shown to produce heifers with higher fertility from yearling mating than heifers from commercial Brahman herds (Schatz *et al.* in press). In a study from Nebraska (USA), Cundiff (2005) reported a pregnancy rate of 83% in F1 Brahman cross heifers mated to calve as 2 year olds that had an average 400 day weight of 347 kg. This is quite similar to the pregnancy rate predicted for this weight (ie 84.5%) by the equation produced in this study.

This study found that high grade Brahman heifers are too late maturing to achieve high conception rates from yearling mating when grazing pasture in the NT. This is in agreement with Randel (1994) who states that Brahman and Brahman-based heifers reach puberty at too old an age to routinely calve at 2 years of age. The overall average PJ Wt of all the heifers in this study was 257 kg and only 33% of the heifers conceived despite the fact that only the heaviest weaner heifers (weighing 190 – 260 kg) were selected for yearling mating. As a result of being late maturing, quite high joining weights are required for high fertility eg. Table 13 shows that a pre joining weight of around 335 kg is required for a pregnancy rate of 80%.

Rudder *et al.* (1985) suggested a target PJ Wt of 275 kg for *Bos indicus* cross heifers mated as yearlings (in central Queensland), however high grade Brahman heifers are not as fertile (Cundiff 2005), and the equation produced in this study predicts a conception rate of only 45% from this PJ Wt. Table 13 shows that to achieve a pregnancy rate of 80% from high grade Brahman heifers mated as yearlings, a PJ Wt of 335 kg is required. In reality it is unlikely that many high grade Brahman heifers will reach this weight before the start of joining as a yearling when grazing pasture in the NT (no heifers in this study had a PJ Wt > 335kg). To reach a weight of 335 kg at the start of joining as a yearling, growth rates would have to be much higher than can be achieved from pasture in most areas of the NT or the heifers would have to be older (and hence would not be yearlings).

The relationship between joining P8 fat depth and pregnancy rate of yearling mated maiden heifers

PJ Fat was found to have highly significant effect (P=0.00007) on pregnancy rate (see figure 9). Year did not have a significant effect (P = 0.1762) on pregnancy rate and there was no interaction between year and PJ Fat (P = 0.7826), so the data from all years was pooled and used to produce an equation to predict pregnancy rate from PJ Fat.

The equation for this model is:

Predicted pregnancy rate = $e^{\theta} / (1+e^{\theta})$, where $\theta = -1.324 + 0.370$ PJ Fat

Approximately 63% of the variation in pregnancy rate can be predicted by PJ Fat ($R^2=0.6321$, $p<0.0001$).

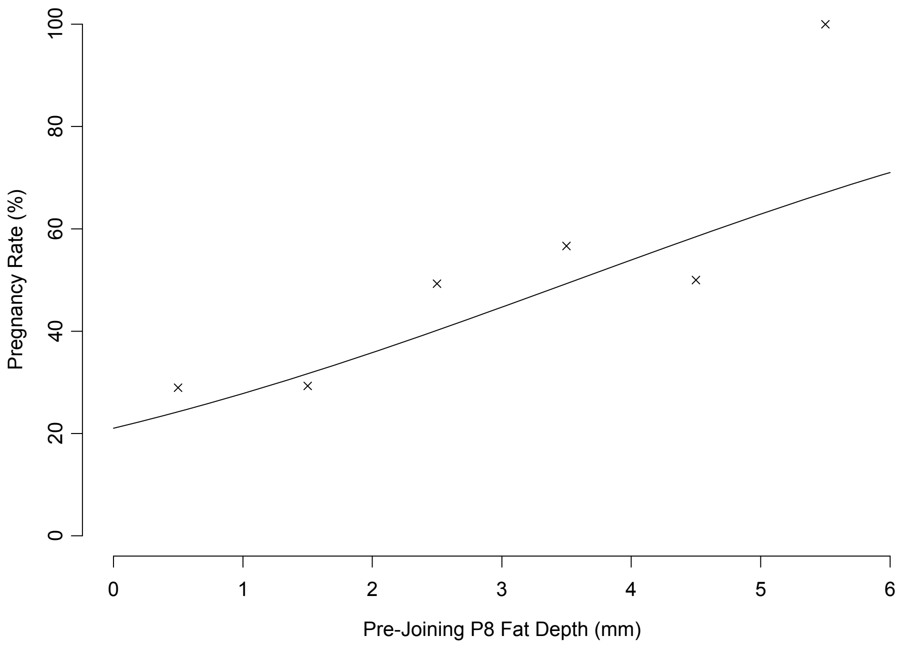

Figure 9. The effect of pre joining P8 fat depth on pregnancy rates in maiden heifers (joined for the first time as yearlings at DDRF). R^2 = 0.6321

This equation was used to produce a table showing the pregnancy rates predicted from different pre joining fat depths and the predicted increase in pregnancy rate from each 1 mm increase in pre calving P8 fat depth (Table 14). Table 14 shows that there is a fairly constant rate of increase in predicted pregnancy rate of around 7-9% for each 1 mm increase in PJ Fat.

It should be noted that yearling heifers have very little measurable fat at the P8 site (fat tends to be laid down at older ages). Only 2% of heifers in this study had a PJ Fat of > 4 mm.

Table 14. Predicted pregnancy rates at different pre joining P8 fat depths and the predicted increase in pregnancy rate for each 1mm increase in PJ Fat.

PJ Fat (mm)	Predicted Pregnancy rate	Predicted increase in pregnancy rate for each 1mm increase in PJ Fat
0	21%	
1	28%	6.8%
2	36%	8.0%
3	45%	8.9%
4	54%	9.2%
5	63%	9.0%
6	71%	8.2%

4.1.2.2 First calf heifers - DDRF

Calf loss between pregnancy diagnosis and weaning in each year group of heifers ranged between 8% - 30% with an overall average of 15% (Table 15). This rate of calf loss is actually quite low for first calf heifers as Schatz and Hearnden (2008) found that the average rate of calf loss in first calf heifers on NT properties was 22%. Observations from that study were that calf loss tends to be higher in larger paddocks, so the small size of the paddocks in this study may be a reason for the lower calf loss.

Table 15. Calf loss in first calf heifers at DDRF

Year group	Treatment	Number Weaned	Number Lost	Total Number	% Loss
# 4	HN	15	9	24	38%
	CON	20	6	26	23%
	Total	35	15	50	30%
# 5	HN	33	3	36	8%
	CON	33	3	36	8%
	Total	66	6	72	8%
# 6	HN	20		20	0%
	CON	16	5	21	24%
	Total	36	5	41	12%
# 7	HN	22	2	24	8%
	CON	17	4	21	19%
	Total	39	6	45	13%
All years	HN	90	14	104	13%
	CON	86	18	104	17%
	Total	176	32	208	15%

The calf loss reduced the number of heifers whose data could be used in analysing the relationship between PC Wt and re-conception rates and also resulted in the number of animals in each treatment being unequal.

Measures of the performance of first calf heifers at DDRF are shown in Tables 16 and 17. This data shows that re-conception rates in first calf heifers were quite high (overall re-conception rate = 67%) by NT standards since Schatz and Hearnden (2008) in extensive performance recording on NT commercial properties only found first calf heifer re-conception rates in excess of 30% on 2 out of 12 (ie 17%) properties.

Pre calving nutrition treatment did not have a significant effect on re-conception rates in any year or over all years. Overall 68% of HN heifers and 65% of CON heifers reconceived. The effects of the treatments are examined in more detail in section 4.3.3 and the probable reason that nutrition treatment had no effect on re conception rates is discussed in the next section (on the relationship between pre calving weight and pregnancy rate of first calf heifers).

Table 16. Measures of first calf heifer performance at DDRF (All measures are averages for the group indicated)

Year group	Treatment	Growth^{C}: EJ - PC (kg)	PC Wt^{C} (kg)	WR1 Wt^{C} (kg)	Growth^{C}: PC – WR1 (kg)	N*	Re-concept. rate
# 4	HN	66.7	377.7	366.2	-11.5	21	62%
	CON	54.6	365.1	363.4	-1.7	14	71%
	Total	61.9	372.6	365.1	-7.6	35	66%
# 5	HN	91.8	409.9	399.7	-10.2	32	66%
	CON	59.4	378.5	394.2	15.6	32	78%
	Total	75.6	394.2	396.9	2.7	64	72%
# 6	HN	74.3	382.9	389.3	6.4	21	71%
	CON	66.3	372.7	383.2	10.5	15	47%
	Total	70.9	378.7	386.8	8.1	36	61%
# 7	HN	71.5	379.3	399.3	19.1	23	74%
	CON	63.0	370.9	364.4	-6.0	16	50%
	Total	68.0	375.9	384.9	8.9	39	64%
All years	HN Total	77.8	389.9	390.1	-0.1	97	68%
	CON Total	60.6	373.4	380.2	7.1	77	65%
	Grand Total	70.2	382.6	385.7	3.1	174	67%

*The reason that the numbers are not equal between treatment groups in each year was due to calf loss (only data from lactating heifers was included in the study).

Table 17. The average P8 fat depths recorded pre calving and at WR1 for first calf heifers at DDRF

Year group	Treatment	PC Fat (mm)	WR1 Fat (mm)	Re-conception rate
# 4	HN	8.1	2.3	62%
	CON	7.1	3.6	71%
	Total	7.7	2.9	66%
# 5	HN	10.5	2.8	66%
	CON	6.7	2.3	78%
	Total	8.6	2.5	72%
# 6	HN	9.1	3.5	71%
	CON	8.7	3.1	47%
	Total	8.9	3.3	61%
# 7	HN	9.2	5.5	74%
	CON	7.3	2.9	50%
	Total	8.4	4.5	64%
All years	HN Total	9.4	3.5	68%
	CON Total	7.3	2.8	65%
	Grand	8.4	3.2	67%

The month in which heifers calved had a large effect on whether they re-conceived. The earlier heifers calved, the higher their re-conception rates were (figure 10). This is likely to be because heifers that calved earlier had more time in which to resume cycling after calving and conceive before joining finished at WR1. This underlines the importance of maiden heifers conceiving early in the joining period (so that they also calve early). Heavier heifers are more likely to conceive early in the joining period and so it follows that increasing joining weights of maiden heifers should be the focus of heifer management.

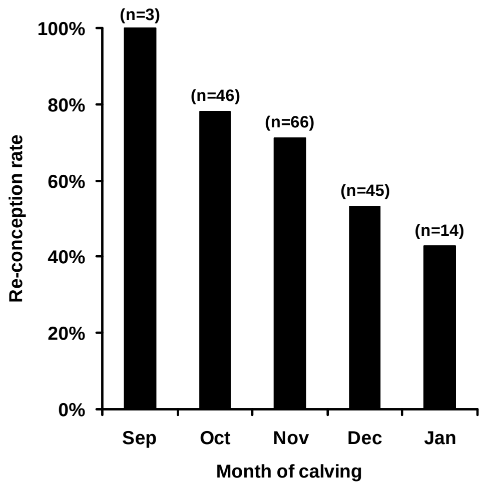

Figure 10. The effect of month of calving on re-conception rates in first calf heifers at DDRF

The relationship between pre calving weight and pregnancy rate of first calf heifers

Analysis of the data from the first calf heifer studies at DDRF found no relationship between re-conception rates and PC Wt (P = 0.9995), Year (p = 0.6702) or nutrition treatment (P = 0.5375). Analysis also showed that there was no relationship between WR1 Wt and re-conception rates (P=0.2251).

This is somewhat surprising since it is generally accepted that pre-calving weight/body condition has a large effect on re-conception rates in first calf heifers (Wettemann 1986b; Short *et al.* 1990b). The reason that there was no relationship in this study is likely to be because the quality of the nutrition at DDRF (from improved and fertilized pastures) allowed the heifers to maintain sufficient weight/ condition through the period while they were lactating (and being joined for the second time) so that most were able to re-conceive. This is evidenced by the fact that overall the heifers actually gained an average of 3.1 kg between the time when their PC Wt^C and WR1 Wt^C were measured (Table16). Most first calf heifers on NT properties actually lose a substantial amount of weight during this time as they don't get sufficient nutrients from the pasture to meet the demands of lactation and growth. For example CON heifers at VRRS lost an average of 38 kg over this period (Table 5).

Other studies have also found no increase in first calf heifer re-conception rates from an improved nutrition treatment where the pasture conditions resulted in the nutrition from both treatments (control and supplemented treatments) being adequate eg. Siebert *et al.* (1976). Holroyd *et al.* (1983), Dixon *et al.* (1997a) and Dixon *et al.* (1997b).

Since there was no relationship between PC Wt and re-conception rates, no equation or predictive tables were produced.

The relationship between pre calving fat depth and pregnancy rate of first calf heifers

There was no relationship between re-conception rates and PC Fat (P = 0.2183) or WR1 Fat (p = 0.2183).

While this is unusual in first calf heifers, the reason for it is the same as for why there was no relationship between re-conception rates and PC Wt and WR1 Wt ie regardless of pre calving nutrition treatment, the pasture provided adequate nutrition to keep most heifers in good enough condition to re-conceive. Overall, PC Fat averaged 8.4 mm and WR1 Fat averaged 3.2 mm (Table 17).

Since there was no relationship between PC Fat and re-conception rates, no equation or predictive tables were produced.

4.2 Creating management tools for heifer target mating weights and body conditions (P8 fat depths)

The data collected in this project (see sections 4.1.1 and 4.1.2) was used to develop equations that predict pregnancy rates from pre joining weights (PJ Wt) and P8 fatness (PJ Fat) for maiden heifers and pre calving weights (PC Wt) and P8 fatness (PC Fat) in first calf heifers. These equations were then used to produce tables that can be used by cattle managers and extension officers to see the pregnancy rates that are likely from different joining weights. The tables are presented in sections 4.2.1 to 4.2.4, however there a number of aspects of this work that require explanation/discussion;

- The pre calving weights that were used to produce the equations predicting pregnancy rates in lactating first calf heifer had been corrected for the stage of pregnancy as this is a more accurate method than using un-corrected weights. However these weights are not very useful as practical tools since very few station managers adjust weights for stage of pregnancy. Therefore the pre calving weights in the tables in 4.2.2 and 4.2.4 have been adjusted so that they are for heifers that are 7 months pregnant. This was done as most first calf heifers would be around 7 months pregnant when pre calving weights are recorded (since the average calving date for first calf heifers on most NT stations would be in November and the pre calving weights were recorded in September). Obviously pre joining weights in maiden heifers do not need to be corrected since they are not pregnant.

- Pregnancy rates are largely determined by weight/condition (Entwistle 1983), and so it follows that these measures should be good predictors of pregnancy rate. However, equations that predict pregnancy rates from weights recorded several months before the time of joining rely on there being a predictable amount of weight change between the time when weights were recorded and through the joining period. In practise this does not always occur (especially in first calf heifers) and weight change during this period can vary markedly from season to season, region to region and even property to property within a region as there are many factors that influence growth (eg. rainfall, stocking rate, supplementation etc.). In the performance recording on NT commercial properties done by Schatz and Hearnden (2008) there was no consistent relationship between pre calving weight and weight at WR1 in first calf heifers from different properties. In fact average weight change for herds over this period ranged from -88 kg to 11 kg (average = -40 kg). Predictive equations are most useful where a property gets similar growth to that which occurred in the data that was used to generate the predictive equation.

  Due to the variation in growth (or weight loss) over the calving/joining period in first calf heifers, their weight at the time when their calves are weaned (WR1) often has a stronger relationship with their re-conception rate than their pre calving weight does. Using data collected on NT commercial properties, Schatz and Hearnden (2008) found a very strong relationship between the average weight of first calf heifers at WR1 and the proportion that had re-conceived. In addition to the tables predicting pregnancy rate produced from data in this study (presented in sections 4.2.1 to 4.2.4), the data from the Schatz and Hearnden (2008) was used to produce a chart that predicts the pregnancy rates likely from first calf heifers at different WR1 weights. This chart is presented in section 4.2.5. Due to the fact that it uses WR1 weights, it is not a predictive table in the strict sense (ie that it doesn't use pre-calving weight to predict future pregnancy rates), however WR1 weights can still be used as targets ie managers can try to manage their heifers in such a way that they will be a certain weight (or condition) at WR1.

- As explained at the start of section 4.1, tables for predicting pregnancy rate from condition score were not produced, but rather P8 fat depth was used to assess body reserves and was used as a predictor of pregnancy rate. Information for converting P8 fat depths to equivalent condition scores (in the 1-5 system) can be obtained from Fordyce *et al.* (2008).

- The pregnancy rates shown in these tables are for current industry standard genotypes of high grade Brahman heifers. Higher pregnancy rates can be achieved with heifers from Brahman herds that have been highly selected for fertility (Schatz *et al.* [in press]).

4.2.1 Maiden heifers first joined as two year olds in the VRD district (grazing native pasture)

The equations from section 4.1.1.1 were used to produce Tables 18 and 19 which predict the pregnancy rate likely from heifers of different pre joining weights (PJ Wt) and P8 fat depths (PJ Fat). Note that this is for high grade Brahman maiden heifers mated for the first time at 2 years of age with a 4 month joining period. PJ Wt and PJ Fat were recorded in November. Bulls were introduced in mid December and remained with the heifers until the end of March. Growth rates averaged 0.593 kg/day between when the PJ Wt was recoded in November and when the heifers were weighed again in the following May. The average weight at which heifers first conceived was 338 kg. Lighter heifers are likely to conceive later in the joining period as they usually require several months of growth before they reach a critical weight for first conception. Conception rates are likely to be lower in the lighter weight ranges when joining periods are shorter.

Table 18. Predicted pregnancy rates from different pre joining weights for (2 year old) maiden Brahman heifers grazing native pasture with a 4 month joining period (in the Victoria River District, NT)

Pre joining weight (in Nov.)	Predicted pregnancy rate
200 kg	50%
210 kg	57%
220 kg	63%
230 kg	69%
240 kg	74%
250 kg	79%
260 kg	83%
270 kg	86%
280 kg	89%
290 kg	91%
300 kg	93%
310 kg	95%
320 kg	96%
330 kg	97%
340 kg	97%
350 kg	98%

Table 19. Predicted pregnancy rates from different pre joining P8 fat depths for (2 year old) maiden Brahman heifers grazing native pasture (in the Victoria River District, NT)

Pre joining P8 fat depth (mm)	Predicted pregnancy rate
0	65%
1	74%
2	82%
3	87%
4	91%
5	94%
6	96%
7	97%
8	98%
9	99%
10	99%

4.2.2 First calf heifers first joined as two year olds in the VRD district (grazing native pasture)

Table 20 was calculated using the logistic equation produced in section 4.1.1.2 as it provides better estimations of pregnancy rates in the upper and lower pre calving weight ranges than the binomial equation (see section 4.1.1.2 for explanation). The equation predicts re-conception rates from pre calving weights that have been corrected for the stage of pregnancy (using the technique of O'Rourke *et al.* 1991a). Since very few cattle managers correct weights for stage of pregnancy, the weights in Table 20 have been adjusted so that they are for heifers that are approximately 7 months pregnant. This is a more practical way of presenting the weights for use by cattle managers.

The adjustment was made by adding 30 kg (approximately the weight of a 7.3 month old pregnancy [O'Rourke *et al.* 1991a]) to the corrected pre calving weights, as most pre calving weights are recorded in September (before heifers start calving) and most heifers would on average be a bit over 7 months pregnant at that time (since peak calving usually occurs in November/December for first calf heifers in the NT).

Table 20. Predicted pregnancy rates from different pre calving weights for Brahman first calf heifers in the Victoria River District, NT

Pre calving weight (not adjusted for pregnancy)*	Predicted Pregnancy rate
280 kg	5%
290 kg	6%
300 kg	7%
310 kg	8%
320 kg	10%
330 kg	11%
340 kg	13%
350 kg	15%
360 kg	18%
370 kg	21%
380 kg	24%
390 kg	28%
400 kg	31%
410 kg	35%
420 kg	40%
430 kg	44%
440 kg	49%
450 kg	53%
460 kg	58%
470 kg	62%
480 kg	67%
490 kg	70%
500 kg	74%
510 kg	78%
520 kg	81%
530 kg	83%
540 kg	86%
550 kg	88%
560 kg	90%
570 kg	91%
580 kg	93%

**These weights are for heifers that are approximately 7 months pregnant at the time when pre calving weights are recorded, and that lose around 45 kg during their lactation (re-conception rates will be lower where heifers lose more weight than this during their lactation).*

Analysis of the data found that there was a significant relationship between pre calving P8 fat depth and pregnancy rates for first calf heifers in the HN treatment ($p<0.0001$) but not the CON treatment ($p=0.3560$). Therefore it is possible to produce a table showing the predicted pregnancy rates from different pre calving fat depths for heifers which undergo the HN treatment but not for CON heifers. It should be noted though that predictive tables are more likely to be used in circumstances where pre partum supplementary feeding is going to be practised (eg. to assess the profitability of such strategies) and that Table 21 applies to these situations.

Table 21 was produced with the equation from section 4.1.1.2 which predicts pregnancy rate in lactating first calf heifers from pre calving P8 fat depth. Table 21 shows the pregnancy rates that are likely from heifers with different pre calving fat depths. It shows that to achieve pregnancy rates of 80% that a pre calving fat depth of 9.5 mm is required. This is equivalent to a condition score of 3.5 on the 1-5 system (Fordyce *et al.* 2008), or 6.5 on the 1-9 system (*pers. obs*.).

Table 21. Predicted pregnancy rates for first calf heifers at different pre calving P8 fat depths (PC Fat). Note – these figures are for heifers that were in the HN treatment (ie were fed a protein supplement in the late dry season prior to calving) at VRRS

Pre calving P8 fat depth (mm)	Predicted pregnancy rate
1	2%
2	4%
3	7%
4	12%
5	21%
6	34%
7	49%
8	64%
9	77%
10	87%
11	92%
12	96%
13	98%
14	99%
15	99%

4.2.3 Maiden heifers first joined as yearlings in the Douglas Daly District (grazing improved pasture)

The equations from section 4.1.2.1 were used to produce Tables 22 and 23 which predict the pregnancy rate likely from heifers of different pre joining weights (PJ Wt) and P8 fat depths (PJ Fat). Note that this is for high grade Brahman maiden heifers mated for the first time as yearlings. PJ Wt and PJ Fat were recorded in December. Bulls were introduced in late December and remained with the heifers until the end of March. Growth rates averaged 0.702 kg/day through the joining period (between when the PJ Wt was recorded in December and when the heifers were weighed again in the following April).

Table 22. Predicted pregnancy rates from different pre joining weights for yearling mated maiden Brahman heifers grazing improved pasture (in the Douglas Daly District, NT)

Pre joining weight (in December)	Predicted pregnancy rate
200 kg	10%
210 kg	13%
220 kg	16%
230 kg	20%
240 kg	25%
250 kg	30%
260 kg	36%
270 kg	42%
280 kg	49%
290 kg	55%
300 kg	62%
310 kg	68%
320 kg	73%
330 kg	78%
340 kg	82%
350 kg	86%

Table 23. Predicted pregnancy rates from different pre joining P8 fat depths for yearling mated maiden Brahman heifers grazing improved pasture (in the Douglas Daly District, NT)

Pre joining P8 fat depth (mm)	Predicted pregnancy rate
0	21%
1	28%
2	36%
3	45%
4	54%
5	63%
6	71%

Note – yearling heifers usually have very little measurable fat prior to their first joining. Fat tends to get laid down as they get older and have been through at least one wet season post weaning.

4.2.4 First calf heifers first joined as yearlings in the Douglas Daly District (grazing improved pasture)

While the data required to produce equation predicting re-conception rates in first calf heifers from pre calving weights and fat depths (at DDRF) was successfully collected, analysis of this data found that there was no relationship between PC Wt and re-conception rates or between PC Fat and re-conception rates. Therefore it was not possible to produce equations to predict re-conception rate from these measures and so predictive tables were not able to be produced.

The reason that there was no relationship between PC Wt or PC Fat and re-conception rates is likely to be because the quality of the nutrition at DDRF (improved and fertilized pastures) allowed the heifers to maintain sufficient weight/ condition through the period while they were lactating (and being joined for the second time) so that most were able to re-conceive. This is evidenced by the fact that overall the heifers actually gained an average of 3.1 kg between the time when their PC Wt^C and WR1 Wt^C were measured. Most first calf heifers on NT properties actually lose a substantial amount of weight during this time as they don't get sufficient nutrients from the pasture to meet the demands of lactation and growth (eg. CON heifers at VRRS lost an average of 38 kg over this period).

4.2.5 First calf heifer pregnancy rates predicted from weight at the time when calves are weaned (WR1). Data from NT commercial properties

Schatz and Hearnden (2008) analysed data collected on NT commercial properties and found that there was a very strong relationship ($p<0.0001$) between the average weight of lactating first calf heifers at WR1 (when their calves were weaned) and their re-conception rate. An equation was produced that calculates the re-conception rates predicted from groups of heifers with different average weights at WR1 and this was used to produce Table 24.

Analysis of the Schatz and Hearnden (2008) data showed that there was no consistent relationship between pre calving weight (PC Wt) and weight at WR1. While most heifers lost weight during this time (the average weight change of heifers from all properties in the study was -40 kg), the amount of weight that they lost varied from property to property (weight change ranged from an average weight loss of 88 kg to an average weight gain of 11 kg). If the weight change from the recording of PC Wt to WR1 Wt is known (or can be estimated) then for management purposes a rough approximation of target pre calving weight can be calculated from WR1 Wt. For example if heifers gain an average of 10 kg from PC WT to WR1 Wt then PC weight can be calculated by subtracting 10 kg from WR1 Wt. Or if heifers lose an average of 40 kg (which was the average for properties in the Schatz and Hearnden 2009 study) then PC Wt can be calculated by adding 40 kg to WR1 Wt. Table 24 shows the equivalent PC Wt's calculated from WR1 Wt's when heifers lose 20, 40, or 60 kg from PC to WR1.

Table 24. Predicted re-conception rates for first calf heifers on NT cattle properties from different average weights at the time when their calves are weaned (WR1). The equivalent approximate pre calving weights are shown for scenarios when heifers lose 20, 40, or 60 kg from PC to WR1

WR1 Wt (kg)	**Re-conception rate**	**PC Wt** - if lose 20 kg from PC - WR1 (kg)	**PC Wt** - if lose 40 kg from PC - WR1 (kg)	**PC Wt** - if lose 60 kg from PC – WR1 (kg)
250	**1%**	270	290	310
260	**2%**	280	300	320
270	**3%**	290	310	330
280	**3%**	300	320	340
290	**5%**	310	330	350
300	**6%**	320	340	360
310	**8%**	330	350	370
320	**11%**	340	360	380
330	**14%**	350	370	390
340	**18%**	360	380	400
350	**23%**	370	390	410
360	**29%**	380	400	420
370	**36%**	390	410	430
380	**43%**	400	420	440
390	**50%**	410	430	450
400	**58%**	420	440	460
410	**65%**	430	450	470
420	**72%**	440	460	480
430	**77%**	450	470	490
440	**82%**	460	480	500
450	**86%**	470	490	510
460	**90%**	480	500	520
470	**92%**	490	510	530
480	**94%**	500	520	540
490	**96%**	510	530	550
500	**97%**	520	540	560

4.3 Demonstrating the costs and benefits of high and low input management systems for heifers in the NT

Three different management systems were compared to the way heifers are normally managed on NT cattle stations. These were;

> 4.3.1 – Feeding protein supplements to first calf heifers during the dry season prior to calving in the Victoria River District.
>
> 4.3.2 – Transporting Brahman weaner heifers to the Douglas Daly region to be mated as yearlings.
>
> 4.3.3 - Feeding protein supplements to first calf heifers during the dry season prior to calving in the Douglas Daly district.

Each of these management systems is examined in separate sections here;

4.3.1 Feeding protein supplements to first calf heifers during the dry season prior to calving in the VRD

The performance of first calf heifers in each treatment group in each year is shown Table 25 as well as the average of each treatment over the 3 year groups. In each year re-conception rates were significantly higher in the HN group than the CON group year (P<0.0001 in #5 and #6 heifers and P=0.0004 in #4 heifers). Over the three years re-conception rates were an average of 42% higher in the HN groups than the CON groups and this difference was also highly significant (P<0.0001).

Table 25. Performance of first calf heifers at VRRS that were either fed (HN) or not fed (CON) a protein supplement prior to calving

Year group	Treatment	EJ Wt^C (kg)	PC Wt^C (kg)	Growth^C EJ - PC (kg)	WR1 Wt^C (kg)	Growth^C PC - WR1 (kg)	N	Re-conc. Rate
# 4	HN	389.1	424.7	37.2	386.1	-38.3	38	82%
	CON	391.0	400.0	8.4	363.6	-33.8	38	39%
# 5	HN	402.7	415.1	12.3	361.0	-54.1	30	63%
	CON	401.1	399.3	-1.8	346.2	-53.0	32	9%
# 6	HN	385.7	394.9	8.9	352.9	-42.0	31	45%
	CON	380.9	368.3	-11.4	342.6	-26.1	33	18%
All years	HN	392.1	411.3	19.4	368.2	-44.7	99	65%
	CON	390.9	389.8	-1.2	351.5	-37.8	103	23%
	Difference (HN-CON)	1.2	21.5	20.6	16.7	-6.9		42%

EJ Wt = end of joining weight, PC Wt = pre calving weight, WR1 Wt = weaning round 1 weight.
^{C} *denotes where a weight is corrected for stage of pregnancy or growth has been calculated from corrected weights.*
**In 2006 3 animals escaped from the HN treatment paddock at some stage over the wet season. As a result their information was not used in the analysis of treatment effects but could be used in examining the effect of weight on pregnancy rate.*

The feeding of the protein supplement during pregnancy resulted in HN heifers gaining more weight between the end of their first joining (EJ) and when the PC Wt was recorded (average = 20.6 kg), however it was not possible to accurately measure the full benefit due to the HN treatment in terms of weight gain as feeding continued past the date when the PC Wt was recorded (until the break in the season). Nevertheless HN heifers had lost less weight from EJ to WR1 than CON heifers (average = 13.8 kg) and re-conception rates were significantly higher (average = 42%).

Re-conception rates declined over the 3 years of the study (figure 11). Possible reasons for this are:

- The stocking rates used in this work (ie 10 heifers per km^2 each year, plus 0.5 bulls per km^2 for the 5 months that they were with the heifers. This is a total of around 15 AE per km^2) were higher than are recommended for this region (ie 10.5 AE per km^2) and this may have had a cumulative effect on re-conception rates as time went by. The higher stocking rates were used to try to maximise the number of heifers in the study (for statistical purposes) and it was felt that the paddocks wouldn't suffer too much during the 3 years of the project. Also it is not uncommon for commercial properties in the area to run cattle at similar stocking rates.

The paddocks did not appear to be visibly over grazed throughout the project, but re-conception rates did trend downwards over the study (figure 11) suggesting that the stocking rate may have been too high.

- HN heifers were fed the protein supplement for shorter periods of time after the first year and so this may have affected re-conception rates in the HN group (but not in the CON group).

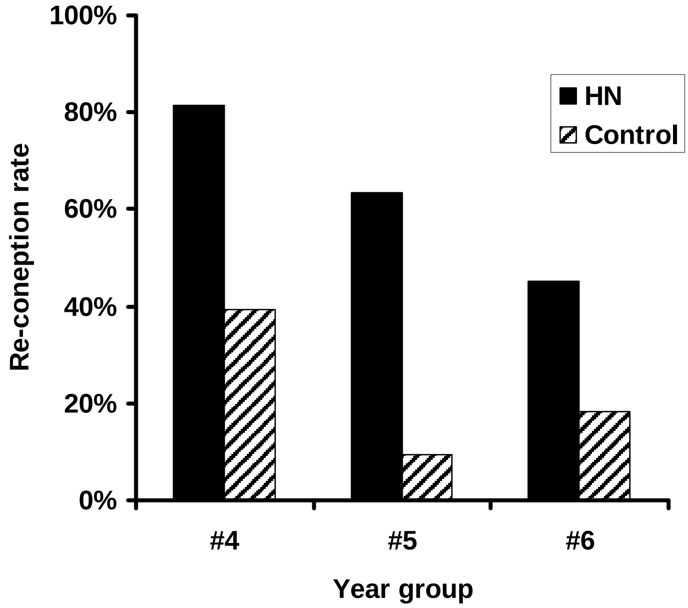

Figure 11. The effect of pre calving nutrition treatment on re-conception rates in first calf heifers at VRRS

This data shows that re-conception rates in first calf heifers that were not given a protein supplement prior to calving (CON) were low (ie 39% in #4 heifers, 9% in #5 heifers and 18% in #6 heifers). This is consistent with the findings of Schatz and Hearnden (2008) who found that re-conception rates in lactating first calf heifers on NT cattle stations are often low (<20%). Re-conception rates were significantly higher (average = 41% higher) in heifers that were given a protein supplement prior to calving (HN treatment) (figure 11).

While feeding protein supplements to first calf heifers prior to calving in the VRD was found to be a way of consistently increasing re-conception rates, the question for managers of cattle stations is whether this strategy is profitable. Due to the high transport costs involved in getting supplements to remote regions such as the VRD, even management strategies that result in large improvements in reproductive rates are not always profitable.

In assessing the profitability of this strategy it was difficult to assign a value to the labour involved in feeding out the supplement. This is because the supplement was fed out twice a week and it was done so during the “water run” (ie when the water supply was being checked). This is a normal part of station maintenance and so the amount of extra labour required to feed out the supplement was very small (it just involved the person doing the water run putting about 8 bags of pellets or copra meal on the back of the ute and putting them in the trough as they drove past it). As a result labour was left out of the assessment of profitability of this strategy and each property can assess for themselves the cost that they would put on feeding out the supplement required for this strategy.

In the calculation of profitability for each year group it was assumed that calf loss would be 14% (the average calf loss found in this study) ie for every 100 heifers fed supplement prior to calving, 86 would wean a calf (then the re-conception rate was applied to this figure to find out how many re-conceptions there were). Also it was assumed that all heifers that lost their calf would re-conceive (as was found in this study). Calves were not mothered up and both paddocks were mustered and walked to the yards together and so while it is likely that the weaners from the HN group were heavier, it was not possible to establish whether there was a difference in the weight of weaners produced by the 2 treatment groups. Weaners were valued at $306 (180 kg x $1.70/kg)

Assessment of profitability:

#4 heifers – The HN group was fed live export pellets at a rate of 2.3 kg/head/day for 154 days (17/7/06 to 18/12/06) leading up to calving, while the CON group received no protein supplement. Subsequently re-conception rates were 43% higher in the HN group (82% vs 39%).
The cost of the pellets was $405/t. Using these figures the total cost of feeding 100 heifers was $14,158 (ie $141.58 per heifer) and the value of the extra calves produced was $11,322. This equates to a loss of $28.36 per heifer fed.

#5 heifers - The HN group was fed copra meal at a rate of 1.6 kg/head/day for 109 days (30/7/07 to 16/11/07). Subsequently re-conception rates were 54% higher in the HN group (63% vs 9%). The cost of the copra meal was $605/t. Using these figures the total cost of feeding 100 heifers was $10,683 (ie $106.83 per heifer) and the value of the extra calves produced was $14,198. This equates to a profit of $35.15 per heifer fed.

#6 heifers - The HN group was fed copra meal at a rate of 1.6 kg/head/day for 98 days (11/8/08 to 17/11/08). Subsequently re-conception rates were 27% higher in the HN group (45% vs 18%). The cost of the copra meal was $726/t. Using these figures the total cost of feeding 100 heifers was $11,526 (ie $115.26 per heifer) and the value of the extra calves produced was $10,159. This equates to a loss of $13.67 per heifer fed.

The calculation of the profit in each year is shown in Table 26. The main factors affecting the profitability of the feeding strategies are the cost of supplement, the number of days that supplement is fed and the number of extra weaners produced. The length of the feeding period is largely determined by the timing of the start of the wet season. This is because it was decided to feed up until the season broke since previous work (eg Fordyce *et al.* 1994b, Fordyce *et al.* 1996) has shown that when feeding is stopped before the break in the season that much of the benefit from the feeding can be lost (as unsupplemented first calf heifers lose weight rapidly at the end of the dry season).

- The main reason that a loss was made with the #4 heifers was there was a delayed start to the wet season and feeding continued longer than was expected. If they had been fed for the same period of time as the #5 heifers then a profit of $13.01 per heifer would have been made.
- The main reason that a loss was made with the # 6 heifers was the high cost of supplement. If the supplement could have been purchased at the same price as the previous year then a profit of $5.54 per heifer fed would have been made.

Table 26. Calculation of the profitability of feeding protein supplements to 100 first calf heifers at VRRS

	#4 heifers	#5 heifers	#6 heifers
cost supp. $/t	$405	$605	$726
kg/hd supp. Fed	2.27	1.62	1.62
# days fed	154	109	98
# heifers	100	100	100
total kg supp. fed	34958	17658	15876
cost supp ($)	$14,157.99	$10,683.09	$11,525.976
calves lost	14	14	14
HN re-conception %	82%	63%	45%
CON re-conception %	39%	9%	18%
extra calves	37	46.4	33.2
value per weaner ($)	$306	$306	$306
value extra weaners ($)	$11,322	$14,198	$10,159
profit ($/head)	-$28.36	$35.15	-$13.67

The fact that this strategy (feeding a protein supplement to first calf heifers during the dry season prior to first calving) was not always profitable does not necessarily mean that it won't be profitable in other situations. This study was undertaken primarily to study the effect of weight on re-conception rates, not to maximise profit. The strategy has been shown to provide significant increases in re-conception rates and the key to whether it is profitable is the cost of the supplement feeding. Managers deciding whether to adopt such a strategy need to consider the cost of supplement, how long they are likely to need to feed it for (this will depend on the season and the desired target pre-calving weight) and what sort of increase in conception rate they are likely to get (the tables produced in this project can be used for this). Each property is in a unique situation and if low cost supplements are able to be sourced (eg. *Leucaena*) then such a strategy could be highly profitable. However if the cost of supplement is high then even large increases in conception rates such as were achieved in this study may not be profitable.

4.3.2 Transporting Brahman weaner heifers to the Douglas Daly region for yearling mating

The pregnancy rates from mating as yearlings were quite low (average = 33%) even though only heavier (>195 kg) weaners were selected for use in this study (Table 27).

Table 27. The performance of high grade Brahman maiden heifers mated as yearlings at DDRF

Year group	Wn Wt (kg)	PJ Wt (kg)	EJ Wt (kg)	Growth: weaning to PJ (kg)	Growth: during joining period (kg)	Non preg. heifers cycling*	Preg. rate	Calf loss
# 4	216.0	259.3	319.2	49.2	59.9	5%	27%	30%
# 5	220.2	252.1	332.3	31.9	73.0	5%	36%	8%
# 6	233.4	264.5	350.0	31.1	68.7	3%	36%	12%
# 7	230.0	252.7	321.0	23.6	68.2	3%	35%	13%
Total	224.9	257.1	324.4	34.1	67.1	4%	33%	16%

**CL detected during ovary ultrasound scanning.*

The #4 heifers had slightly lower conception rates compared the other year groups. This is likely to be because they came from a property that used control mating and so were younger on average than the heifers from the other year groups which came from continuously mated herds. The heifers from the continuously mated herds were all weaned at the 1st round but some had been branded as small calves at the 2nd round the previous year (and returned to their dams) which shows that they are slightly older.

Over all the average weight at the end of the joining period (EJ Wt) was 324 kg and the low pregnancy rates achieved (average = 33%) suggest that most heifers were not fertile by this age and weight. In a study of 1007 Brahman heifers by the Beef CRC it was found that the average weight and age at puberty in Brahman heifers was 334 kg and 24.7 (Johnston *et al.* 2009). There are a number of reports in literature of weights and ages of Brahman heifers at puberty. These are summarised in Table 11 and when the quoted figures are averaged, the average age and weight at puberty is 587 days (19.3 months) and 319 kg. From this and the fact that the average EJ Wt was 324 kg it is likely that many of the heifers in this study had not reached puberty by the end of the joining period. This was confirmed by the results of the ovary ultrasound scanning that showed that most non pregnant heifers were not cycling at the end of joining (Table 12).

Note - the average weight at which yearling mated heifers conceived for the first time in this study was 316 kg (Table 10), however as this figure is only calculated from heifers that did conceive as yearlings, it is likely to be lower than the actual average critical weight for first conception if all heifers had remained with bulls until they became pregnant. The average weight at first conception in heifers mated as 2 year olds at VRRS was 338 kg and since this is likely to be higher than if heifers had been mated before 2 years of age, it is likely that the actual average weight at first conception is somewhere between the DDRF yearling figure (of 316 kg) and the VRRS 2 year old figure 338 kg. If the figure from Johnston et al. (2009) for the average weight at puberty in Brahman heifers (334 kg) is used as a critical weight for first conception, then management of heifers should aim to have them reaching this weight fairly early in the joining period. The fact that most heifers mated as yearlings at DDRF did not reach this weight by the end of the joining period explains why the majority did not conceive.

These results suggest that current industry genotypes of high grade Brahman heifers are too late maturing for high pregnancy rates to result from yearling mating when grazing pasture in the NT. This makes it difficult to justify a management system that involves transporting weaner heifers from areas like the VRD to the Douglas Daly region and bringing them back when they are pregnant with their second calf. Table 28 shows the figures used in calculating the profitability of this assumption.

Table 28. Comparison of the profitability of the two management systems

	DDRF - yearling mating	DDRF – non pregnant heifers from yearling mating	DDRF total*	VRRS (2 y.o mating)
No. of heifers eg. weaned in Jun '03	100			100
Pregnancy rate yr 1 – eg. by May "04	35%			0
Calf loss 1st calf	15%			0
Number of weaners yr 2 eg. May '05	29.8		29.4	0
No. of heifers mated Dec 04 – Apr 05	29.8	70.2		100
Pregnancy rate year 2 eg. by May '05	67%	99%		87%
No. preg heifers year 2 (by May '05)	20.0	69.5		87
Calf loss year 2	13%	13%		13%
Number of weaners yr 3 (May '06)	17.4	60.5	77.8	75.7
Total weaners produced	46.5	60.8	107.2	75.7
Value of weaners @ $306/head			$32,803	$23,164
Transport costs - weaners to DDRF			$2,269	
Transport costs - cows to VRRS			$2,792	
Transport costs - culls to Darwin			$127 (8 hd)	$384 (11 head)
Profit			$27,615	$22,780

**The DDRF total column is the sum of 2 columns to the left of it (ie includes heifers that got pregnant as yearlings and those that didn't).*

Assumptions:

- *The calculation of transport costs: Using estimates from Road Trains Australia (pers. Comm.) the cost of sending a 6 deck road train from VRRS to DDRF (550 km) is about $1.50 (+GST) per deck per km. On average there would be about 26 cows or 40 weaners per deck. This is equivalent to a price of 6.35 cents/head/km for cows and 4.13 cents/head/km for weaners.*
- *Pregnancy rates and calf loss rates recorded in this project were used in calculating the number of weaners produced. Heifers that didn't conceive as yearlings at DDRF or that lost their first calf were mated again the following year (shown in the 2nd column in Table 28).*
- *2% mortality in heifers was assumed when working out the number of culls.*
- *After 2 years (eg. in mid 2005 in the above example) pregnant heifers are transported back to VRRS where those that weaned a calf from yearling mating and re-conceived (n=20 in above eg) would have their 2nd calf and those that didn't but got pregnant the next year (n=69.5) would have their first calf. The non pregnant heifers were culled and sent to Darwin for live export.*
- *The figure used for the value of a weaner was $306 (ie 180 kg x $1.70/kg).*

From Table 28, the extra profit (from the heifer phase of production) from a system in which weaner heifers are transported to the Douglas Daly region for yearling mating was $4,835 for 100 heifers or $48.80 per heifer. If a company or family group already have stations in the VRD and Douglas Daly regions and were to adopt this strategy (ie transporting young heifers up to the Douglas Daly for yearling mating and bringing them back when pregnant with their second calf) with 1,000 heifers per year, then they should make around an extra $48,350 per year from their heifers. However this would be offset by the reduced area available for other cattle production activities on the Douglas Daly property (eg. growing out steers for live export), and the relative profitability of the activities would need to be compared when considering adopting the yearling mating strategy.

It is likely that the extra profit from the heifer phase of production would not be enough to prompt adoption of such a strategy, especially if it would require the purchase of another property. Higher pregnancy rates would be required to justify the expense of transporting

Brahman heifers to the Douglas Daly region and using this highly productive land for the purposes of yearling mating.

4.3.3 Feeding protein supplements to first calf heifers during the dry season prior to calving at DDRF

The performance of the two treatment groups is shown in Table 29. Over all the years there was no significant difference in re-conception rate between the two nutrition treatments (the average re-conception rates were 68% for HN and 65% for CON) and so there was no benefit from feeding the protein supplement to the HN group during the dry season prior to mating. The most likely reason for this was that the (improved) pasture that all the heifers grazed between calving and WR1 was of sufficient quality to result in the CON group remaining in similar body condition to the HN group.

Table 29. The performance of first calf heifers at DDRF that were either fed (HN) or not fed (CON) a protein supplement prior to calving

Year group	Treatment	Growth^C: EJ - PC (kg)	PC Wt^C (kg)	WR1 Wt^C (kg)	Growth^C: PC – WR1 (kg)	N*	Re-concept. rate	Calf loss
# 4	HN	66.7	377.7	366.2	-11.5	21	62%	38%
	CON	54.6	365.1	363.4	-1.7	14	71%	23%
	Total	61.9	372.6	365.1	-7.6	35	66%	30%
# 5	HN	91.8	409.9	399.7	-10.2	32	66%	8%
	CON	59.4	378.5	394.2	15.6	32	78%	8%
	Total	75.6	394.2	396.9	2.7	64	72%	8%
# 6	HN	74.3	382.9	389.3	6.4	21	71%	0%
	CON	66.3	372.7	383.2	10.5	15	47%	24%
	Total	70.9	378.7	386.8	8.1	36	61%	12%
# 7	HN	71.5	379.3	399.3	19.1	23	74%	8%
	CON	63.0	370.9	364.4	-6.0	16	50%	19%
	Total	68.0	375.9	384.9	8.9	39	64%	13%
All Years	HN	77.8	389.9	390.1	-0.1	97	68%	13%
	CON	60.6	373.4	380.2	7.1	77	65%	17%
	Total	70.2	382.6	385.7	3.1	174	67%	15%

**The reason that the numbers are not equal between treatment groups in each year was due to calf loss (only data from lactating heifers was included in the study).*

Since there was no significant difference in re-conception rate between the 2 treatment groups, the extra cost involved with feeding the HN group means that the strategy of feeding protein meal to first calf heifers grazing improved pastures in the Douglas Daly region is not a profitable management system. This is due to the fact that even without pre-calving protein supplementation, when stocking rates are appropriate heifers gain sufficient nutrients from the pasture to remain in good body condition through their first lactation and achieve good re-conception rates (eg. 65%). Other studies have also found no increase in first calf heifer re-conception rates from an improved nutrition treatment where the pasture conditions resulted in the nutrition from both treatments being adequate eg. Siebert *et al.* (1976). Holroyd *et al.* (1983), Dixon *et al.* (1997a) and Dixon *et al.* (1997b).

As an indication of the cost of the HN treatment: Feeding was for an average of 95 days and using the # 6 and #7 heifers as and example where copra meal (price = $605/t) was fed at a rate of 1.43 kg/head/day, the cost for that period of time was around $82.19 per heifer (or $8219 per 100 heifers fed). In effect this was the amount of money that would be wasted if this management system was adopted since it gave no benefit in terms of extra pregnancies.

5 Success in achieving objectives

The success in achieving each objective is assessed separately here:

5.1 Establishing the relationship between weight, condition and fatness in Brahman heifers in the NT

This objective has been achieved. The relationship between weight, condition/fatness and conception rates was established for maiden and first calf heifers in the VRD region and for maiden heifers joined as yearlings in the Douglas Daly region.

Predictive equations and tables showing the pregnancy rates likely from different weights and fatnesses were produced for maiden and first calf heifers in the VRD region, and for maiden heifers in the Douglas Daly region. Equations and tables could not be produced for first calf heifers in the Douglas Daly region as there was not a significant relationship between pre calving weight or fatness and re-conception rates. This is because the improved and fertilised pasture at DDRF provided adequate nutrition for most first calf heifers to re-conceive regardless of their pre calving weight or fatness.

All the heifers in this study were in a very narrow range of condition scores which makes producing predictive equations and tables for condition score difficult. Condition score is a more useful method of assessing body reserves in older females where the effect of lactation can result in large differences in condition, however in younger heifers that have not had a calf there is usually not much of a range in body condition (especially where appropriate stocking rates have been used). It is not possible to produce a relationship between condition score and pregnancy rate that can be used to predict pregnancy rate from a range of condition scores when all the measurements are in one or two condition scores. For this reason and because condition scoring has been found to be quite an inaccurate method of assessing body reserves (Schatz and Ridley 2002), it was decided to use fat depth at the P8 site as the criteria for assessing body reserves. Therefore predictive equations and tables were produced for P8 fat depth rather than for condition score.

5.2 Creating management tools for heifer target mating weights and conditions

The management tools produced were tables showing the likely pregnancy rates from different weights and fat depths for maiden heifers (joined first as 2 year olds) and first calf heifers in the VRD, and for yearling mated heifers in the Douglas Daly region.

These tables can be used by cattle managers and advisors to:

- Calculate the return on investment associated with feeding strategies aimed at reaching different target weights (ie work out how many extra pregnancies are likely from increasing joining weight by a certain amount).
- Work out target joining weights for different situations.

- Perform cost benefit analyses to work out the most profitable target joining weights for a property.
- Work out the weight range of heifers in which supplementation to achieve target joining weights will be profitable (ie some heifers will be heavy enough anyway and some will be too light to make a target joining weight even with supplementing and so supplementary feed would be wasted).

This objective was completed successfully for maiden heifers in the VRD and Douglas Daly regions and for first calf heifers in the VRD. However although the data required to achieve this objective was collected for first calf heifers at DDRF, analysis found that there was no relationship between pre calving weight (or pre calving fat depth) and re-conception rate. This is because the improved and fertilised pasture there provided adequate nutrition for most first calf heifers to re-conceive regardless of their pre calving weight or fatness. As a result tables could not be produced for first calf heifers in the Douglas Daly region

One of the limitations of equations that predict pregnancy rates from pre joining and pre calving weights is that they rely on there being a fairly constant amount of growth over the joining periods. Equations will be most accurate where similar growth occurs over joining periods as occurred in the data which was used to produce the equations. If heifers grow less during the joining period then it is likely that pregnancy rates will be lower than predicted by the equations in this study since lower joining weights will be reached during the joining period. Conversely if growth was higher during joining then pregnancy rates are likely to be higher than predicted. Never the less, the equations and tables produced in this study should be relevant to most high grade Brahman herds in the NT as the growth that occurred over the joining periods in this study is typical for heifers on most NT properties if inorganic supplements are given and stocking rates are not excessive.

5.3 Demonstrating the costs and benefits of high and low input management systems for heifers in the NT

This objective was met successfully for three different management systems where inputs are higher than in traditional heifer management systems in the NT.

These systems were:

– Feeding protein supplements to first calf heifers during the dry season prior to calving in the Victoria River District.
– Transporting Brahman weaner heifers to the Douglas Daly region to be mated as yearlings.
– Feeding protein supplements to first calf heifers during the dry season prior to calving in the Douglas Daly district.

The profitability of each management system was compared to that of traditional heifer management.

Feeding protein supplements to first calf heifers prior to calving in the VRD proved to be a method of reliably increasing re-conception rates and the strategy was more profitable in one year but less profitable in the other two years.

The main factors affecting the profitability of this management strategy are the (on farm) cost of the feed supplement and the length of time that the supplement is fed for. This work has shown that this strategy has great potential to increase the profit made from heifers as it produces significantly more calves but the costs need to be minimised. The main ways of doing this would be to;

- find a cheap supplementary feed (and one possibility may be *Leucaena* grown on station)
- and to reduce the length of time that the supplement is fed for. More research is required to determine the optimum length of time for feeding (where much of the benefit from feeding could be maintained while reducing the cost)

Transporting large (> 190 kg) high grade Brahman weaner heifers to the Douglas Daly region for yearling mating proved to be more profitable than the traditional method of keeping them on station to be joined as two year olds. However the increase in profit ($48.80 per heifer) is probably not large enough to justify adopting this strategy, especially if it requires purchasing another property to implement it, or if the other cattle operations that it would displace in the Douglas Daly region (eg. growing out steers for live export) are more profitable. The main reason that profitability was only slightly increased was that only 33% of heifers conceived from yearling mating. It was concluded that this was because most high grade Brahman heifers currently produced on NT commercial properties are too late maturing to achieve high pregnancy rates from yearling mating.

The feeding of protein supplements to first calf heifers prior to calving in the Douglas Daly region did not prove to be profitable as most heifers were able to get sufficient nutrition from the (improved and fertilised) pasture to re-conceive after calving for the first time. The average weights at WR1 and re-conception rates of the four year groups of heifers studied were very similar for heifers that were fed (HN treatment) and not fed (CON treatment) protein supplement prior to calving and heifers.

6 Impact on meat and livestock industry – now & in five years time

This project has already had considerable impact on the NT meat and livestock industry. In conjunction with project NBP.344 (Schatz *in press*) it has increased the awareness of the relationship between weight/condition and fertility in heifers and has resulted in some stations changing their management practises to increase heifer joining weights. A survey of NT managers was done towards the end of 2009 as part of project NBP.344 and it found that over 80% of managers identified weight/condition and nutrition/season (which affects fertility through the effect of weight) as the biggest factors affecting heifer fertility (Schatz in press).

This project also has the potential to benefit the northern Australian meat and livestock industry over the next 5 years (and into the future) if it's findings are applied. The project has demonstrated that there is a strong relationship between the joining weights and fertility of Brahman heifers in the NT, and has quantified (or "put the numbers on") this relationship. Using the charts produced by this project, managers and extension officers can find out the likely pregnancy rates from different joining weights. They can then use this information to analyse the profitability of different management strategies aimed at increasing joining weights. Previously they could not do this as the potential returns were unknown ie the pregnancy rates from different joining weights were not known for high grade Brahman heifers in northern Australia.

Producers can also use this information to make management decisions about heifers in different weight ranges. For example, they will be able to work out which heifers that it will be most cost effective to spend money on (ie supplementation aimed at increasing joining weights). Some heifers may still be too light by joining and so it would be better to hold them over for another year rather than spending money trying to increase their joining weight.

This research has shown that increasing the pre calving weight of first calf heifers through feeding protein supplements prior to first calving in the VRD is a reliable method of increasing re-conception rates. This is very likely to apply to most other areas in the NT where native pasture is grazed. Adoption of strategies aimed at increasing pre calving weight should result in significant increases in profitability if properties can find cost effective methods of doing this.

Another aspect of this project was the research into yearling mating of high grade Brahman heifers from commercial properties in the NT. The project has documented the resulting pregnancy rates from heifers in different weight ranges and this will be useful information for producers considering adopting yearling mating in the future.

The findings of this research have been communicated to producers at several field days and through a number of rural media articles. The importance of the relationship between weight/condition and fertility is now better understood, and it is more widely known that management practises aimed at increasing the weight/condition of heifers through the joining period are the key to increasing heifer fertility.

This project and MLA project NBP.344 (Schatz in press) have shown that there is scope for large improvements in first calf heifer fertility on most NT cattle stations and this would result significant economic benefits to the properties on which such improvements were made. Economic modelling using the “Bcowplus” program (Holmes 2009) showed that increasing first calf heifer re-conception rates by a realistic 30% (from 15% to 45%) throughout the NT would result in an annual increase in GM of $10.95 million for the NT pastoral industry (Schatz in press). This economic modelling shows that increasing first calf heifer fertility on NT cattle properties can result in large benefits for the NT pastoral industry and for individual properties. It is quite possible that this could be achieved in 5 years if properties were to implement the relevant management practises (as outlined in the next section).

7 Conclusions and recommendations

The aim of this project was to gain a better understanding of the relationship between joining weight/condition and pregnancy rates of high grade Brahman heifers and to apply this knowledge so that beef producers in northern Australia can improve the performance of their heifers. The project has been successful in achieving these aims in that it:

- Has established the relationship between joining weights and fatnesses for Brahman maiden heifers (joined first as 2 year olds) and first calf heifers in the VRD.
- Has established the relationship between joining weights and fatnesses for maiden Brahman heifers mated as yearlings in the Douglas Daly region.
- Has used these relationships to produce charts that show the pregnancy rates that are likely to result from different joining weights/fatnesses in maiden and first calf heifers. These charts can be used as management tools by producers and advisors.
- Has shown that yearling mating of high grade Brahman heifers from NT cattle stations usually only results in pregnancy rates of around 33%.
- Has demonstrated that increasing the pre calving weight of first calf heifers through feeding protein supplements prior to first calving in the VRD is a reliable method of increasing re-conception rates This is very likely to apply to most other areas in the NT where beef production systems are based on grazing of native pasture. However it should be noted that the profitability of such strategies is highly dependent on the price of supplements (the cost/benefit of this practice was negative in 2 out of 3 years at current commercially available prices).
- Has shown that feeding protein supplements to first calf heifers grazing improved pastures in the Douglas Daly region it is not cost effective, as the pasture provides sufficient nutrition to give good re-conception rates when appropriate stocking rates are used.
- Has shown that profit from the heifer phase of production was increased when larger (190-260 kg) Brahman weaner heifers were transported to the Douglas Daly region for yearling mating compared to when they are mated for the first time as two year olds in the VRD. However the increase in profit from the replacement heifer phase was probably not enough to justify displacing other cattle activities in the Douglas Daly or the purchase of another property there to implement such a strategy (due to the low pregnancy rates from yearling mating).

MLA Project NBP.344 (Schatz in press) showed that there is potential for large improvements in heifer performance on NT cattle stations with re-conception rates in first calf heifers often below 20%, high rates of calf loss and some incidences of low pregnancy rates in maiden heifers even when they are first mated at two years of age. A number of strategies to improve heifer performance in northern Australia have been suggested (eg. Fordyce 1996: Holroyd and Fordyce 2001) and the next section discusses how the research from this project relates to these strategies.

The main ways of increasing the production efficiency of heifers in northern Australia that have been suggested are;

- having heifers in good condition through joining periods due to the large influence of joining weight on fertility (Holroyd and Fordyce 2001). The results of this study reinforce this recommendation and detail the pregnancy rates that are likely from Brahman heifers of different joining weights.
- adopting yearling mating so that calves start being produced a year earlier than normal and cows produce more calves over their lifetime (Fordyce 1996). This study has shown that the high grade Brahman heifers currently produced by most commercial cattle stations in the NT are too late maturing to achieve high pregnancy rates from yearling mating. However yearling mating may still have a place in preventing out of season pregnancies in heifers that do reach puberty early, and where earlier maturing genotypes are used.
- the use of strategic supplementation to increase joining weights of maiden heifers (Fordyce 1996) especially when they are mated as yearlings. This study has documented the joining weights likely from different pre joining weights for high grade Brahman heifers and shown that conception rates increase as joining weight increases. The research also showed that when yearling mated heifers conceive early in the joining period their re-conception rates as first calf heifers are higher as they have more time to re-conceive before joining finishes.
- the use of strategic pre partum supplementation to increase re-conception rates in first calf heifers (Fordyce 1996). This study showed that this management strategy reliably increased first calf heifer re-conception rates (by an average of 42%), but that this did not always ensure that the strategy was profitable due to the high on farm costs of supplementary feeds in the NT. Profitability was largely determined by the length of the feeding period (determined by the timing of the start of the wet season) and the cost of supplementary feed. The table produced in this study showing the pregnancy rates likely from first calf heifers with different pre-calving weights (Table 20) will be useful in planning first calf heifer supplementation programs and assessing their potential profitability.

The general conclusion/recommendation from the project is that higher joining weights give higher pregnancy rates and so heifer management should aim at increasing joining weights at both the first and second joinings. This simple statement is a general overarching principle for heifer management. Specific guidelines on the weight/condition required for good fertility are as follows: (note that these guidelines are for heifers that have been immunised against botulism, vibriosis and leptospirosis with 7-in-1. Not immunising against these diseases may or may not result in lower fertility):

a) In extensive areas of the NT where native pastures are grazed:

- When maiden (Brahman) heifers are first joined at two years of age (and for a period of at least 4 months), heifers with joining weights greater than 250 kg should achieve pregnancy rates of 80% or more (provided that they grow at a similar rate during the joining period as the heifers did in this study [ie 0.593 kg/day]). Note that the average weight at first conception was 338 kg and so an aim of heifer management should be to have as many heifers as possible reaching this weight early in the joining period.
- When maiden (Brahman) heifers are first joined at two years of age (and for a period of at least 4 months), heifers with pre joining fat depths of at least 2 mm

should achieve pregnancy rates of 80% or more (provided that they grow at a similar rate during the joining period as the heifers did in this study).

- A pre calving weight of 460 kg (adjusted for stage of pregnancy or 490 kg unadjusted) is required for re-conception rates of 70% in first calf heifers (where heifers lose around 45 kg between pre-calving and weaning). Pre calving weights this high are difficult to achieve for first calf heifers grazing native pasture in the NT, and so it is likely that re-conception rates will be lower (Schatz and Hearnden 2008). A pre calving weight of about 440 kg (unadjusted for stage of pregnancy ie assumes heifers are 7 months pregnant) is required for a 50% re-conception rate.
- A pre calving P8 fat depth of 9.5 mm (equivalent to a condition score of 6.5 on the 1-9 system or 3.5 on the 1-5 system) is required for re-conception rates of 80% in first calf heifers (where heifers lose around 45 kg between pre-calving and weaning). It is difficult to get heifers in this sort of condition grazing native pasture in normal seasons in the NT, and so it is likely that re-conception rates will be lower.

b) In regard to yearling mating in areas of the NT where higher growth rates can be achieved (eg. from improved pasture in the Douglas Daly region and in good seasons in the Barkly and Alice Springs regions):

- The current genotypes of high grade Brahman heifers on most NT Cattle stations are too late maturing to give high pregnancy rates from yearling mating. This study found that only about 1/3 of such heifers conceive from yearling mating (as most did not reach their critical weight for first conception before the joining period finished). It should be noted that selection can produce high grade Brahman genotypes that are earlier maturing and that give higher pregnancy rates from yearling mating (Schatz *et al. in press*).
- A pre joining weight of 335 kg is required to achieve 80% pregnancy rates from current commercial genotypes of high grade Brahman heifers mated as yearlings. In the NT it is not common for heifers to reach these sort of weights by 12 months of age and so most yearling mating programs with high grade Brahman heifers will achieve lower pregnancy rates.

The findings of this study can be incorporated with pre-existing knowledge to produce some general recommendations for Brahman heifer management in northern Australia. These recommendations are:

- Segregation of heifers from weaning is recommended as it allows targeted management (eg. specific supplementation) and ensures that pregnancies occur at the best time of year (if bulls can be controlled).
- Weight is the biggest factor affecting conception rates (at both the first and second joinings) so the aim of heifer management should be to keep them in good condition.
- Heifers that grow well from weaning reach puberty at younger ages so heifers should be managed to achieve good growth between weaning and first joining. Moderate stocking rates and the use of better paddocks are 2 of the simplest and most effective ways of achieving this. Cost effective supplementation programs also assist. Earlier born heifers in a calf crop have an advantage in reaching target joining weights.

- Heavier heifers usually conceive earlier in the joining period and this has significant benefits (eg. a greater chance of re-conception rates as 1st calf heifers and they produce heavier weaners). Target joining weights for maiden heifers should be set so that heifers reach the average weight at puberty fairly early in the joining period. For current industry Brahman heifers the average weight at puberty is around 320-330 kg. Studies have shown that a good target joining weight for maiden heifers is 280 kg.
- Appropriate vaccination programs should be considered. All heifers should be vaccinated against botulism. There may be benefits from vaccinating heifers against vibriosis, pestivirus and leptospirosis but the results will vary from property to property depending on circumstances.
- Yearling mating can be considered to ensure that early maturing animals conceive at the desired time of year, however only about 1/3 of high grade Brahman heifers weighing >200 kg at weaning are likely to conceive from yearling mating (note that this is for current industry genotypes but that higher pregnancy rates can be achieved in heifers that come from herds that have been selected for fertility). Pregnant yearling heifers should be managed to prevent weight loss as they are prone to calving difficulties.
- Supplementation to improve body condition of heifers prior to calving increases re-conception rates but the profitability depends on the cost of the supplementation program.
- A target pre calving weight of about 440 kg is required to ensure re-conception rates of at least 50% in first calf heifers. Management should aim to keep first calf heifers in at least moderate condition (score 3 in the 1-5 system) at calving and through lactation. First calf heifer re-conception rates are often low (<25%) in the NT due to heifers being too light (in poor condition) at these times.
- Calves should be weaned from first calf heifers before their condition slips too much, although the timing of weaning of weaning is a balance between reducing the weight loss of heifers and maximising the weight of their weaners. Weaning preserves body condition which results in higher re-conception rates in future years (although for a first calf heifer to produce another calf within 12 months it must re-conceive within 3 months of calving [ie before weaning] and this is largely dependent on the heifers condition during lactation).

In conclusion this project has been successful in increasing the understanding of the relationship between joining weight/condition and pregnancy rates in high grade Brahman heifers and exploring strategies where this knowledge can be used to improve heifer performance in the NT.

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