final report

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Nutritional influences on beef breeding performance

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TABLE OF CONTENTS

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This study was supported by The North Australian Pastoral Company, the Northern Territory's, Department of Business, Industry and Resource Development, Ridley Agri-Products, Meat and Livestock Australia and The University of Queensland. A study of this kind in this region of Australia has only been attempted once before, in 1965. Research under commercial conditions is always challenging and this is even more pertinent when the commercial conditions are a remote cattle station covering an area of 1.8 million hectares. The unwavering support of the funding organisations for this study has been praiseworthy.

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ABSTRACT

This five year project investigated 5000 breeder cattle on Alexandria Station on the Barkly Tableland to improve knowledge on the optimum timing and level of supplementation under commercial conditions.

This project achieved the following outcomes that are of benefit to industry:

- Established new production benchmarks for beef breeding in northern Australia.
- Demonstrated that *Bos indicus* content as low as 37.5% (50% tropical adaptation) can achieve high breeding performance in the tick-free regions of northern Australia.
- Demonstrated that heifers can achieve high (90%) pregnancy rates and subsequent high pregnancy rates as second-calf heifers and cows.
- Modelled the influence of nutrition through breeder weight and condition on pregnancy rate, duration of anoestrus, calf growth from birth to weaning and weaning weight for three age-groups of breeders (heifers, second-calf heifers and cows).
- Identified an optimum breeder condition of approximately score 5 (using a nine-point scale) for pregnancy and calf growth.
- Modelled the relationship between important nutritional parameters of faecal and pasture samples.
- Identified mean Mitchell grass (*Astrebla pectinata*) protein concentration of 5% to be associated with approximately 8% faecal protein concentration and therefore the level at which a response to supplementation can be expected.
- Created an understanding of the importance of objective measurements for nutritional management and developed models suitable for decision support in the Barkly Tableland region.
- Increased awareness of the importance of timing of rainfall (as opposed to amount of rainfall) on pasture quality and therefore supplementation requirements.
- Facilitated the development of on-station training courses (Barkly Rangeland Management Course and Barkly Herd Management Course) based on the findings and methods of this project. Such courses have been subsequently developed in other regions of northern Australia.
- Facilitated discussion of research outcomes applicable for Barkly Tableland beef producers through various fora such as on-station field days, workshops and industry-driven steering committees. Such activities in the Barkly Tableland region were non-existent at the initiation of the project.

EXECUTIVE SUMMARY

Native pastures of northern Australia are seasonally deficient in nutrients for the purposes of cattle breeding (Fordyce and Entwistle 1992), and nutrition is considered one of the key factors influencing reproduction (Entwistle 1983). Nutrient supplementation improves reproductive performance (McCosker *et al.* 1991). However, there is a need to improve knowledge regarding timing and level of supplementation (Dixon 1994) under commercial conditions (Miller *et al.* 1997). The only previously published nutritional research in the Barkly Tableland district (Hart and Michell 1965) examined phosphate-only delivery during the dry season, a practice now considered unviable (Winks 1990).

The current study involved the investigation of over 5000 individually identified cattle that were fed over 100 tonnes of supplement. The cattle were managed as four herds, grazing an area of 740km^2 of native pastures on a commercial cattle station in the Northern Territory of Australia. The extensive nature of this study proved to be both its greatest strength and greatest challenge. The outcome of this study has changed the way beef producers in the Barkly Tableland region of the Northern Territory (an area covering 145,000 km^2, running 500,000 head of cattle) manage nutrient supplementation and has established new production benchmarks for extensive beef breeding herds in northern Australia. More specifically, producers have re-evaluated their approach to determining the timing of supplementation by adopting objective approaches such as faecal sampling, pasture sampling and breeder body condition scoring.

To address the issues regarding amount and timing of delivery of breeder supplementation, measurement of current breeder herd productivity and the means by which animal nutrient status can be estimated was necessary, as this information has not been previously investigated in the Barkly Tableland region. Pregnancy rates, duration of anoestrus, calf growth and weaning weight were analysed for the influence of breeder body condition, breeder weight and breeder age-group. The relationship between nitrogen and phosphorus concentration in monthly samples of pasture and faeces were described as a means of estimating animal nutrient status.

Due to the large size of paddocks and number of cattle investigated, adequate replication of supplementation regimes and paddock rotation was impossible and therefore there was the potential for confounding effects between variables. To strengthen the discussion of commercial implications, measurement of potential confounding variables was undertaken. Satellite imagery, aerial photography and assessment of pasture composition and yield were used to determine uniform paddock selection for the study. Pasture quality, water and soil nutrient concentrations and daily rainfall in all paddocks were recorded. All animals were of the same breeding and were stocked in paddocks to achieve as similar as possible utilisation rates. However, a statistical comparison of the supplementation regimes is inappropriate and is therefore neither undertaken nor the focus of the discussion. The models developed from the current study provide wider application of the findings than any comparison of selected supplement recipes. The models are applicable to beef breeding operations in the Barkly Tableland,

regardless of nutritional management practice.

The annual rainfall amounts for the years 1996 to 2001 were above average every year, with 2000 registering the highest annual rainfall recorded in over 100 years. In contrast to previous research, mean second-calf heifer pregnancy rate (89%) was not significantly different to heifer pregnancy rates (90%), with both being less than mature cow pregnancy rates (95%). It was found that as breeder weight and condition increase, the probability of pregnancy increases. As breeders proceed through the first three or four years of reproductive activity, they are more likely to be pregnant and will take longer to conceive. Conversely, as breeder weight and condition increase (for breeders with condition scores 4 to 9), the growth from birth to weaning and their weaning weights were found to decrease. Calf growth from birth to weaning is highest for the progeny of mature cows.

A significant association between monthly pasture samples of Barley Mitchell grass (*Astrebla pectinata*) and faeces for nitrogen was found. More specifically, average Mitchell grass protein concentration of 5%, is associated with faecal nitrogen concentration of approximately 8% and therefore below this level (Winks *et al.* 1979), a response to supplementation can be expected. This coupled with the known consistency of pasture sampling comparative to faecal sampling and relative monotony of Barkly Tableland pastures, lead to the conclusion that monthly pasture sampling using the described ‘indicator species’ method can be used to estimate faecal nitrogen concentration.

MAIN RESEARCH REPORT

1.0 Project objectives

Supplementation of breeding cattle in the Barkly Tableland is a standard management practice. Therefore in validating research under commercial conditions it was considered that investigating a 'nil supplementation' regime would be nugatory. Industry surveys (Goodacre and Adams 1999; Savage 1997; Dixon 1994) have shown that two primary concerns relating to supplementation emerge as issues requiring attention. The two issues are interconnected:

1. Cost/amount of supplementation ($/cow/year)
2. Timing of supplementation (when to start supplementing)

When this project commenced, management decisions regarding when to start supplementing were based on approaches ranging from initiating supplementation to follow annual events (e.g. Mount Isa rodeo) to breeder body condition and occasionally faecal nitrogen levels. Unfortunately, experience has shown that regardless of attempts to improve the consistency of sampling, storage and transportation technique, variations in sample quality were contributing to erratic faecal nitrogen patterns. The variations in faecal sample quality do not occur for pasture samples due to the relatively simple nature of sampling technique and lack of need for refrigeration and special packaging of samples for analysis.

The current study was established with a commercially driven focus to reduce the cost of annual supplementation without sacrificing production in extensive beef breeding herds in the Barkly Tableland region. To address this commercial issue, an understanding of current production levels and the means of measuring animal nutrient status was required. This information has not been researched in the Barkly Tableland region previously. While the cost of supplementation is crudely measured as $/breeder/year, the true value of supplementation is a function of this cost against breeder performance, measured as:

- Breeder fertility (pregnancy rate and duration of post-partum anoestrus)
- Calf growth rate and weaning rate

In testing the hypotheses on a commercial scale, all investigations were undertaken on the Barkly Tableland commercial cattle breeding operation, Alexandria Station. The most suitable approach for this study was to establish the current level of breeder herd productivity, describe the relationship between 'useable' measurements of animal nutrient requirements and estimate the influence of reducing annual nutrient supplementation by at least 40% (from the current practice) on pregnancy rate, duration of post-partum anoestrus, calf growth and weaning weight. Three objectives for the study were established:

Objective 1

Model the effect of breeder body condition (by visual assessment using a nine-point scale) and weight (kg – adjusted for stage of pregnancy) on pregnancy rate (%) and duration of anoestrus (month of pregnancy) for three age-groups (heifers, second-calf heifers and mature cows) of composite-bred cattle.

Objective 2

Model the effect of breeder body condition and weight on calf growth from birth to weaning (g/d) and weaning weight (kg) for three age-groups of composite-bred cattle.

Objective 3

Describe the relationship between monthly samples of native pasture and breeding beef cattle faeces analysed for nitrogen and phosphorus concentration.

The study was conducted on four herds of cattle. Due to the size of the paddocks (total 740km^2), and large number of cattle involved (over 5000), replication of supplementation regimes and paddock rotation was impossible. Therefore, compilation of evidence from the project objectives was undertaken within and across supplementation regimes, in combination with the measurement of potential confounding variables. Satellite imagery, aerial photography and assessment of pasture composition and yield were used to determine uniform paddock selection for the study. Pasture quality, water and soil nutrient concentrations and daily rainfall in all paddocks were recorded. All animals were of the same breeding and were stocked in paddocks to achieve as similar as possible utilisation rates. However, a statistical comparison of the supplementation regimes was not undertaken as there was insufficient replication. The models developed from the current study provide wider application of the findings than any comparison of selected supplement recipes. The models are applicable to beef breeding operations in the Barkly Tableland, regardless of nutritional management practice.

1.1 Background

Australia is the world’s largest exporter of beef (MLA 2001). The value of Australia’s beef industry is valued at $4.3 billion (MLA 2003). The north Australian beef industry (north of 26^{o}S) runs more than half of the Australian cattle population with over 14 million head (MLA 2003). The vast majority (85%) of beef properties in this region operate breeding enterprises on native pastures that are predominantly deficient in essential nutrients for beef breeding (Fordyce and Entwistle 1992). The loss of production due to nutrient deficiencies has been estimated in excess of $80 million annually (Miller *et al.* 1997).

Significant improvements in the efficiency of beef production have occurred in northern Australia over the last twenty years (Bortolussi *et al.* 1999; Miller *et al.* 1997; O'Rourke *et al.* 1995a; Holt and Bertram 1981).

A number of factors such as improved pasture management, disease eradication and control, increased breeder fertility through genetic selection and improved nutritional management have contributed to higher production. For example, in 1980 only 43% of Barkly Tableland properties had an average branding rate over 50% (Holt and Bertram 1981). Nineteen years later, Barkly Tableland properties averaged a branding rate of over 50% (Bortolussi *et al.* 1999).

Reproductive performance of cattle in the extensive pastoral areas of northern Australia is affected by many factors. Nutrition is considered to be one of the most critical factors influencing reproduction (Bolanos *et al.* 1996; Entwistle 1984; Entwistle 1983). While reproductive performance is affected by many factors and can be measured in several ways, branding rate is perhaps the easiest and therefore most widely used measure of reproductive performance by beef producers. In a survey by Bortolussi *et al*. (1999), 100% of respondents felt that branding rate was the most important factor to improve profitability.

One of the most critical steps to the advancement of nutritional management on northern cattle stations has been improved control of cattle through fencing and yard facilities. The Brucellosis and Tuberculosis Eradication Campaign (BTEC) placed a requirement on northern cattle stations to regularly muster and test cattle. This necessitated the need for vastly improved cattle handling facilities. These facilities remain today and have allowed producers improved control and management of their cattle. An example of the change can be seen by comparing two surveys reported twelve years apart. Robertson (1980) reported that 3% of properties in the Victoria River District practiced two rounds of mustering and weaning. That figure increased to 92% for northern Australia and 60% for the Northern Territory in the survey by O'Rourke *et al*. (1992).

Energy, nitrogen and phosphorus have been identified as the major nutrients limiting production in northern Australia (Dixon *et al.* 1996a; Bortolussi *et al.* 1996; Miller *et al.* 1996; Bortolussi *et al.* 1992; McCosker *et al.* 1991; Ternouth 1990; Coates *et al.* 1987; Hennessy 1980; Hennessy *et al.* 1978). Research undertaken on Victoria River Research Station (Kidman Springs, NT) has shown that improved nutritional management on a Droughtmaster herd has lifted weaning by 30% (from 50% to 80%), weaning weight by 30kg (from 150kg to 180kg) and breeding herd efficiency (measured as kg calf weaned per 100kg cow mated per year) from 23.4kg to 37.5kg (Sullivan and O'Rourke 1997). Trials undertaken on Mt Bundey Station (Top End, NT) showed a 17% increase in pregnancy rates with wet season protein supplementation compared to not providing protein supplement during the wet season (McCosker *et al.* 1991).

Work conducted at Swan's Lagoon Research Station in Queensland has shown that the effect of dry season and wet season supplements on breeder liveweight and body condition score (BCS) is additive (Dixon *et al.* 1996a). It could then be expected that combined wet and dry season supplementation may enhance reproductive efficiency as increasing breeder liveweight improves pregnancy rate (Goddard *et al.* 1980) and improving BCS may improve pregnancy rates and weaning weights (Wikse *et al.* 1995).

The excellent potential for pastoralism in the Barkly Tableland district has been recognised for many years. The explorer, William Landsborough who, while searching for Burke and Wills in 1861, described the Barkly Tableland as "carrying a good body of nutritious grasses" (Holt and Bertram 1981). With improvements in fencing, sub-artesian water sourcing and animal handling facilities (yards), the Barkly Tableland has developed into one of the most valuable and progressive beef breeding districts in northern Australia (Goodacre and Adams 1999). One factor associated with this development has been the ownership structure of the Barkly Tableland with over 90% of the land and cattle owned by large corporate interests. Nutrition management has emerged as a priority area of importance in terms of research for the Barkly Tableland beef producers (Goodacre and Adams 1999).

There is recognition by the industry that improvements in supplementation procedures are possible and that these improvements may result in increased profit margins (Savage 1997; Dixon 1994). However, there is a need to validate research results on a commercial scale and in a wider range of circumstances (Coates *et al.* 1996; Miller *et al.* 1996). The only previous supplementation research conducted on the Barkly Tableland was undertaken almost forty years ago by Hart and Michell (1965). While this work was useful in emphasising the potential impact of dry season phosphate supplementation, it has limited application today.

2.0 General Materials and Methods

This section describes the location of the study, animal management, supplementation and procedures for measurement. Study of the relationship between production variables and environmental variables was undertaken addressing each of the study objectives (Section 1.1).

2.1 Location

The Barkly Tableland is a region of northern Australia stretching from Headingly Station (21°45′S 138°30′E) in north-west Queensland to Newcastle Waters (17°23′S 133°24′E) in the Northern Territory covering an area over 150,000 km^2 (Figure 2.1). The work was undertaken on a commercial cattle operation, Alexandria Station, located in the eastern portion of the Barkly Tableland (latitude 19°3´S; longitude 136°42´E) region of the Northern Territory (Figure 2.1). The cattle used in this project were run in four paddocks, covering a total area of 740 km^2 of unimproved native pasture on treeless, flat to slightly undulating downs typical of the Barkly Tableland. The Barkly Tableland is renowned for the monotony of an expansive sea of Mitchell grass (*Astrebla spp*.) and Flinders grass (*Iseilema spp*.) it supports. Alexandria Station is within the designated cattle tick (*Boophilus microplus*) free zone.

The Barkly Tableland climate is sub-tropical with a distinct hot, wet season during the summer months and cool, dry season during the winter months. The one hundred year average annual rainfall for the Barkly Tableland is 402 mm (398mm for Alexandria) with 86% of the rainfall occurring over the five months from November to March (Figure 2.2) when pasture growth and corresponding animal weight gain is at its maximum. While research from other regions of Australia report weight loss during the dry season as common place (Dixon *et al.* 1997a; McCosker and Winks 1994; Entwistle 1984; McCown *et al.* 1981), results from the current study indicate that dry season weight loss in the Barkly region may be limited to lactating breeders only. Fire is not used on the open downs land types as a management tool however, the occasional wild fire does occur. A small wildfire was experienced in one corner of one trial paddock (Paddock 1 in 1999). Rainfall variability over the wet season is rated as “high” to “very high” (BOM 2002).

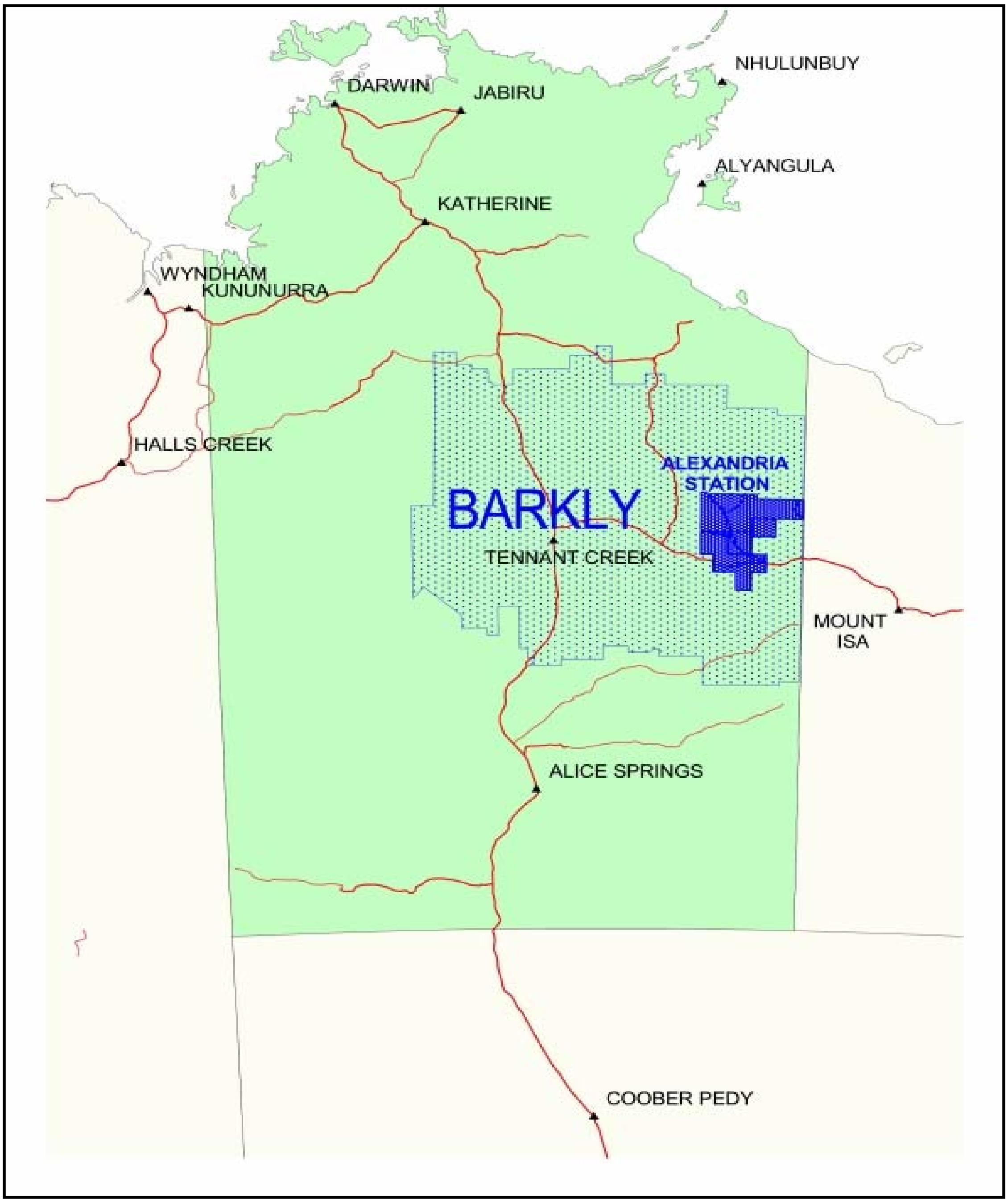

Figure 2.1 Map of the Northern Territory showing location of the Barkly Tableland and Alexandria Station. (Source: DIPE 2002)

Average maximum and minimum temperatures range from a peak of 38°C and 25°C respectively in January to 27°C and 11°C respectively in July (Figure 2.3). Winter temperatures do not reflect the wind-chill factor, which can be significant, with average daily wind speeds of 21.9 km/h and average daily maximum wind gusts of 116.6 km/h (BOM 2002). Variability in rainfall patterns and a sub-tropical climate, contribute to lower relative humidity levels in the Barkly Tableland than the coastal areas of northern Australia where most previous nutrition research has been undertaken. Annual changes in relative humidity for the Barkly region based on thirty years of records from 1961 to 1990 are shown in Figure 2.4. Average annual evapotranspiration ranges between 400mm and 500mm while evaporation has been recorded as high as 2921mm (Holt and Bertram 1981; Randal 1966).

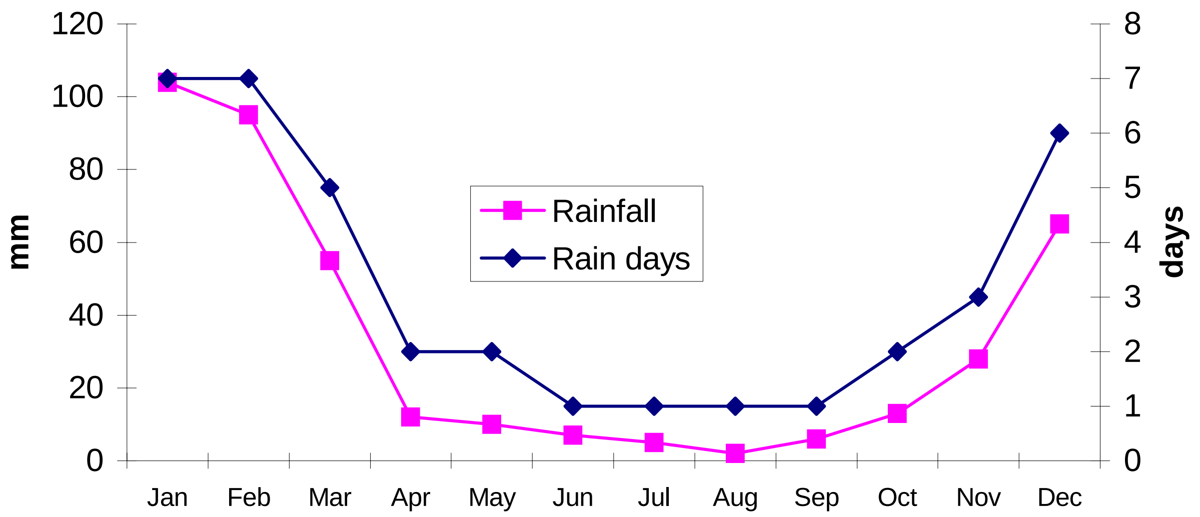

Figure 2.2 Average monthly rainfall and rain days for the Barkly Tableland. Adapted from (BOM 2002).

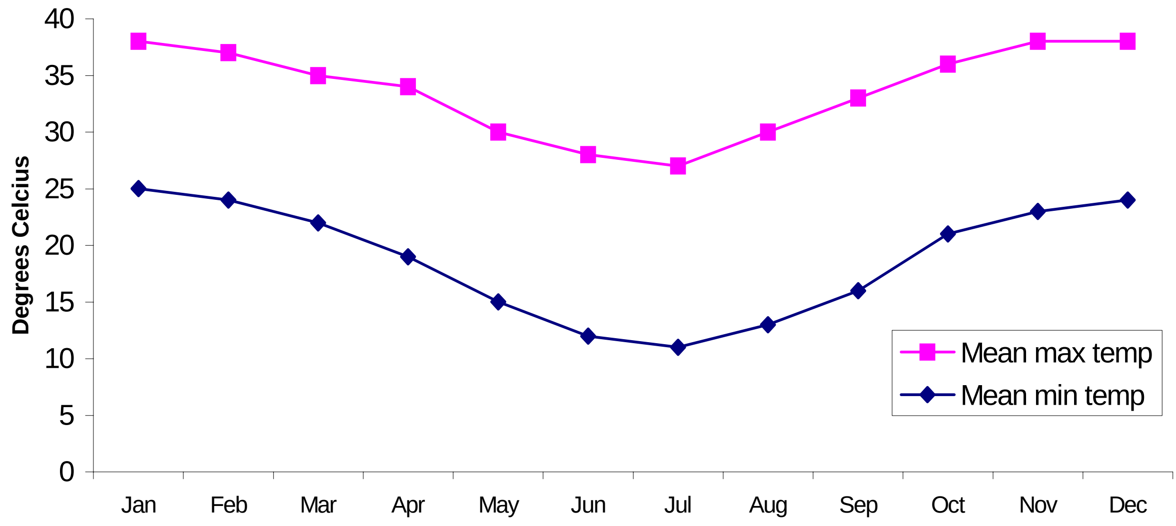

Figure 2.3 Average monthly maximum and minimum dry bulb temperatures for the Barkly Tableland. Adapted from (BOM 2002).

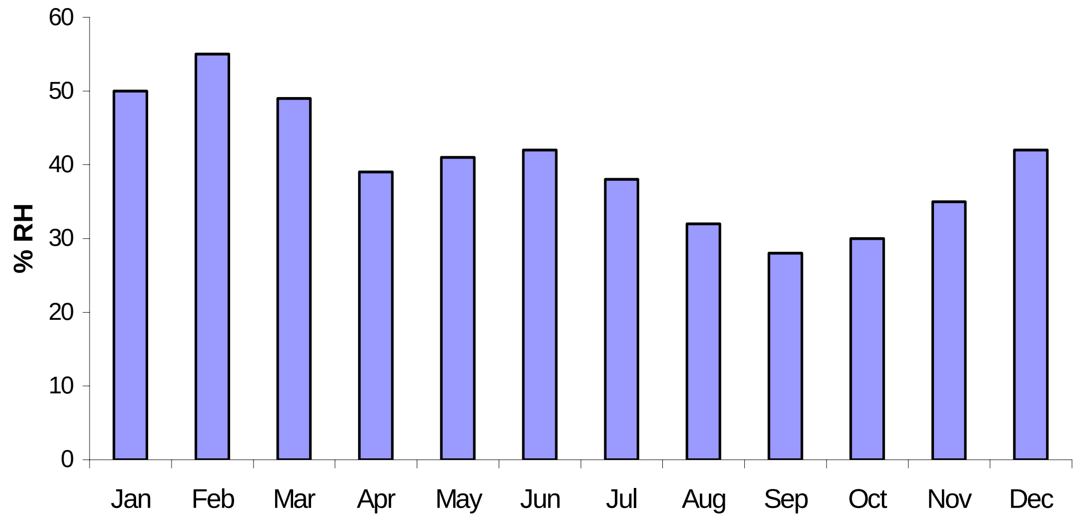

Figure 2.4 Average monthly Relative Humidity (%) for the Barkly Tableland. Adapted from (BOM 2002).

There were three dominant soil types encountered in the project area on Alexandria Station. The most dominant of these land units was the alluvial grey or brown cracking clays, which occur at the lowest level of the catena. Another dominant unit was the gravelly gilgaied terrain overlying alkaline clays derived from the underlying carbonate rocks supporting annual species such as *Aristida spp*., *Iseilema spp*. and *Brachyachne convergens*. Gilgaied alkaline clays with chert gravels, supporting Bull Mitchell grass (*Astrebla squarrosa*), Golden Beard grass (*Chrysopogon fallax*) and Silky Browntop (*Eulalia aurea*) were also recorded.

2.2 Project animals and paddock management

Four herds of similar cattle of the same composite breed (6/16 Brahman, 2/16 Africander, 5/16 Shorthorn, 2/16 Charolais, 1/16 Hereford) were used in this study. All cattle were grazed in a set-stocked (no rotation) manner typical of commercial production in the region. Paddock selection was undertaken at the beginning of the study to minimise the possibility of paddock differences. Satellite images and aerial photographs of the possible project areas were taken. A series of ‘ground-truthing’ exercises were undertaken to match the satellite and aerial images to on-ground characteristics of pasture and soil communities. Following examination, paddocks that appeared uniform were selected for the study. This process coupled with intensive measurement during the study found no observable or measurable feed quality differences (Tables 3.4 and 3.5). Pasture yields throughout the study period provided an excess of feed quantity due to five consecutive years of above average rainfall. While numbers of cattle in each herd were different (Table 2.1), stocking rates were determined such that paddock utilisation rates were similar.

Table 2.1 Numbers of maiden heifers (H), second-calf heifers (2) and mature cows (M) tested for pregnancy status, lactation status, liveweight and body condition score in each of the four herds from 1997 to 2001.

	‘97	**1998**		**1999**			**2000**			**2001**		**TOTAL**
	H	**H**	**2**	**H**	**2**	**M**	**H**	**2**	**M**	**2**	**M**	
HERD 1	243		176	204		116	46	177	85	34	212	**1293**
HERD 2		374		76	373		243	66	222	219	270	**1843**
HERD 3		216		67	171			36	41	107	46	**684**
HERD 4	689		570			487			424		384	**2554**
TOTAL	**932**	**590**	**746**	**347**	**544**	**603**	**289**	**279**	**772**	**360**	**912**	**6374**

All cattle in herds 1, 2 and 3 were individually identified and monitored. Of the 1800 head in herd 4, 689 were individually identified and monitored. All breeders and bulls received annual vaccinations for botulism (*Clostridium botulinum*) and bulls received annual vibriosis (*Campylobacter foetus*) booster vaccinations. Cattle were mustered biannually in April (first muster round) and August (second muster round).

Bulls are control mated from late December to early April each year. Any breeder that failed to conceive within the first four months of joining was culled from the herd. Conception periods were determined by rectal palpation in August at the second muster round. Any breeder that conceived and failed to raise a calf, regardless of cause, was culled from the herd.

Replacement heifers were introduced to the herds each year prior to joining in late December. Replacement heifers were selected using condition score, weight, conformation and temperament as the main selection criteria. Only heifers from cows of proven high fertility are selected for the replacement heifer group. Calves are mothered-up at birth and are individually identified with ear tags. All calves were weaned at first round muster and weighed.

2.3 Supplementation

Project cattle were subject to one of three supplement regimes (Figure 2.5). Supplements were fed on an *ad libitum* basis using compressed mineral blocks. Blocks of 18kg and 20kg weight were used for the project as this is the commercial size of blocks used on Alexandria Station. The nutrient composition of blocks used is found in Table 2.2.

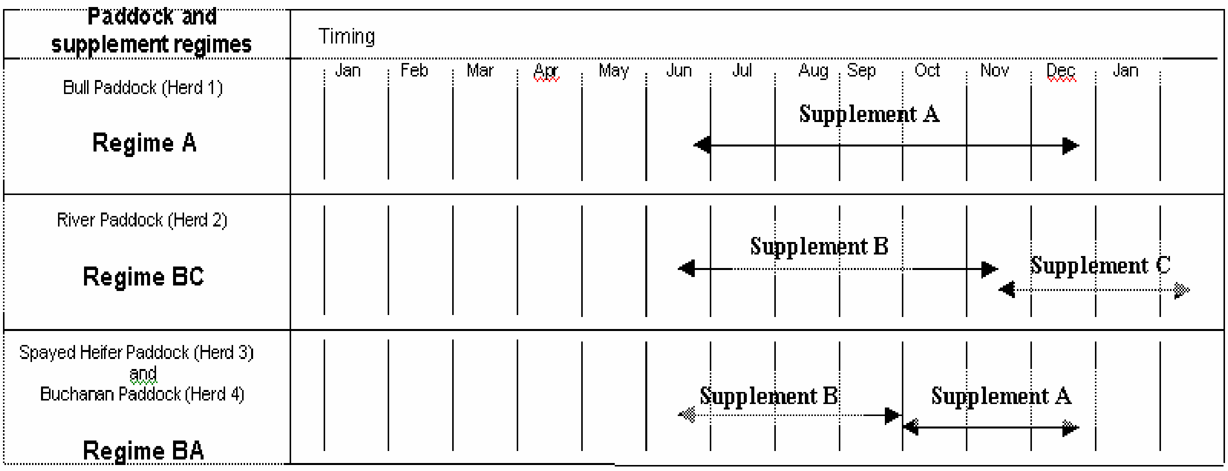

Figure 2.5 Schematic diagram of the approximate timing and supplement fed for the three supplement regimes imposed during the study. Timing of supplementation was flexible according to seasonal conditions.

Table 2.2 Summary of supplement block weight (kg) and nutrient composition (%) for the three supplement blocks used in this study.

Composition	**Supplement A**	**Supplement B**	**Supplement C**
Urea (%)	8	15.7	10.5
Protein meal (%)	13	Nil	6
Total protein (%)	30	40	30
Phosphorus (%)	4	5	6
Calcium (%)	8	7.5	8
Sulphur (%)	2	3	0.5
Magnesium (%)	0.2	Nil	3.5
Salt (%)	25	48.4	10
Molasses (%)	Nil	0.5	40
Copper (ppm)	300	300	40
Cobalt (ppm)	30	30	4
Iodine (ppm)	30	30	4
Zinc (ppm)	500	500	140

For the twelve month period before entry to the study (Herd 1 and Herd 4 in 1996; Herd 2 and Herd 3 in 1997), all animals grazed in the same paddock and received the same supplementation (Supplement B) before random allocation to the project herds. Herd 1 (Bull paddock) were fed supplement regime A, which involved supplement A fed in the manner used on Alexandria Station in previous years (Figure 2.5). Herd 2 (River paddock) were fed supplement regime BC, which involved feeding supplement B in the dry season and supplement C in the growing (wet) season (Figure 2.5). To maximise the opportunity for supplement intake during the growing season, Supplement C was fed approximately one month prior to the start of the growing period. District experience suggests that this technique may encourage intake of supplement during the growing season, when supplement intake is often difficult to achieve. Herd 3 (Spayed Heifer paddock) and Herd 4 (Buchanan paddock) received the same supplement regime, referred to as regime BA, which involved feeding Supplement B early in the dry season and Supplement A later in the dry season (Figure 2.5).

Due to a prolonged wet season in 2000, station management determined not to feed supplement in that year. Supplement was fed as planned from 1997 through to 1999.

All supplements used in the study (Table 2.2) contained urea as the primary nitrogen source. Only supplement C contained a significant (40%) proportion of molasses as the energy source. Supplement A contained an energy source referred to as 'EC Feed' which is a patented supplement additive. Both supplements A and C contained amounts of protein meal (13% and 6%, respectively).

Consumption of supplement was measured weekly by an estimation of remaining supplement and recording of total distributed. Supplements were placed in a semi-circle fashion around a stock water bore approximately 500m from the drinking trough.

Measurement of supplement wastage by factors other than cattle consumption was undertaken by placing four blocks in turkey nest enclosures. Rain and wind appeared to cause no measurable wastage of supplement. Native animals (such as Kangaroos) appeared to show an interest in the supplement however were unable to consume any significant amount of supplement due to block hardness.

2.4 Animal performance recording procedures

All records of animal performance were collected electronically using a Ruddweigh *KD-1 Datacollecta* connected to the weigh scales. The KD-1 enabled all records of ear tag numbers, weights, condition scores, lactation status, pregnancy diagnosis and other comments to be recorded crush-side and downloaded onto computer and directly into a spreadsheet program at night. A paper record of each animal's previous history was kept beside the KD-1 for all data collections and cross-checked for each animal. This procedure enabled immediate identification of any missing animals and minimised the chance for data recording errors (e.g. mis-read ear-tag numbers).

2.4.1 Pregnancy diagnosis

Pregnancy diagnosis was performed in a cattle crush by rectal palpation and determined to the closest month. Steps were taken to maximise the accuracy of the pregnancy diagnosis. As it was considered that most inaccuracies in pregnancy diagnosis would be observed in the early stages of gestation, breeders were pregnancy tested at the second round muster (August) when any developing foetus conceived within the joining period would be a minimum of 5 months of age.

2.4.2 Weighing animals

Breeders were weighed at both first (April) and second (August) muster rounds. A set procedure was followed for weighing to minimise variation in weight caused by gut-fill. Animals were mustered and yarded the night prior to weighing. Animals were fasted overnight (13 to 20 hours) prior to weighing, while having *ad libitum* access to water. Breeder weights were adjusted for stage of gestation (and therefore weight of foetus and gravid uterus) using the procedure described by O'Rourke *et al*. (1991c). Weighing was performed in a cattle crush.

2.4.3 Condition scoring

All breeders were condition scored using the nine-point scale as described by Herd and Sprott (1996) at both first and second round musters. Condition scoring was conducted by the same operator (Darryl Savage) throughout the duration of the project, in order to make this procedure less subjective. Condition scores were allocated to each cow immediately prior to entering the cattle crush (for weighing and/or pregnancy diagnosis) as animals' appearance of condition may be altered while standing in the cattle crush or during rectal palpation. Breeders may "hunch" their backs in response to weighing and rectal palpation and so give a slightly altered appearance of condition score.

2.4.4 Lactation status

Lactation status was recorded for all breeders at both first and second round musters. Lactation status was recorded as 1 = wet (suckling calf) or 0 = dry (not suckling). Lactation status was determined by examination of the udder and stripping of the teats. A breeder that may be producing milk in preparation for birth ("springing") was recorded as a non-lactating breeder (although heavily pregnant) at the time of testing.

2.4.5 Mothering-up of calves

All calves in herds 1, 2 and 3 were individually identified and "mothered-up" to their dam within two days of birth. Calves in herd 4 were not mothered-up due to the large size of the herd (approximately 1800 breeders) and paddock (350km^2). The process of mothering-up involved one person travelling around the project paddocks during the calving period every day. When a new-born calf was found, the calf would be ear tagged with a number unique to that animal. The calf tag number and dam's ear tag number would be recorded and the date of birth recorded. During this process, any cows experiencing calving difficulty were identified as were the dam's of still-born calves. Cows and calves were monitored daily throughout this period for any mis-mothering of calves. Breeders would be culled if they did not raise a viable calf to weaning.

To assist in calculations of calf gain from birth to weaning, 20% of calves were weighed at birth to provide an estimate of average birth weight. All calves in each herd were weaned and weighed on the same date.

2.5 Faecal measurements

Faecal sampling was conducted monthly following the procedure described by Lyons and Stuth (1992). As the cattle at Alexandria Station are accustomed to human presence, one could walk freely amongst the cattle and collect samples from the ground while the cattle rested at the bore. Fresh samples were collected from breeders only and not bulls or calves.

Analysis was undertaken at the Arid Zone Research Institute Laboratory, Alice Springs, to determine faecal nitrogen and phosphorus concentration and dry matter content.

2.6 Pasture measurements

Pasture measurements were undertaken in each of the study paddocks. The pasture measurements involved monthly sampling of ‘indicator’ plant species and biannual assessment of pasture yield, cover and composition. Pasture measurements were important for measurement of confounding variables and establishing the relationship between pasture and faecal measurements.

2.6.1 Pasture samples

Monthly pasture samples of Barley Mitchell grass (*Astrebla pectinata*) and Red Flinders grass (*Iseilema vaginiflorum*) were collected from each trial paddock using the “grab sample” technique as described by Willms *et al*. (1998) and Ash and McIvor (1995). These plant species were selected for sampling as “indicators” of available plant nutrition rather than diet quality. Changes in the nutritive value of “indicator” plant species may reflect changes in diet quality of the animal as the season progresses (Ash and McIvor 1995).

Plucked plant samples were analysed for nitrogen and phosphorus levels following Kjeldahl digestion. Plant samples were also analysed for *in vitro* digestibility (McLeod and Minson 1978).

2.6.2 Pasture assessments

Pasture assessments were conducted at the conclusion of each wet season and dry season following the BOTANAL – dry weight rank procedure described by Tothill *et al.* (1978) to estimate pasture biomass, ground cover, grazing intensity and plant species diversity.

A total of thirteen sites were established across the project area. Site location was selected by the use of satellite imagery, aerial photographs and ground-truthing to provide an equal representation of each land type in each paddock. Sites were positioned at similar distances from watering points to provide equal opportunity for grazing.

2.7 Soil measurements

Soil samples were collected from ten sites that were estimated as representative of the soil types present in the project area (all four paddocks), as determined by the use of satellite imagery and ground-truthing. Soil samples were collected in June 1997 (Appendix 8). Soil samples were collected using the method described by Buurman (1996). All soil sample analyses were performed in the Chemistry laboratory, Berrimah Agriculture Research Centre, Berrimah, Northern Territory.

Soil pH and Electrical Conductivity (EC) analyses were undertaken by measurement of the supernatant solution obtained after one hour. This was followed by 1:5 soil to distilled water extraction with a pH and conductivity meter. Measurement of cations was by ICP (inductively coupled plasma) analysis. When soluble salts were not present (EC < 0.10 mS/cm) the values are equivalent to exchangeable cations. Measurement of extractable P was by FIA (flow injection analysis) utilising a molybdenum blue procedure.

2.8 Water measurements

Water samples were collected from four sites that were deemed to be representative of water quality consumed by stock. These sites were considered the most representative as they were the sources most commonly used by cattle in these paddocks in previous years (Peatling 2001). Samples were collected from each site in June and November 1997 (Appendix 8). The timing of sampling was to establish if any differences in water quality occurred with a change of season. The availability of sub-artesian water on the Barkly Tableland is plentiful (Holt and Bertram 1981) and therefore does not impact on water quality changes during the year. Evaporation rates do however fluctuate during the year, with changing temperatures (Figure 2.3) and relative humidity (Figure 2.4). The impact of changing rates of evaporation on water quality was unknown and therefore measurements were taken at June and December to measure if there was any change in water quality due to evaporation.

Water samples are generally taken from the bore head or the turkey's nest. Experience has shown that large differences in water quality can occur between the bore head and water trough. The purpose of the water sampling was to provide an indication of water quality and the potential impact on animal nutrient status, therefore water samples were collected from the water trough where cattle were drinking.

The procedure followed for sampling was to rinse a sterilised air-tight container (1L) with trough water and empty the rinse water onto the ground. The container was then immersed in the trough water until completely full. The lid of the container was applied while still immersed to ensure that no air bubbles were present in the sample. The sample was then placed in a fridge at approximately 10^0C until freighted in a foam container with an ice-block to the laboratory for analysis.

All analyses were performed in the Chemistry laboratory, Berrimah Agriculture Research Centre, Berrimah, Northern Territory. Electrical Conductivity (EC) and pH were analysed by respective meters and Total Alkalinity (TA) by an auto-titrator using American Public Health Association (APHA) methods. Nitrate (NO_3^-) was analysed by cadmium reduction with flow injection analysis. All other analytes were measured by ICP spectrometric analysis.

2.9 Rainfall measurements

Rainfall was recorded at three sites within the project area. Two pluviometers (RD-2 tipping bucket rain gauges) (Appendix 9) recorded timing, amount and intensity of rainfall in 1mm increments, 24 hours a day. The pluviometers were located at bore numbers 4 and 3 to provide an indication of differences in rainfall across the project area. Daily rainfall amounts were also recorded by station management at the homestead which is located on the north western corner of the project area.

2.10 Statistical analysis

The data have been analysed in three distinct sections - reproduction (pregnancy rates and duration of anoestrus), calf performance (growth from birth to weaning and weaning weight), and pasture and faecal measurements. All analyses were undertaken using either GenStat version 6.1 (2000), or SAS version 8.02 (2001). Measures of animal performance were analysed for year, herd, age-group (heifers, second-calf heifers and mature cows), breeder body condition score (BCS, using a nine-point scale), breeder weight (adjusted for stage of pregnancy), and sex (of calf, where applicable). Breeder body condition scores and body weights were also analysed for year, age-group, and herd.

The unbalanced nature of the design meant that general or generalized linear models were used. From these models, adjusted means are quoted. These are obtained as the best statistical fit to the data, and rather than being the actual averages from the unbalanced data set, they form the best expectation of the overall means had the data been properly balanced across all modelled factors. Pair-wise testing between means was conducted using least significant difference (LSD) testing.

The design indicates that multi-strata models should be used, as the herd and year factors are applicable at the paddock level, whilst age-group, BCS and weight are all applicable at the individual animal level. However, the lack of paddock replication means that there is no valid estimate of variation at this top level. Hence, the herd and year main effects, as well as their interaction, must be assumed as dominant and important effects, as there is no valid statistical test for these (although an approximate indication can be based on the variance from the lower strata). Given previous studies and the observed patterns in these data, this assumption (of a real herd by year interaction) seems reasonable. Importantly, the two-way and higher-level interactions of herd and year with the other factors (primarily age-group) can validly be tested against the between-animal variation.

As well as being probable predictor variables for reproduction rates, BCS and breeder weight can also be a result of the other factors, such as year and herd. To account for this likely confounding between factors, hierarchical models have been fitted – the ‘definitive’ effects of years, herds and age-groups are estimated from a model containing just these terms (because, for example, it would be meaningless to quote age-group means if these had been adjusted back to a common weight, as age-groups obviously have different ranges of weights). Next, the effects of BSC and breeder weight are estimated by hierarchically adding them (separately) to the base model, so these are effectively fitted ‘within’ the other treatments.

Seasonal conditions were analysed by two methods. Analyses of variance (ANOVA) of monthly pasture and faecal measurements were undertaken by general linear models procedure of SAS (2001). To develop a greater understanding of the relationship between pasture and faecal measurements, a correlation analysis using Pearson’s correlation coefficients method was used.

Where significant associations of benefit in nutritional management were found, the relationships are described (Section 3.3). By use of the regressions, prediction of dependent variables (pasture) from the independent variables (faeces) was undertaken. Confidence intervals (95%) and prediction intervals (95%) were calculated. Both regressions were calculated as they are an interval estimate of average and a single observation respectively. As such, the confidence intervals may have application for further research while the prediction intervals are more applicable for nutritional management.

3.0 Results and Discussion

The data collected and analyses results are presented and discussed in three distinct sections; pregnancy (Section 3.1), calf growth (Section 3.2) and pasture and faecal measurements (Section 3.3). Each section is discussed individually followed by a consolidated discussion of the results in relation to their implications for the north Australian beef industry (Section 4.0).

3.1 Pregnancy

3.1.1 Methodology

A total of 5279 individual animal records were collected from the four herds of composite-bred (6/16 Brahman, 2/16 Africander, 5/16 Shorthorn, 2/16 Charolais, 1/16 Hereford) breeders on Alexandria Station. Animal records were categorised into age-groups according to the number of lifetime pregnancies. Breeders were classified as heifers on their first pregnancy, second-calf heifers on their second pregnancy and mature cows thereafter. Breeders were individually identified and were culled from the herd if they failed to conceive or successfully raise a calf to weaning.

Data collection of pregnancy status, body condition score (BCS) and weight was undertaken annually in August. Herds 1 and 4 were processed from 1996 to 2001 and Herds 2 and 3 from 1997 to 2001. The four herds of cattle were processed consecutively to minimise the effect of time. Processing of all four herds took from 8 to 10 days in total.

BCS was assigned in the manner described in Section 2.4.3 using the nine-point scale (Herd and Sprott 1996) at the time of pregnancy diagnosis. Breeders were also weighed at the time of pregnancy diagnosis, following an over-night fasting period. Animals had *ad libitum* access to water from stock water troughs during the fasting period. Breeder weights were adjusted for stage of pregnancy (O'Rourke *et al.* 1991c).

Duration of anoestrus was estimated by rectal palpation. For each breeder, stage of pregnancy (months) was recorded at the annual August processing. From this figure, the month of conception is calculated. Bulls were joined in the four herds at the end of December each year and therefore the duration of anoestrus after joining can be subsequently estimated.

For the analyses of pregnancy rates, pregnancy diagnoses were converted to binary data, with non-pregnant breeders assigned a value of 0 and pregnant breeders a value of 1. The probability of a breeder being pregnant was modelled using a generalized linear model with a binomial distribution and logit link. For the analyses of duration of anoestrus (or pregnancy month), a normal distribution with the identity link was used. Breeders diagnosed as non-pregnant were removed.

3.1.2 Results

Analysis of pregnancy rate showed year, herd, the interaction of herd and year, breeder BCS and weight to be the significant and dominant effects (Appendix 2). Other screened interactions occasionally proved to be marginally significant, but tended to be far less pronounced. For consistency, they were omitted from all fitted models.

Pregnancy rates and diagnoses for each herd and each year of the study are presented in Appendix 1. The effect of breeder age-group was almost statistically significant, at P=0.068 (Appendix 2). Analysis of pregnancy diagnosis (month) showed all independent variables to be significant (Appendix 3).

The pregnancy rate of heifers (90%) was effectively the same as second-calf heifers (89%). The pregnancy rate of cows (95%) was higher than heifers and second-calf heifers (Table 3.1). Heifers and cows were recorded with the same mean pregnancy diagnosis (6.3 months). Mean pregnancy diagnosis of second-calf heifers was slightly higher than heifers and cows (6.4 months)(Table 3.1). The trend was for high pregnancy rates that increased as breeders got older.

Table 3.1 Adjusted means for pregnancy rate and pregnancy diagnosis (± s.e.) are compared for breeder age-group.

Age-group	**Pregnancy rate (%)***		**Pregnancy diagnosis (month)**	
	n	**mean**	**n**	**mean**
Heifers	2155	90 ± 1^{a}	2144	6.3 ± 0.04^{a}
2nd-calf heifers	1861	89 ± 1^{a}	1627	6.4 ± 0.04^{b}
Cows	2194	95 ± 0.05^{b}	2078	6.3 ± 0.03^{a}

[ab] Numbers in columns with different superscripts are different (P<0.05).

* Pregnancy rate refers to prediction of pregnancy rate from regression model.

There was a trend for pregnancy rate to increase with increasing BCS and corresponding mean breeder weight (Figure 3.1). Breeder BCS ranged from 4 to 9, with most (5509 of 6204) breeder records from 5 to 7. Mean pregnancy rate increased from 79% (BCS = 4) to 93% (BCS = 7, 8&9). The largest changes in pregnancy rate are associated with the lower half of the BCS range, with a 12% (79 to 91%) change in pregnancy rate from BCS 4 to 5 and a 2% (91 to 93%) change from BCS 5 to 9 (Figure 3.1).

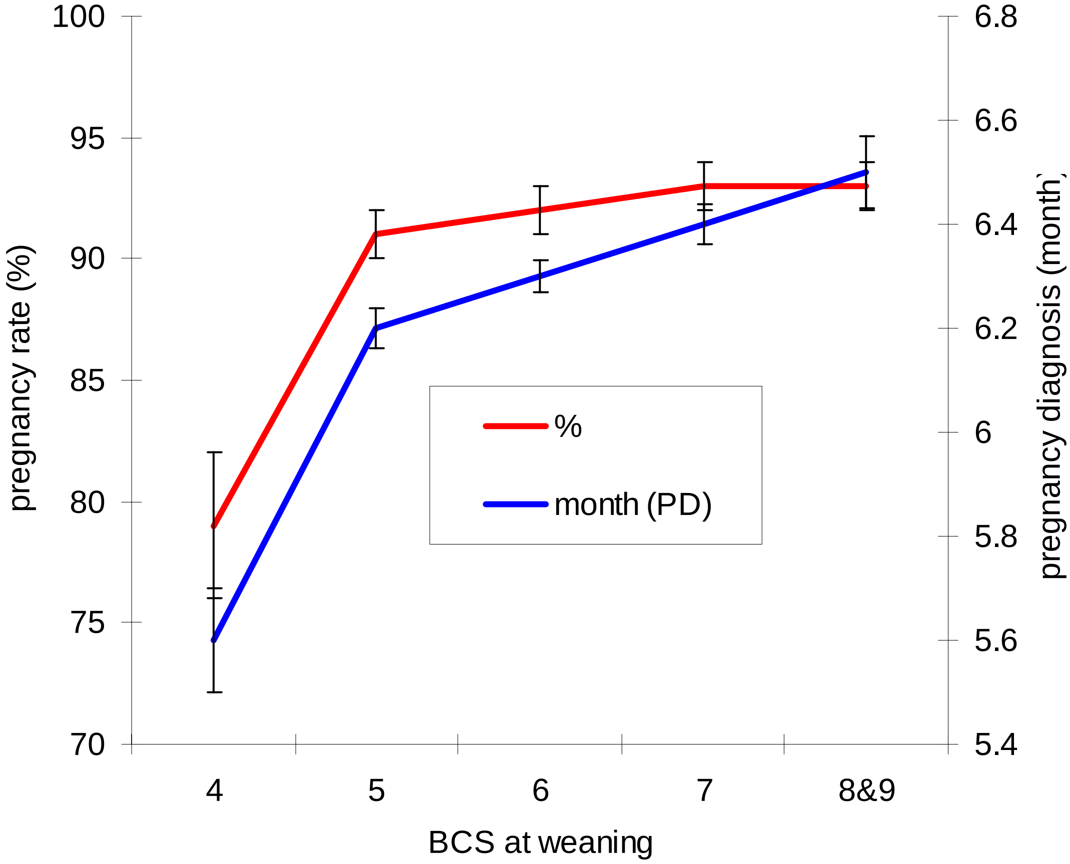

Figure 3.1 Relationship between BCS and pregnancy rate (%) and pregnancy diagnosis (month) by rectal palpation.

In a similar trend to pregnancy rate, pregnancy diagnosis increased with increasing BCS and corresponding mean breeder weight (Figure 3.1). As non-pregnant breeders are removed from the analyses of pregnancy diagnosis, there are fewer observations than for the same analyses with pregnancy rate.

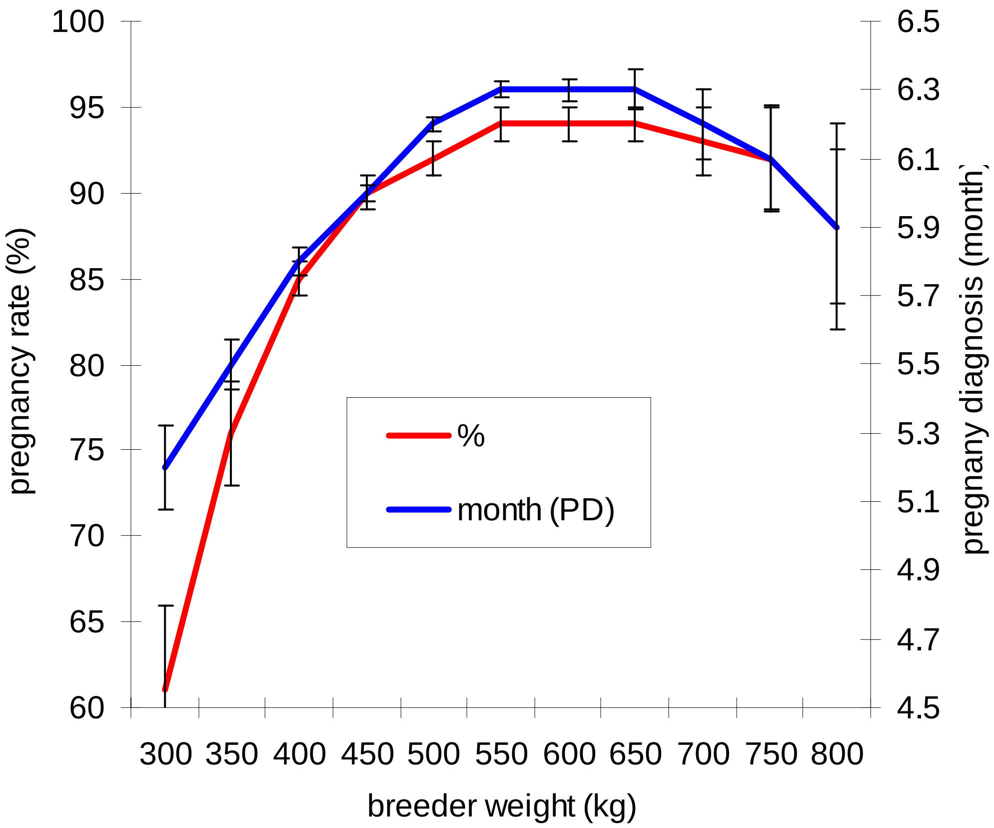

Figure 3.2 Relationship between breeder weight and pregnancy rate (%) and pregnancy diagnosis (month) by rectal palpation.

The relationship between breeder weight and pregnancy rate and pregnancy diagnosis is very similar as that for breeder BCS. A sharp increase in pregnancy rate (61 to 90%) and pregnancy diagnosis (5.2 to 6.0) was observed as breeder weight increased from 300 to 450kg. As weights increased beyond 450kg, slight improvements in pregnancy were observed, however the level of increase is reduced (Figure 3.2).

3.1.3 Discussion

The influence of nutrition on fertility has been associated with improvements in breeder weight and body condition (Bolanos *et al.* 1996; Herd and Sprott 1996) resulting in increased ovarian activity (Lalman *et al.* 1997; Bolanos *et al.* 1996), conception (Rae *et al.* 1993) and pregnancy (Derouen *et al.* 1994; Fordyce and Entwistle 1992; Laflamme and Connor 1992) The results reported by Herd and Sprott (1996) stating that cows in condition score 5 (using a nine-point scale) and above achieve optimal fertility are supported by the findings of this study. Cows below condition score 5 achieved a lower pregnancy rate and experienced extended periods of post-partum anoestrus.

The current study has modelled the relationship between breeder weight and BCS for three age-groups of composite-bred cattle. The analyses demonstrate that of pregnancy rate and pregnancy diagnosis are influenced by breeder weight and BCS.

Figures 3.1 and 3.2 illustrate that there is a distinct trend for pregnancy to increase as BCS and weight increase however the benefit beyond BCS of 5 or approximately 450 kg liveweight are minimal. This trend is of relevance for nutritional management and follows the relationship reported by others (Spitzer *et al.* 1995).

Breeder age-group has been found to influence reproductive performance in previous studies (Osoro and Wright 1992; Doogan *et al.* 1991). The reproductive performance of the three age-groups of breeders in the current study (Table 3.1) exceeds industry benchmarks for bovine reproductive performance in northern Australia (Hasker 2001). While high levels of pregnancy are achieved, differences between age-groups were measured. However, in contrast to previous research, second-calf heifer pregnancy rate (89%) is the same as heifer pregnancy rate (90%).

Research in northern Australia has reported the fertility of second-calf heifers to be the lowest of all age-groups (Holroyd *et al.* 1979a). It is considered that susceptibility of second-calf heifers to extended periods of post-partum anoestrus is the cause of the reduced fertility (Jolly *et al.* 1996; McSweeney *et al.* 1993a) and nutrition is the key to managing this sensitivity (McSweeney *et al.* 1993b; O'Rourke *et al.* 1991a). The mean weight and BCS of breeders in the current study are higher than is reported for most work in northern Australia (Hasker 2000). As the results in this report indicate, improvement in breeder weight and BCS result in higher pregnancy rates. The improvements in weight and BCS are most likely achieved through higher nutrient intakes as a consequence of season (quality and quantity of available pasture) and nutrient supplementation.

Pregnancy diagnosis (month) provides a measure of the duration of anoestrus. The similarity in the mean pregnancy diagnosis for the three age-groups of breeders indicates that performance was being driven by breeder weight and BCS.

The outcomes of the analyses for this objective of the project can be summarised with two broad statements relating breeder weight, condition and age to pregnancy. As breeder weight and BCS increase, the probability of pregnancy increases, however the benefit increases in weight and BCS reduce for weights greater than 450kg and BCS 5. As breeders proceed through the first three or four years of reproductive activity, they are more likely to be pregnant.

The caveats for these models warrant description. These models are applicable to the composite-bred (Section 2.2) cattle grazing in the Barkly Tableland region. Validation on different breeds in other regions, and therefore nutritional and environmental conditions, would be required before wider application of the models could be recommended.

3.2 Calf growth

3.2.1 Methodology

One thousand nine hundred and fifty eight composite-bred (6/16 Brahman, 2/16 Africander, 5/16 Shorthorn, 2/16 Charolais, 1/16 Hereford) calves, individually identified at birth and cross-referenced to their corresponding dam were used in the study. The process of 'mothering-up' is described in Section 2.4.5 and was only performed on Herds 1, 2 and 3. Calving occurred annually from September to December and weaning was undertaken the following May. All three herds were weaned at the same time and the process took 2 to 3 days. Dams were classified by age-group in the same manner as described in Section 3.1.

Breeder body condition was assigned in the manner described in Section 2.4.3 using the nine-point scale (Herd and Sprott 1996) at the time of weaning. Breeders were also weighed at the time of weaning, following an over-night fasting period. Animals had *ad libitum* access to water from stock water troughs during the fasting period. Breeder weights were adjusted for stage of pregnancy determined at the August processing (O'Rourke *et al.* 1991c).

3.2.2 Results

Analysis of calf growth and weaning weight proved all independent variables to be significant (Appendices 4 and 5). The overall calf growth rates and weaning weights for each herd for each year of the study are presented in Appendix 1. Male calves experienced higher growth from birth to weaning (925 g/d) than female calves (861 g/d). Similarly, male calves were heavier at weaning (207 kg) than female calves (195 kg). Calf growth and weaning weight models are presented in Appendices 4 and 5 respectively.

Table 3.2 Adjusted means for calf growth and weaning weight (± s.e.) are compared for breeder age-group.

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Age-group	n	Calf growth (g/d)	Weaning weight (kg)
Heifers	1066	889 ± 6[a]	202 ± 1.1[a]
2nd-calf heifers	567	881 ± 7[a]	198 ± 1.2[b]
Cows	373	928 ± 8[b]	203 ± 1.4[a]

[ab] Numbers in columns with different superscripts are different ($P < 0.05$).

The growth of calves from birth to weaning of heifers and second-calf heifers was the same (889 and 881 g/d respectively). The calves of cows experienced the highest growth rate from birth to weaning (928 g/d)(Table 3.2). Weaning weight of calves from heifers (202 kg) was the same as cows (203 kg). The weaning weight of calves from second-calf heifers (198 kg) was lower than that of heifers or cows (Table 3.2).

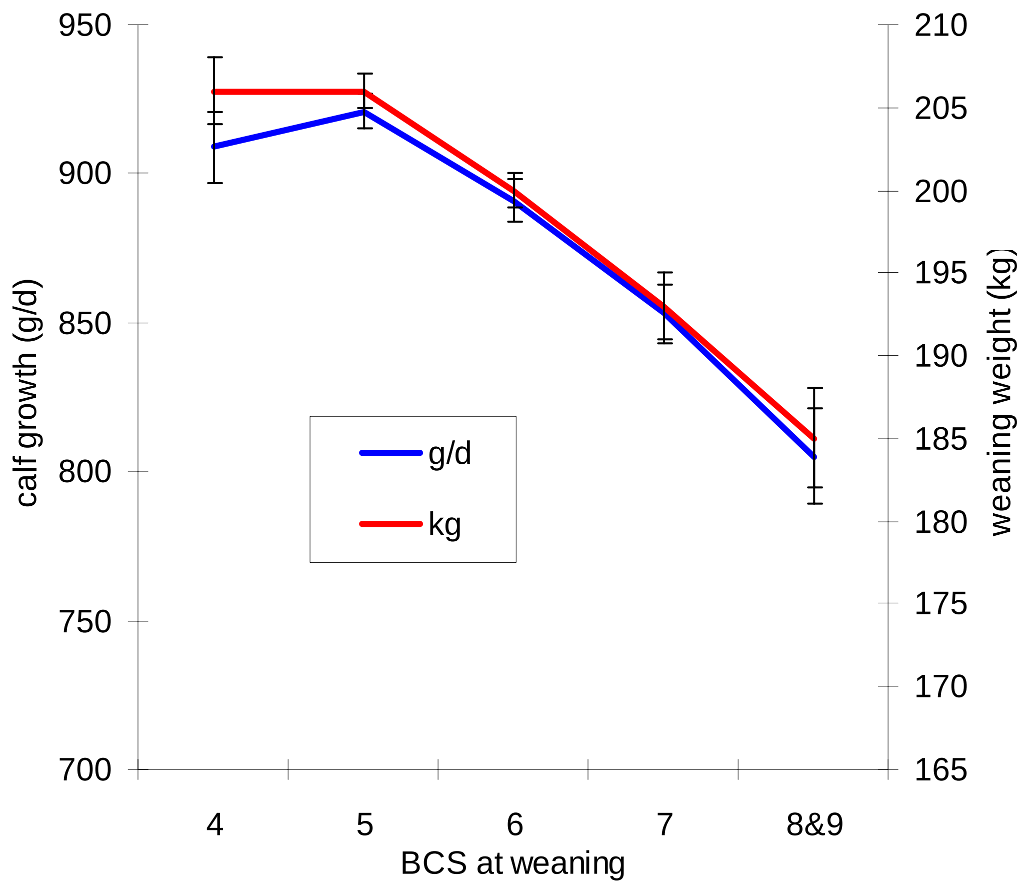


Figure 3.3 The relationship between calf performance (growth and weaning weight) and breeder BCS at weaning.

There is a trend for calf growth and weaning weight to decrease with increasing breeder BCS (Figure 3.3). Breeders that raised calves to weaning, ranged in BCS from 4 to 9, with most (1651 of 1962) breeder records from 5 to 7. Mean calf growth ranged from 909 g/d (BCS = 4) to 805 g/d (BCS = 9). Mean weaning weight ranged from 206 kg (BCS = 4) to 185 kg (BCS = 9). There is a trend for calf growth and weaning weight to decrease more rapidly as breeder BCS approaches 9, with BCS of 5 appearing to be the optimum breeder condition for calf growth and weaning weight (Figure 3.3).

3.2.3 Discussion

Nutrient intake determines breeder BCS and weight and affects calf growth through the influence of nutrition on dam milk production (Hennessy *et al.* 2001a; Arthur *et al.* 1997; Topps 1977). Improvements in breeder BCS have been associated with decreases in calf growth from birth to weaning (Paputungan and Makarechian 2000). Calf growth has been found to improve as breeder age increases (Fordyce *et al.* 1993; Entwistle 1984). The results of the current study indicate that calf growth and weaning weight reduces as breeder BCS and corresponding weight approaches BCS of 9. An important caveat to this conclusion is that the relationship only applies for breeders at BCS 4 or above.

The BCS and weight of breeders in the current study are higher and heavier than reported in most investigations of north Australian beef production (Hasker 2000). While calf growth is inversely related to breeder BCS (when BCS is above 5) in the current study (Figure 3.3), it is higher than typically recorded for northern Australia (Hasker 2001). Another factor contributing to the difference between the current study and previous research is breed differences. The current study used cattle of a new breed combination consisting of 50% *Bos taurus* and 50% *Bos indicus*/Sanga, as opposed to the more common breeding for northern Australia with a high (>70%) *Bos indicus* content. *Bos indicus* breeders (typical of previous research in northern Australia) express lower milk production than the *Bos taurus* breeds present within the breed composition of the current study.

An interpretation of the relationship between calf performance and breeder BCS is that cow milk production is driving the relationship. In particular, the higher milk producing cows are providing more nutrition to their calves, by partitioning nutrients to milk production in preference to growth and therefore show lower BCS. The cows in better BCS are expressing preferential partitioning of nutrients to growth rather than milk production. The impact of lower milk production is expressed in lower calf growth. For cows on a minimal protein diet, milk production takes priority with a compensating reduction in the synthesis of body protein (Bolanos *et al.* 1996). Further contributing to the trends observed in this study between calf growth and breeder BCS is the effect of BCS on energy requirements. The net energy requirement changes as the condition score changes with NRC (1996) calculating the change as 5% per condition score (using the nine point scale as described by Herd and Sprott (1996)). Thus breeders in higher BCS had higher energy requirements and therefore less nutrients available for milk production. In the current study, increases in calf growth are associated with increasing breeder age, presumably due to increased milk production. .

The outcomes of the analyses of this chapter can be summarised with two broad statements relating to breeder condition and weight and calf performance. As breeder weight and BCS increase (for breeders with BCS 4 to 9), calf growth and weaning weight decrease, with BCS of 5 an optimum for calf growth. Calf growth from birth to weaning is highest for the progeny of cows, which is likely to be a consequence of increased udder development and associated milk production.

3.3 Pasture and faecal measurements

3.3.1 Methodology

Samples of faeces and native pasture were collected monthly using the methodology described in Sections 2.5 and 2.6. Faecal and pasture samples were analysed for nitrogen (N) and phosphorus (P) concentration. Pasture samples were also analysed for dry matter digestibility and faecal samples for dry matter content. Dry matter content of faecal samples provides an indication of sampling quality (Wilson, D. 2001, *pers. comm*.).

Analysis of monthly pasture and faecal measurements was undertaken by general linear models procedure using of SAS (2001). Correlation analyses using Pearson's correlation coefficients method were used to establish the associations between pasture and faecal measurements. A regression analysis of Mitchell grass N concentration and faecal N concentration was performed and confidence intervals and prediction intervals calculated.

Analyses of mean values for paddocks correspond to herds. For example, Herd 1 grazed in Paddock 1, Herd 2 grazed in Paddock 2 and so forth.

3.3.2 Results

Analyses of faecal concentrations (N and P) found differences between years and season whilst all paddocks were the same. Analysis of pasture N and P concentrations found differences between years and season. Pasture dry matter digestibility (DMD) measurements found no differences between years or paddocks. All mean pasture N concentrations were the same across all paddocks and mean P concentrations were the same for all paddocks except Paddock 3, which measured higher Mitchell grass P concentrations than all other paddocks.

<u>Comparison of mean values</u>

No differences were found between paddocks for monthly samples of faecal N and P (Table 3.3). Wet season faecal samples showed higher concentrations of N and P than samples collected during the dry season months. Mean faecal N concentrations for 1999 (1.3%) were lower than all other years (Table 3.3). Mean faecal N concentrations in 1998 (1.5%) were higher than in 1999, but lower than 2000 (1.7%). Mean faecal N concentration in 2001 (1.6%) was not different from 1998 or 2000 (Table 3.3).

Mean faecal P concentration followed the same pattern as faecal N, with no differences between paddocks and wet season concentrations higher than the dry season concentrations. Faecal P concentrations were higher in 2000 (0.28) than 1998 and 2001. In contrast to faecal N measures, mean faecal P concentrations for 1999 were not different to any other year (Table 3.3).

Table 3.3 Relationship between adjusted means (± s.e.) for monthly samples of faecal nitrogen (Faecal N) and faecal phosphorus (Faecal P) concentration (%) with paddock, season and year effects.

	Faecal N	**Faecal P**
Paddock 1	1.5 ± 0.07[a]	0.23 ± 0.02[a]
Paddock 2	1.5 ± 0.07[a]	0.23 ± 0.01[a]
Paddock 3	1.4 ± 0.07[a]	0.26 ± 0.02[a]
Paddock 4	1.5 ± 0.07[a]	0.23 ± 0.01[a]
WET SEASON	1.7 ± 0.05[a]	0.27 ± 0.01[a]
DRY SEASON	1.3 ± 0.05[b]	0.21 ± 0.01[b]
1998	1.5 ± 0.06[b]	0.21 ± 0.01[a]
1999	1.3 ± 0.05[a]	0.24 ± 0.01[ab]
2000	1.7 ± 0.06[c]	0.28 ± 0.01[b]
2001	1.6 ± 0.11[bc]	0.22 ± 0.02[a]

[abc] Means within column sections are different ($P<0.05$).

Monthly Mitchell grass (*Astrebla pectinata*) N concentrations and DMD did not differ between years (Table 3.4). Monthly Mitchell grass P concentration was higher in Paddock 3 than all other paddocks. All other paddocks measured the same monthly P concentration for Mitchell grass. Paddock 3 measured the highest mean concentrations of Mitchell grass N (0.97%) and P (0.11%) (Table 3.4).

Table 3.4 Relationship between adjusted means (± s.e.) of monthly samples for Mitchell grass (*Astrebla pectinata*) nitrogen (N), phosphorus (P) and dry matter digestibility (DMD) concentrations (%) with paddock, season and year effects.

	N	P	DMD
Paddock 1	0.90 ± 0.04[a]	0.09 ± 0.01[a]	44.3 ± 1.1[a]
Paddock 2	0.93 ± 0.05[a]	0.08 ± 0.01[a]	44.5 ± 1.1[a]
Paddock 3	0.97 ± 0.05[a]	0.11 ± 0.01[b]	44.0 ± 1.1[a]
Paddock 4	0.83 ± 0.05[a]	0.09 ± 0.01[a]	44.4 ± 1.1[a]
WET SEASON	1.05 ± 0.04[a]	0.10 ± 0.01[a]	46.9 ± 0.8[a]
DRY SEASON	0.76 ± 0.03[b]	0.08 ± 0.01[b]	41.7 ± 0.7[b]
1998	0.81 ± 0.04[a]	0.08 ± 0.01[a]	44.7 ± 1.0[a]
1999	0.87 ± 0.04[a]	0.09 ± 0.01[a]	43.5 ± 0.9[a]
2000	1.00 ± 0.04[b]	0.11 ± 0.01[b]	44.7 ± 1.0[a]
2001	0.94 ± 0.06[ab]	0.09 ± 0.01[ab]	

[ab] Means within column sections are different ($P < 0.05$).

Monthly Flinders grass (*Iseilema vaginiflorum*) N, P and DMD did not differ between years (Table 3.5). In the same pattern as faecal and Mitchell grass analyses, wet season mean N and P concentrations and DMD for Flinders grass were higher than the dry season samples (Table 3.5). Monthly samples of Flinders grass found the same pattern of N and P concentrations between years. Mean Flinders grass N and P was higher in 2000 (0.83% and 0.13% respectively) than all other years. There were no differences in Flinders grass N and P concentrations for all other years (Table 3.5).

Table 3.5 Relationship between adjusted means (± s.e.) of monthly samples for Flinders grass (*Iseilema vaginiflorum*) nitrogen (N), phosphorus (P) and dry matter digestibility (DMD) concentrations (%) with paddock, season and year effects.

	N	P	DMD
Paddock 1	0.65 ± 0.04[a]	0.10 ± 0.01[a]	45.8 ± 1.4[a]
Paddock 2	0.70 ± 0.04[a]	0.10 ± 0.01[a]	48.7 ± 1.4[a]
Paddock 3	0.69 ± 0.05[a]	0.11 ± 0.01[a]	47.7 ± 1.4[a]
Paddock 4	0.63 ± 0.04[a]	0.10 ± 0.01[a]	48.7 ± 1.4[a]
WET SEASON	0.77 ± 0.03[a]	0.12 ± 0.01[a]	51.3 ± 1.1[a]
DRY SEASON	0.57 ± 0.03[b]	0.08 ± 0.01[b]	44.1 ± 0.9[b]
1998	0.63 ± 0.04[a]	0.09 ± 0.01[a]	48.4 ± 1.2[a]
1999	0.61 ± 0.04[a]	0.09 ± 0.01[a]	47.6 ± 1.2[a]
2000	0.83 ± 0.04[b]	0.13 ± 0.01[b]	47.1 ± 1.2[a]
2001	0.62 ± 0.05[a]	0.10 ± 0.01[a]	

[ab] Means within column sections are different ($p < 0.05$).

Associations between mean values

An association between faecal N and pasture (Mitchell grass and Flinders grass) N was found, when correlated for all paddocks, the effect of supplement and the effect of season (Table 3.6). Mitchell grass N concentrations are higher than Flinders grass N concentrations for many of the measurements (Figure 3.4). More commonly, the Mitchell grass N concentrations were higher than Flinders grass in the latter part of the dry season. The association between faecal N and pasture N concentrations remain for both the dry season and wet season measurements when correlated separately (Table 3.6).

Table 3.6 Number of observations (n), mean nutrient concentration (%) and Pearson's correlation coefficients for monthly samples of faecal nitrogen (Faecal N) and faecal phosphorus (Faecal P).

	Faecal N	**Faecal P**
n	136	136
Mean (%)	1.45	0.23
Correlation coefficient		
Mitchell grass N	0.69	0.34
Mitchell grass P	0.47	0.35
Mitchell grass DMD	0.26	0.15
Flinders grass N	0.69	0.62
Flinders grass P	0.60	0.54
Flinders grass DMD	0.50	0.35

There is an association between faecal P and pasture (Mitchell grass and Flinders grass) P when correlated for all paddocks, the effect of supplement and the effect of season (Figure 3.5). The associations are weaker than for N (Figure 3.4). As can be seen by examining the correlation coefficients (R), N values (0.694 and 0.692 for Mitchell grass and Flinders grass respectively) are higher than the values for P (0.350 and 0.543). The association between faecal P and Flinders grass P is stronger than for Mitchell grass and there is less variation from the linear relationship with Flinders grass (R^2 = 0.2951) than Mitchell grass (R^2 = 0.1229) (Figure 3.5). Flinders grass P reaches higher concentrations during the wet season than Mitchell grass (Figure 3.5). As such, when pasture P levels are correlated for the wet season and dry season separately, the association between Mitchell and Flinders grass is stronger for the dry season (R = 0.445) than the wet season (R = 0.341).

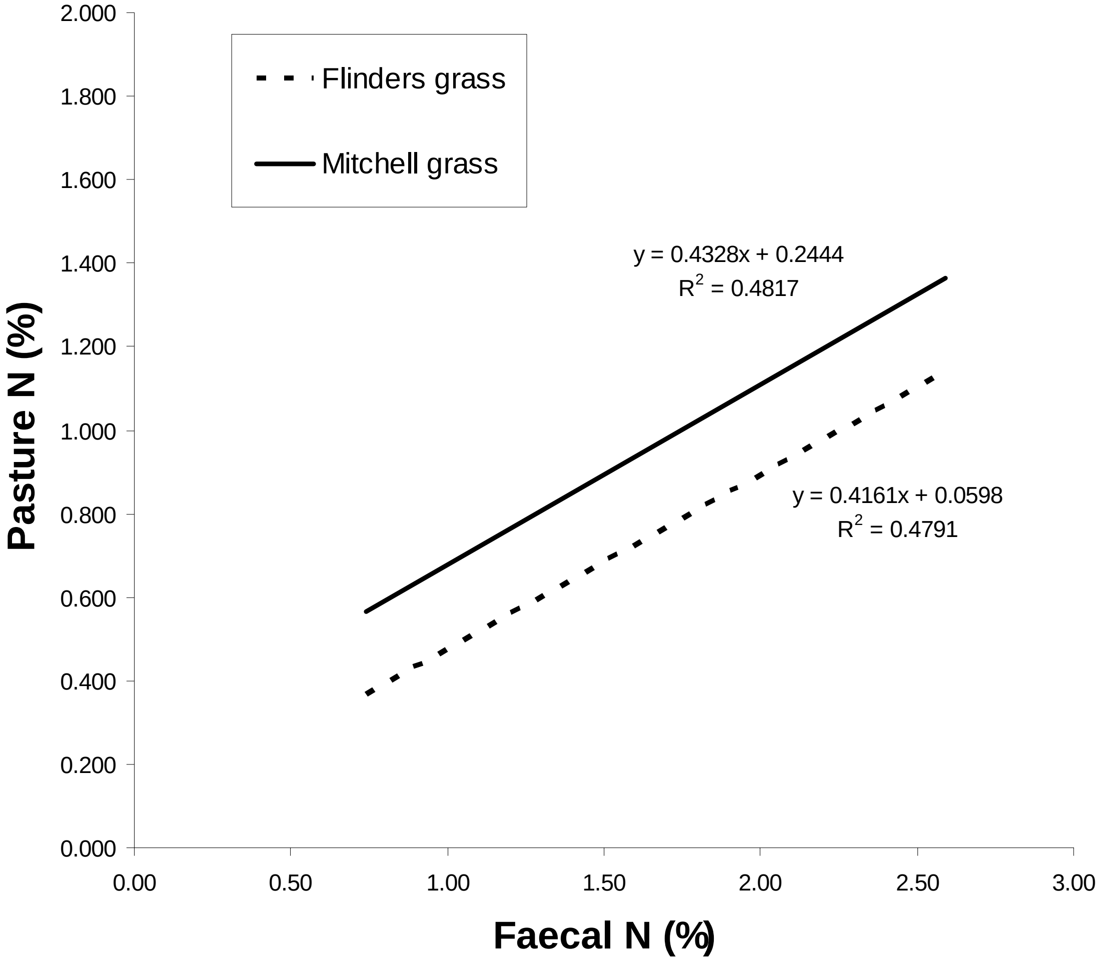


Figure 3.4 Relationship between faecal and pasture nitrogen (%) for both Mitchell grass (*Astrebla pectinata*) and Flinders grass (*Iseilema vaginiflorum*).

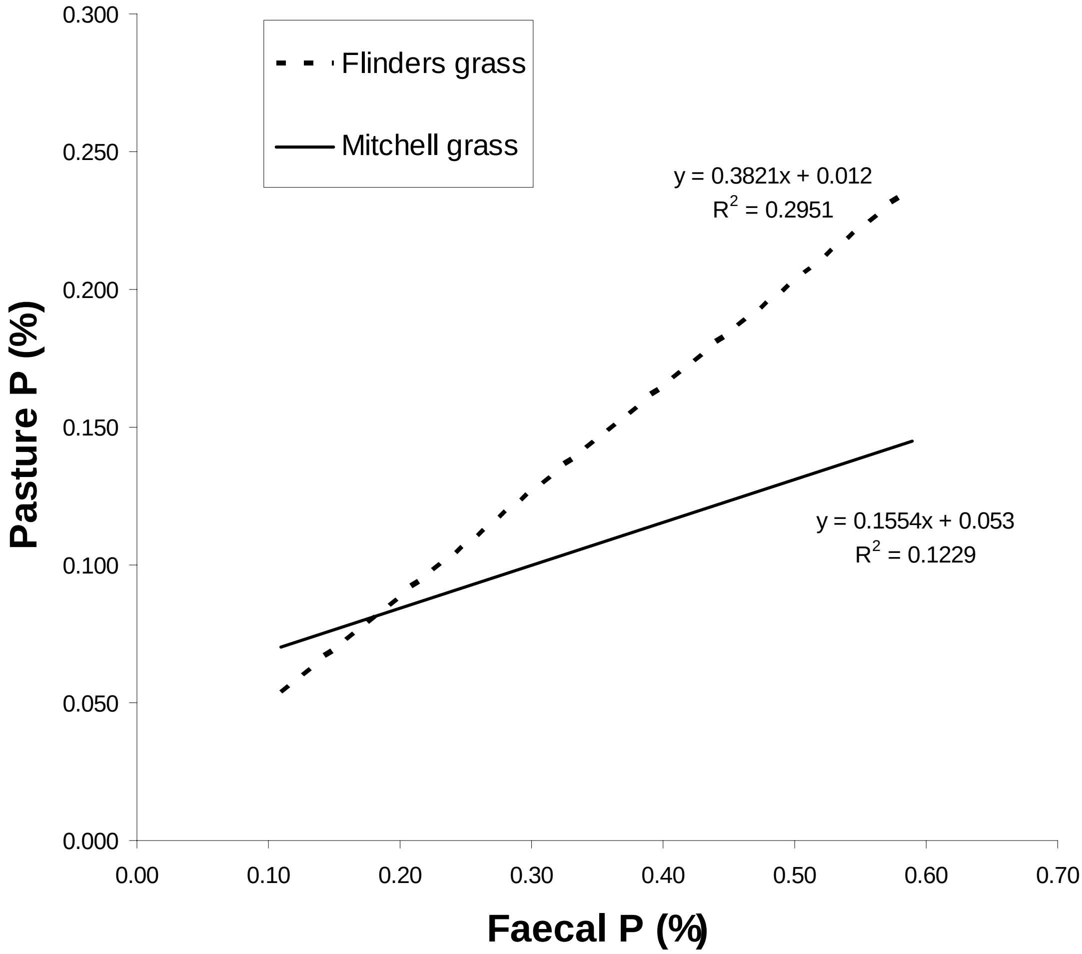


Figure 3.5 Relationship between faecal and pasture phosphorus (%) for both Mitchell grass (*Astrebla pectinata)* and Flinders grass (*Iseilema vaginiflorum)*.

There was no association found between Mitchell grass DMD and faecal measurements for both N and P. An association was found for the relationship between Flinders grass DMD and faecal measurements for N (R = 0.464) and P (R = 0.453) during the wet season. This association weakened during the dry season.

The associations between pasture and faecal N are stronger than associations for P when correlated for wet season and dry season measurements separately. The strongest correlation is found between faecal N and Flinders grass N during the wet season (R = 0.71). The weakest association is found between faecal P and Mitchell grass P during the wet season (R = 0.11). An anomaly with pasture P measurements is found in the wet season correlations, where pasture P is more strongly correlated to faecal N than to faecal P (R = 0.345 and 0.521 respectively).

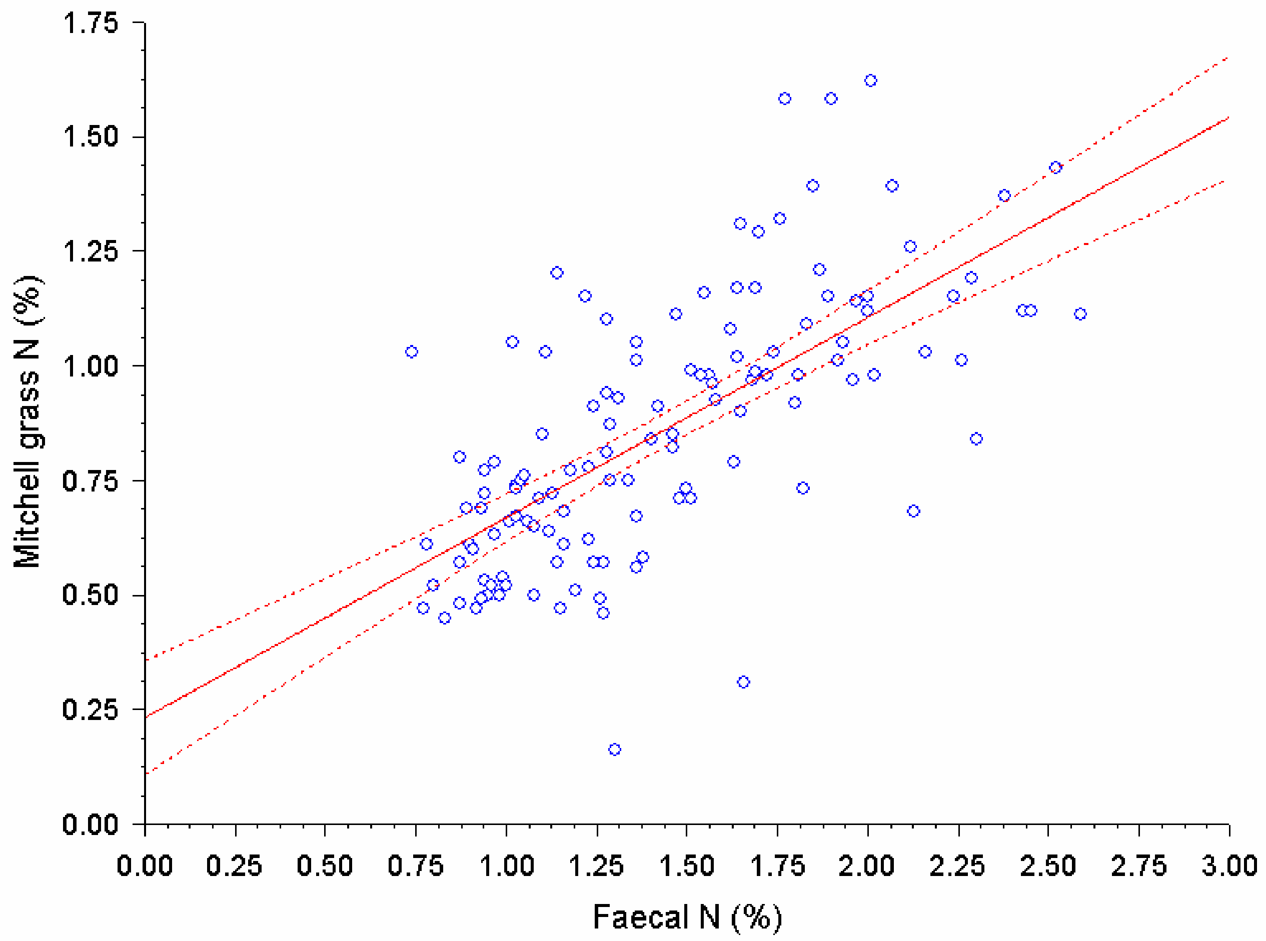


Figure 3.6 95% confidence interval (dotted red) and regression plot for Mitchell grass and Faecal N.

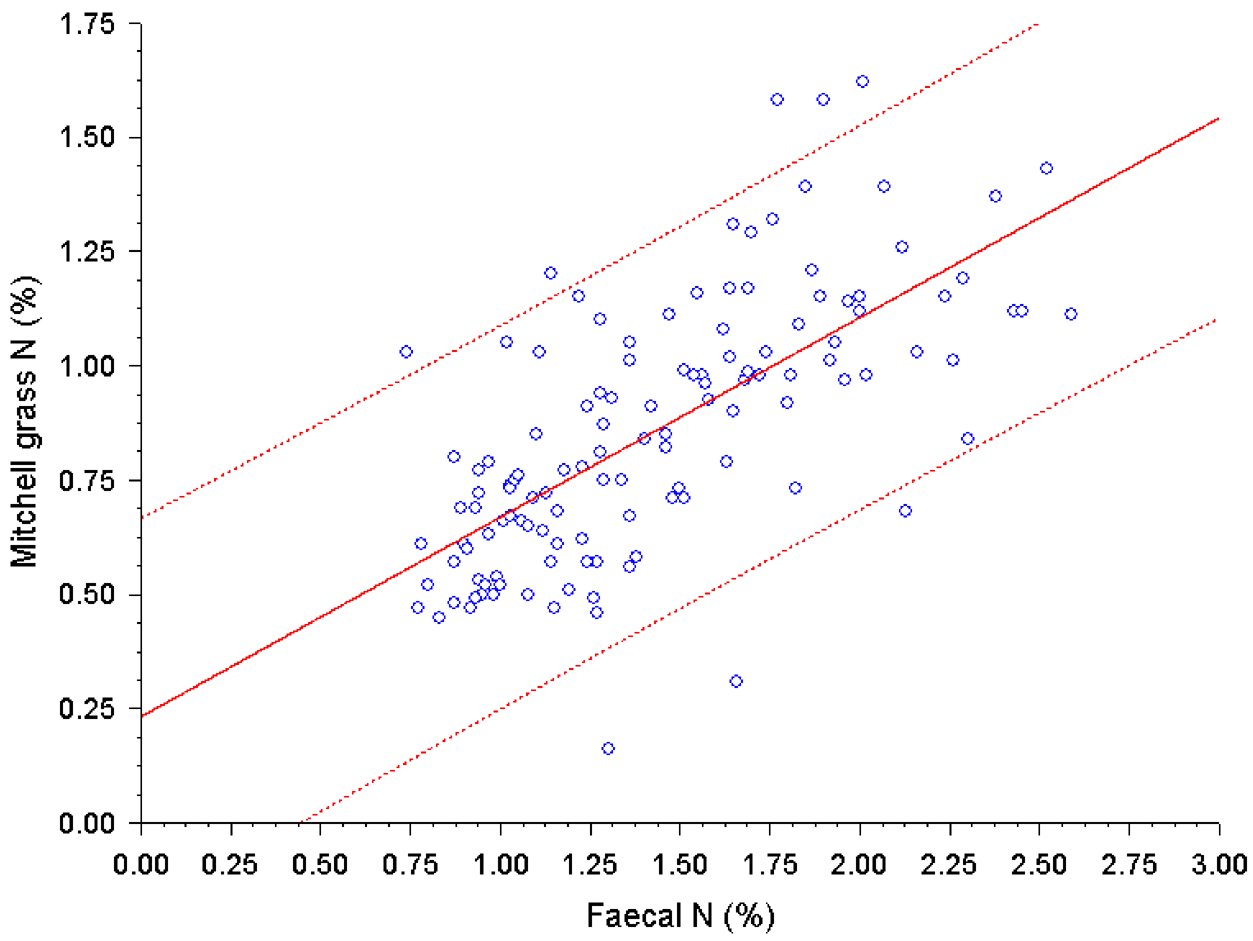


Figure 3.7 95% prediction interval (95%)(dotted red) and regression plot for Mitchell grass and Faecal N.

The regression analysis of Mitchell grass N versus faecal N concentration was performed and the regression equation (Equation 3.1) is:

MN = 0.244 + 0.433*(FN) ……………………….. **Equation 3.1**

Where MN = Mitchell grass N concentration (%) and

FN = Flinders grass N concentration (%)

Prediction intervals (95%) and confidence intervals (95%) for the regression plot are presented in Figures 3.5 and 3.6 respectively. Predicted Mitchell grass N concentrations for a faecal N concentration of 1.4% are 0.45 to 1.25% (prediction interval) and 0.81 to 0.88% (confidence interval).

3.3.3 Discussion

Monthly measurements of faecal phosphorus and nitrogen revealed some interesting differences between the two analyses. It is important to remember that the monthly analyses were performed on the same sample and therefore no differences in quality of sample between the two analyses are possible. As reported by previous research, faecal sampling of phosphorus is often an insensitive measure of dietary intake (Coates *et al.* 1996; Bortolussi 1994) and is even less reliable during periods of supplementation (Coates and Ternouth 1992a). Faecal nitrogen has provided a more reliable indication of dietary intake (Winks *et al.* 1979) and the results of this study support those previous findings.

Differences in nitrogen concentrations were measured between years by analysis of faecal nitrogen, Mitchell grass nitrogen and phosphorus and Flinders grass nitrogen and phosphorus, however faecal phosphorus measured no differences between years of the study. This is a reasonable indication that faecal phosphorus was not detecting changes in diet quality between years as differences were found by the other measurements. Further contributing to the questionable reliability of faecal phosphorus are the standard error values. The standard errors for faecal measurements are much higher than for faecal nitrogen measurements, indicating wider variation in the sample results. Due to this variation in sampling results, a significant difference in faecal phosphorus concentrations between seasons was not found.

Monthly pasture measurements of nitrogen and phosphorus followed similar patterns to monthly faecal measurements. As such, pasture measurements indicated no differences in feed quality between paddocks, in the same way as faecal measurements. Pasture nitrogen and phosphorus levels appear to provide reasonable indications of changes in Barkly Tableland feed quality however, measurements of pasture dry matter digestibility detected no such differences. Differences in pasture dry matter digestibility were not measurable, however it is clear from evidence of pasture nitrogen, pasture phosphorus and faecal nitrogen that differences in feed quality between years did exist.

Reliability and consistency of sampling quality is a strength of pasture measurements. The standard errors (Tables 3.4 and 3.5) are low and consistent for both Mitchell grass and Flinders grass samples. In general, standard error’s for Flinders grass phosphorus measurements were the highest of the pasture quality measurements. The sampling quality of pastures appears reasonably consistent between Mitchell grass and Flinders grass. However, there was considerable greater effort required for Flinders grass sampling, particularly toward the latter part of the dry season as frequency of Flinders grass plants declined sharply.

Several significant associations between pasture and faecal measurements were found. The most important of these in terms of implications for nutrition management is the association between faecal nitrogen and Mitchell grass nitrogen (Figure 3.4). By substituting the value of 1.3 for faecal nitrogen (Winks *et al.* 1979), into the equation describing this relationship;

$$\text{Mitchell grass nitrogen} = 0.2444 + 0.4328\ (\mathbf{1.3})$$

the value for Mitchell grass nitrogen of 0.8% is obtained. Therefore, the findings of this study indicate that when mean Mitchell grass (*Astrebla pectinata*) protein concentration is 5% (0.8% nitrogen x 6.25), faecal nitrogen will measure 1.3% and therefore, based on findings by Winks *et al*. (1979), a response to supplementation can be expected.

Significant associations between faecal nitrogen and flinders grass nitrogen also exist and the association during the wet season is the strongest association measured. Wet season indications of animal nutrient status have little application for extensive nutritional management as animal nutrient requirements are normally satisfied by native pastures at this time of year (Foran and Bastin 1984).

The associations between faecal and pasture measurements are consistently stronger for nitrogen than phosphorus. While the associations between faecal phosphorus and pasture phosphorus are significant, they do not represent reliable indications of animal nutrient status. Due to the proven unreliability of faecal phosphorus as a measure of animal phosphorus status, the association with pasture measurements has no practical application (Miller *et al.* 1997).

4.0 Implications

This study has established new benchmarks for breeding performance of north Australian extensive beef production enterprises, developed models suitable for objective nutrient supplementation management decision support and provided an improved understanding of how aspects of breeding performance respond to nutritional manipulations. This has been achieved by a detail of herd recording, not previously undertaken in the Barkly Tableland region.

Breeder pregnancy rates (Table 3.1) and calf growth rates (Table 3.2) recorded in this study exceed the levels previously measured for extensive beef production in northern Australia (Hasker 2001). Perhaps the most notable benchmark established under such management conditions is the pregnancy rate achieved by second-calf heifers (Table 3.1). This class of breeder is the lowest performing in north Australian beef herds, with pregnancy rates lower than 30% reported (Hasker 2001). The levels of herd performance achieved in this were with cattle of only 50% *Bos indicus* content in a tick-free region of northern Australia.

Breeder BCS is widely used by beef producers as a guide for nutritional management decisions (Herd and Sprott 1996; McCosker and Winks 1994). While research has shown that BCS is an insensitive measure of animal nutrient status (Bortolussi 1994), BCS strongly influences breeding performance (Bolanos *et al.* 1996; Herd and Sprott 1996; Jolly *et al.* 1996; Derouen *et al.* 1994). Although most breeders maintained ‘good’ BCS (score 5 and above) throughout the study, distinct trends in the relationship between BCS and pregnancy and BCS and calf growth were found (Figure 4.1). These trends indicate that approximately score five (BCS = 5) represents optimal breeding condition, a finding supported by other work (Herd and Sprott 1996; Rae *et al.* 1993; Osoro and Wright 1992; Richards *et al.* 1986; Lamond 1970). Breeders below score five measured lower pregnancy rates and took longer to conceive, however breeders above condition score five produced slower growing calves, assumed to be a result of partitioning of nutrients to growth in preference to lactation.

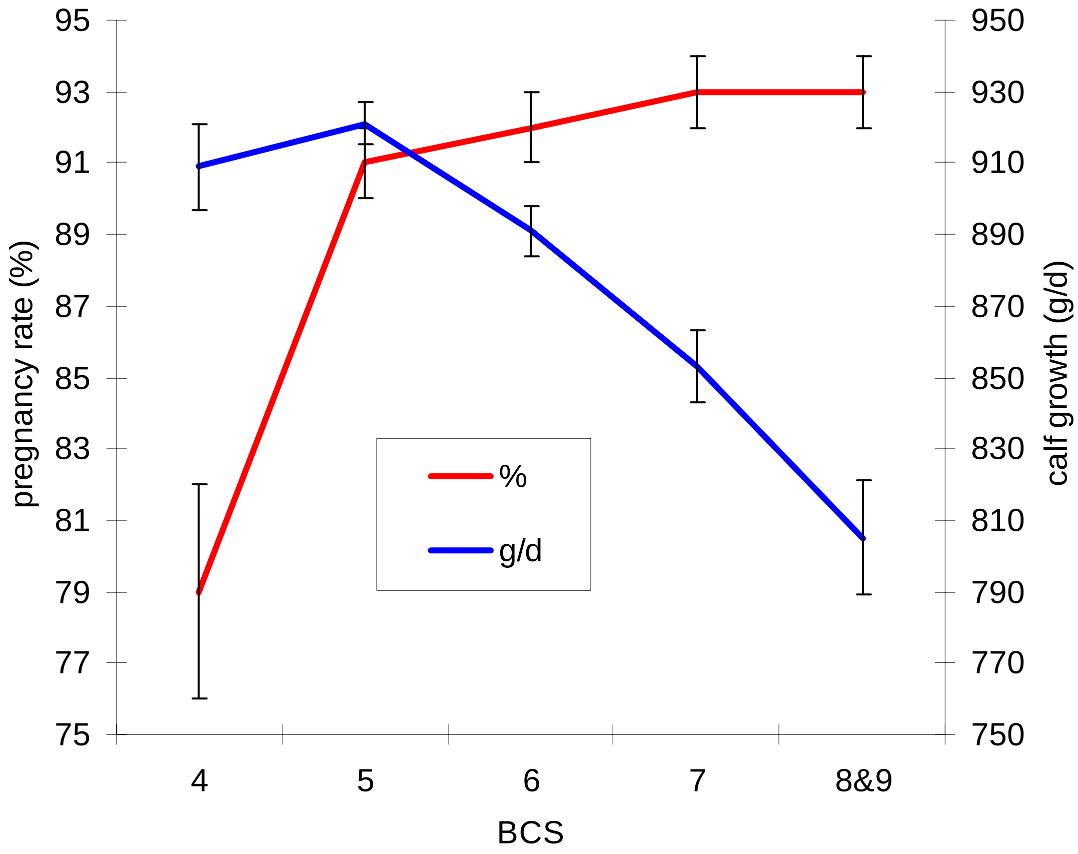


Figure 4.1 Relationship between breeder body condition (BCS) and pregnancy rate and breeder body condition and calf growth.

While annual rainfall is a commonly used benchmarking figure, it has little relevance (Entwistle 1983) in regions such as the Barkly Tableland. The

limited relevance of annual rainfall measurements is due to two factors:

a) The rainfall period is primarily from December to March and therefore rainfall incidence as it influences pasture growth is spread across two calendar years.
b) The timing of rainfall is often more critical than the amount of rainfall.

For these reasons, the importance of a dynamic measurement of diet quality and/or nutrient status of the grazing animal is essential for informed decisions regarding the optimal time to start supplementation. The figure of 1.3% (Winks *et al.* 1979) faecal nitrogen has been adopted by industry as the best guide available. As was seen in this study, the time of year at which this measurement was reached varied from May to August, even with a run of 'favourable' seasons. Due to the complexities associated with faecal sampling, storage and transportation of faecal samples, a more simple alternative is sought.

Pasture sampling, storage and transportation requirements are relatively simple. Ash and McIvor (1995) developed the principle of 'indicator species' when evaluating the effect of herbage quality on nutritional uptake, using plucked pasture samples. Ash and McIvor (1995) determined that changes in the nutritive value of 'indicator species' may reflect changes in the diet quality of the animal as the season progresses.

This study has adopted the 'indicator species' concept to evaluate the associations between faecal and pasture nitrogen levels and determine if an 'indicator species' of plucked pasture samples could be equally as useful a 'management tool' as faecal nitrogen sampling.

To measure associations, the two dominant pasture species typical of the Barkly Tableland region (Mitchell grass – *Astrebla pectinata* and Flinders grass – *Iseilema vaginiflorum*) were chosen as the 'indicator species' for investigation. Both plant species were found to have a significant association with monthly samples of faecal nitrogen. Of the two plant species, Mitchell grass is considered the better 'indicator species' for three reasons:

1. From observations made during the study, samples of Mitchell grass can be collected year-round, while samples of Flinders grass can be difficult to find in the latter part of the dry season.
2. Mitchell grass is typically more prevalent in the Barkly Tableland than Flinders grass (Ford 1992).
3. The association between faecal nitrogen and pasture nitrogen was slightly stronger for Mitchell grass than Flinders grass.

The measurement of 1.3% faecal nitrogen has been shown to be associated with an average value of 0.8% Barley Mitchell grass (*Astrebla pectinata*) nitrogen (5% protein), for the Barkly Tableland pastures. Therefore, the use of the 'indicator species', Barley Mitchell grass is suggested as an indicator for estimating changes in animal diet quality. This association between Mitchell grass quality and faecal samples may be beneficial for both commercial beef nutrition management and research in the Mitchell grass regions of northern Australia.

APPENDIX 1 ANNUAL REPRODUCTIVE PERFORMANCE FOR EACH HERD

	Herd 1	Herd 2[1]	Herd 3[1]	Herd 4[2]
	mean ± s.e.			
Pregnancy rate (%)				
1997	97 ± 1	-	-	92 ± 1
1998	89 ± 2	91 ± 1	82 ± 3	88 ± 1
1999	94 ± 1	82 ± 2	83 ± 3	91 ± 1
2000	92 ± 1	93 ± 1	96 ± 2	97 ± 1
2001	93 ± 2	92 ± 1	95 ± 2	98 ± 1
Pregnancy diagnosis (month)[3]				
1997	5.2 ± 0.1	-	-	5.1 ± 0.1
1998	5.6 ± 0.1	5.3 ± 0.1	5.5 ± 0.1	6.8 ± 0.1
1999	6.5 ± 0.1	6.4 ± 0.1	6.5 ± 0.1	6.1 ± 0.1
2000	6.1 ± 0.1	7.2 ± 0.1	6.7 ± 0.1	6.2 ± 0.1
2001	7.2 ± 0.1	5.9 ± 0.1	6.9 ± 0.1	6.2 ± 0.1
Calf growth (g/d)				
1998	711 ± 12	-	-	-
1999	726 ± 15	1105 ± 9	753 ± 13	-
2000	963 ± 10	850 ± 11	957 ± 18	-
2001	902 ± 11	869 ± 9	850 ± 12	-
Weaning weight (kg)				
1998	177 ± 2	-	-	-
1999	184 ± 3	245 ± 2	173 ± 2	-
2000	210 ± 2	194 ± 2	215 ± 3	-
2001	201 ± 2	195 ± 1	190 ± 2	-

[1] Herds 2 and 3 were first mated in 1998.

[2] Herd 4 was not mothered-up at calving and therefore calf data is not available.

[3] Pregnancy diagnoses are adjusted to the pregnancy test date of 16th August.

APPENDIX 2 ANALYSIS OF PREGNANCY RATE

Appendix 2a Accumulated analysis of deviance of pregnancy rate for the effects of herd, year, breeder age-group and herd x year interaction.

Parameter	d.f.	deviance	deviance ratio	P-value
Herd	3	34.7172	11.57	< 0.01
Year	4	72.8230	18.21	< 0.01
Herd.Year	10	56.3589	5.64	< 0.01
Age-group	2	5.3854	2.69	0.068
Residual	6174	3497.1553	0.5664	
Total	6193	3666.4397	0.5920	
Inclusion of the effects of breeder weight and BCS				
Weight	2	79.5245	39.76	< 0.01
BCS	4	44.7855	11.20	< 0.01

Appendix 2b A worked application of the pregnancy rate model.

The model for pregnancy rate (%) is described by the combination of Equations 1.1a and 1.1b. Therefore, using the example of a second-calf heifer, from Herd 2 in 1999, with a body condition score of 6::

If Py = probability of being pregnant then we model Logit (Py) = Z

Equation 1.1a

Where $Z = 1.244 + -1.442(\text{Herd}) + 1.171(\text{Herd.Year}) + 0.061(\text{Age-group}) + 1.286(\text{BCS})$

$= 2.32$

Since $Z = \text{Logit}(Py) = \ln(Py / (1 - Py))$

Equation 1.1b

Then $Py = 1 / (1 + \exp(-Z))$

$Z = 2.32$

so $Py = 1 / (1 + \exp(-2.32))$

$= 0.91$

$= 91\%$

Predicted pregnancy rate = 91%

APPENDIX 3 ANALYSIS OF PREGNANCY DIAGNOSIS

Accumulated analysis of variance of pregnancy diagnosis (month) for the effects of herd, year, breeder age-group and herd x year interaction.

Parameter	d.f.	Sum of squares	Mean square	F	P-value
Herd	3	40.450	13.483	8.47	< 0.01
Year	4	1059.488	264.872	166.46	< 0.01
Herd.Year	10	1249.054	124.905	78.50	< 0.01
Age-group	2	218.552	109.276	68.67	< 0.01
Residual	5486	8729.422	1.591		
Total	5505	11296.966	2.052		
Inclusion of the effects of breeder weight and BCS					
Weight	2	127.741	63.870	40.72	< 0.01
BCS	4	34.071	8.518	5.37	< 0.01

APPENDIX 4 ANALYSIS OF CALF GROWTH

Accumulated analysis of variance of calf growth (g/d) for the effects of sex, herd, year, breeder age-group and herd.year interaction.

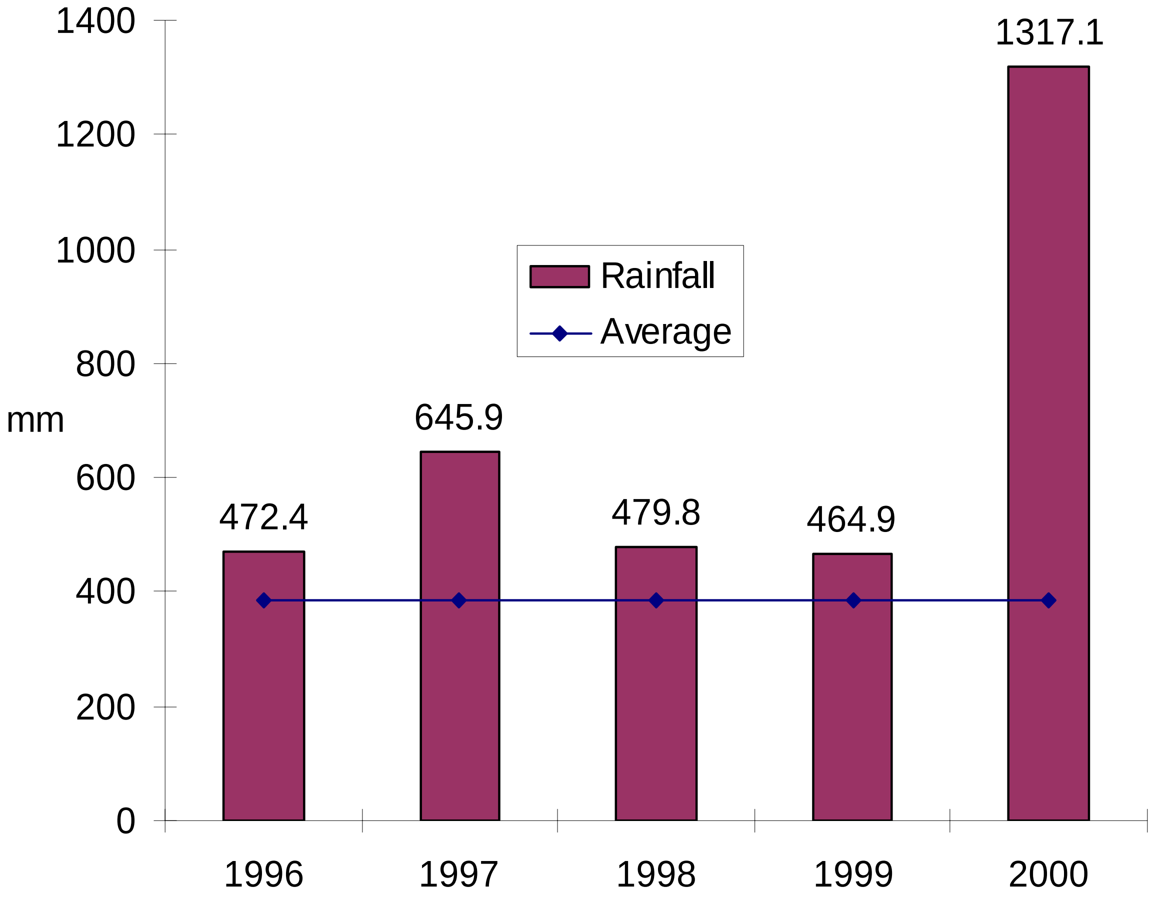
Parameter	d.f.	Sum of squares	Mean square	F	P-value
Sex	1	2077194	2077194	92.73	< 0.01
Herd	2	4859740	2429870	108.48	< 0.01
Year	3	5623505	1874502	83.69	< 0.01
Herd.Year	4	15199312	3799828	169.64	< 0.01
Age-group	2	710471	355236	15.86	< 0.01
Residual	1942	43588965	22399		
Total	1958	72059187	36802		
Inclusion of the effects of breeder weight and BCS					
Weight	2	135423	67712	3.03	0.049
BCS	2	1070128	267532	12.22	0.049

APPENDIX 5 ANALYSIS OF WEANING WEIGHT

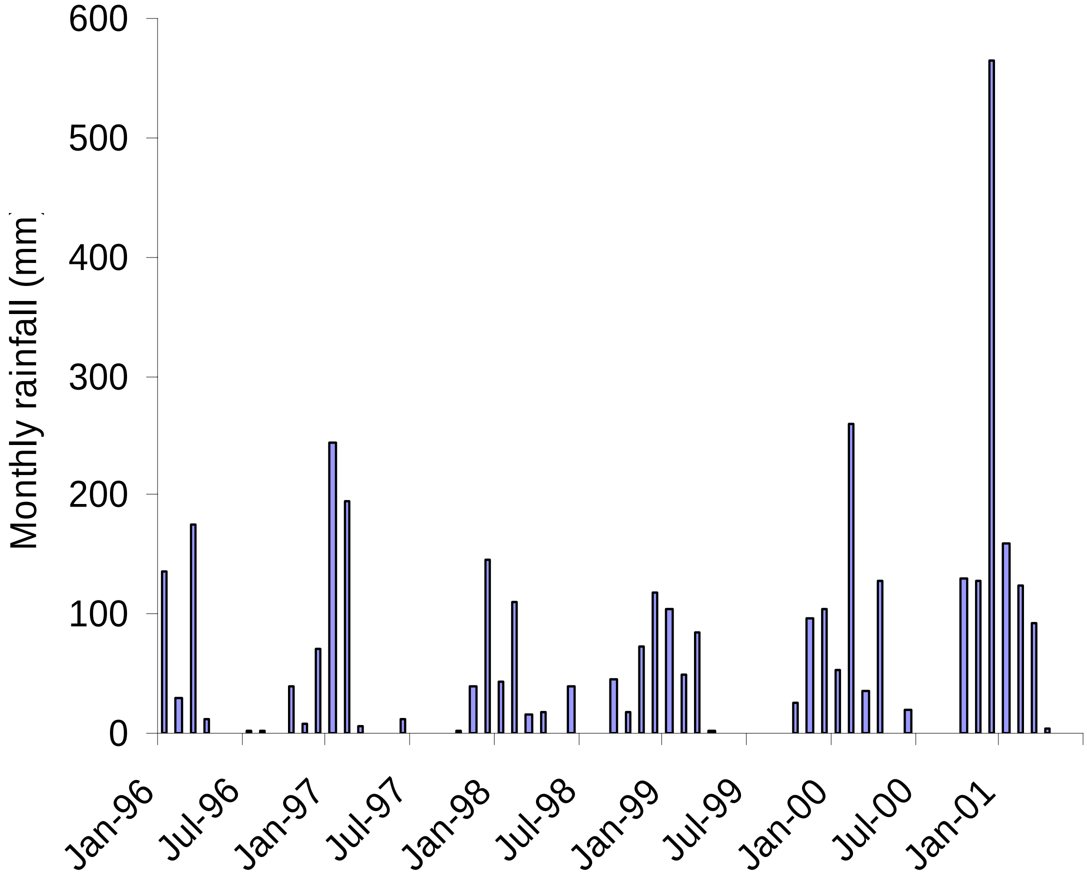
Accumulated analysis of variance of weaning weight (kg) for the effects of age at weaning, sex, herd, year, breeder age-group and herd.year interaction.

Parameter	d.f.	Sum of squares	Mean square	F	P-value
Weaning age	2	1135269.6	567634.8	956.88	< 0.01
Sex	1	75210.5	75210.5	126.79	< 0.01
Herd	2	172296.4	86148.2	145.22	< 0.01
Year	3	169894.5	56631.5	95.47	< 0.01
Herd.Year	4	486471.5	121617.9	205.02	< 0.01
Age-group	2	6771.5	3385.8	5.71	< 0.01
Residual	1944	1153204.7	593.2		
Total	1958	3199118.7	1633.9		
Inclusion of the effects of breeder weight and BCS					
Weight	2	7388.5	3694.3	6.26	< 0.01
BCS	4	32437.0	8109.2	14.04	< 0.01

APPENDIX 6 ANNUAL RAINFALL FOR THE PROJECT AREA AND AVERAGE RAINFALL FOR THE LAST 100 YEARS OF RECORDS.



APPENDIX 7 MONTHLY RAINFALL FOR THE PROJECT AREA FROM JANUARY 1996 THROUGH TO MAY 2001.



APPENDIX 8 SOIL AND WATER SAMPLE CONCENTRATIONS

Soil sample concentrations from study area

Site[1]	**2**	**2**	**1**	**1**	**1**	**4**	**4**	**4**	**3**	**3**
EC[2]	0.04	0.03	0.02	0.03	0.04	0.03	0.03	0.03	0.05	0.03
pH	7.1	7.2	7.1	6.6	7.0	6.9	6.8	6.9	7.6	6.8
K[3]	300	310	350	110	130	340	260	280	150	310
Ca	4500	4100	3300	2000	2200	2800	2700	3900	2200	3100
Mg	980	820	1100	750	660	<25	760	640	560	870
Na	30	<25	40	<25	<25	60	<25	30	<25	30
P	<5	6	<5	<5	6	7	<5	<5	<5	<5
S	8.4	5.1	1.1	2.4	2.1	1.9	3.8	1.9	2.6	2.9
Zn	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.1	0.1	0.1
Cu	0.5	0.5	0.5	0.4	0.5	0.7	0.6	0.5	0.6	0.6

[1] Site numbers refer to the project Herds and their associated paddocks (refer Figure 3.1).

[2] Soil concentration of electrical conductivity (EC) is measured as mS/cm.

[3] All chemical element concentrations are measured as mg/kg.

Water sample concentrations of stock water.

	Bore # 4[1]		**Bore # 3**[2]		**Bore # 54**[3]		**Buchanan bore**[4]	
	June	Nov.	June	Nov.	June	Nov.	June	Nov.
pH	8.3	7.9	8.1	7.5	8.5	8.0	8.9	8.4
EC	730	600	760	700	49	1100	570	510
TA	244	264	147	185	125	170	135	190
P	<0.02	0.18	0.1	0.14	<0.02	0.12	<0.02	0.14
S	12	9	29	27	48	54	26	21
Zn	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
NO_3^-	<0.1	0.3	<0.1	0.3	<0.1	0.1	<0.1	0.2
Ca	45	46	26	30	27	24	12	21
K	6	5	8	10	6	7	7	6
Mg	41	41	36	43	47	70	35	41
Na	40	35	63	63		120	42	35

[1] Bore #4 watered Herds 1, 2 and 3

[2] Bore #3 watered Herd 4

[3] Bore #54 watered Herd 1

[4] Buchanan bore watered Herd 4

Concentration of electrical conductivity (EC) expressed as uS/cm and total alkalinity (TA) as mg CaC.

Concentrations of chemical elements expressed as mg/L.

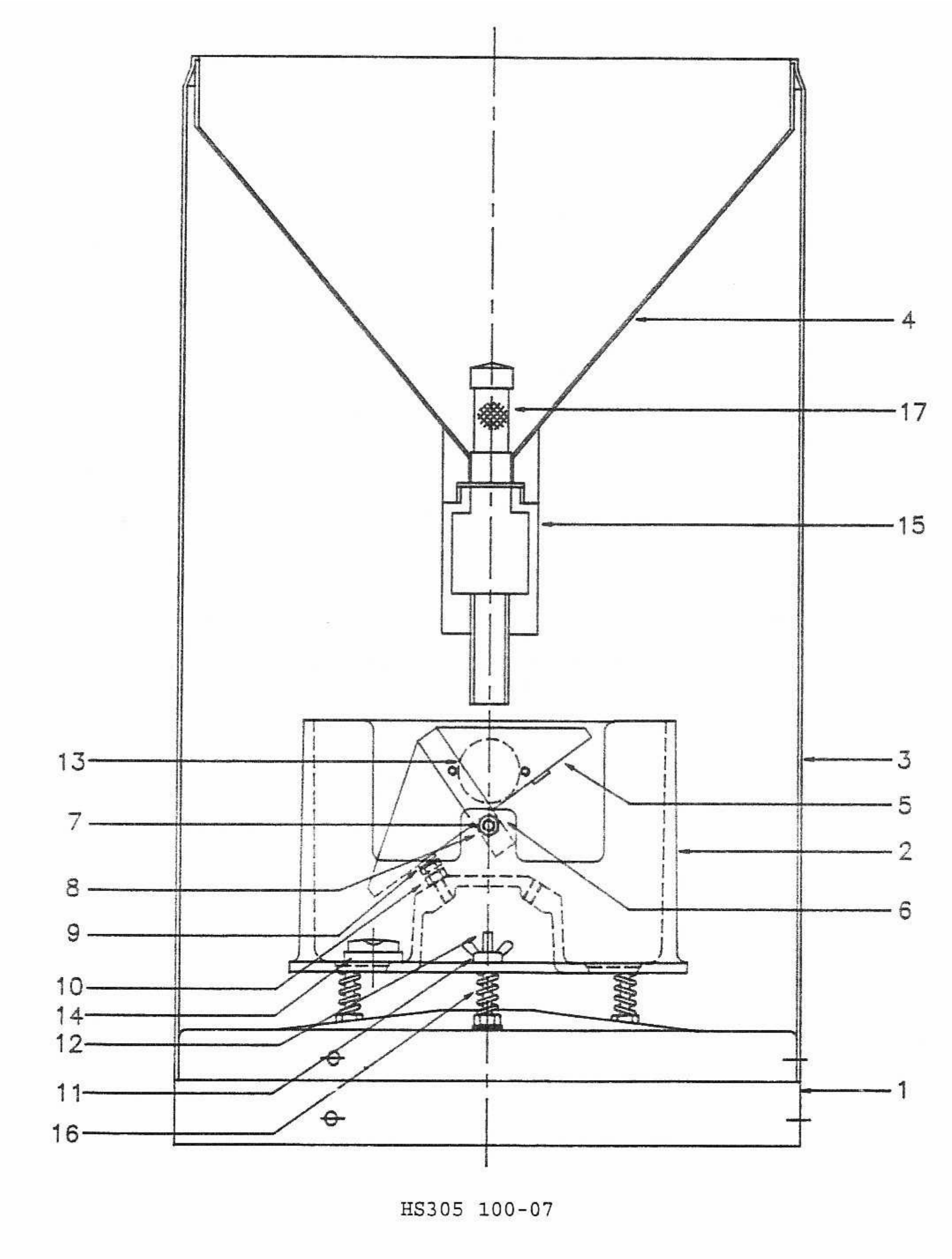
APPENDIX 9 TIPPING BUCKET RAINGUAGE MODEL HS305

General

The HS305 Rainguage operates on tipping bucket principle. A receiver of 305mm diameter collects the rainfall, which is strained by metal gauze before being passed to the synthetic ceramic coated tipping bucket measuring system. Tips of the bucket occur with each 1.0mm of precipitation collected and a reed switch detects these events and produces a momentary contact closure signal for logging in our Rain/River Data Logger Model RRDL-3, for transmission by our Radio Reporting Rainguage Model RRG-1 or for display on our Rainfall Counter.

Specification

Receiver (cover)	:	Diameter 305mm (width ± 0.5mm)
Sensitivity	:	One switch closure per tip of 1mm bucket.
Measuring range	:	Max. rainfall intensity, 600mm/hr
Measuring accuracy	:	Better than 2% @ 100mm/hr.
Sensor	:	Tipping bucket (synthetic ceramic coated brass).
Contact system	:	Dual reed switches (glass encapsulated normally open contact)
Contact capacity	:	12 VA (maximum current 0.5 amp)
Contact time	:	0.1 second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APPENDIX 10 MEDIA RELEASES AND COMMUNICATIONS WITH INDUSTRY ASSOCIATED WITH PROJECT

Industry workshops and presentations

- Presentation of the project objectives and findings led to the development of the *Barkly Herd Management Course*. This is now a self-funding course delivered to middle management of beef operations. Past-participants have been from cattle stations in the Northern Territory, Queensland, Western Australia and South Australia.
- Five presentations/workshops with the local district producer group, *Barkly Research and Advisory Committee*.
- Presentation at the *NT Beef Stakeholder's Summit*, held at Helen Springs Station, 2002.
- Presentations at The North Australian Pastoral Company, Australian Agricultural Company and Stanbroke Pastoral Company senior management meetings.

Print media

- Four articles in the newspaper, *Queensland Country Life*.
- Two project progress reports sent to relevant producers and industry representatives throughout northern Australia.
- One article in the newspaper, *North Queensland Register*.
- Three articles in the University of Queensland magazine, *UQ Graduate*.
- Three articles in the Northern Territory newspaper, *NT News*.
- One article in the national magazine published monthly, *The Veterinarian*.
- Two articles in the Northern Territory newspaper, *Tennant Creek Times*.
- Two articles in Meat and Livestock Australia's, *Feedback* magazine.
- Three articles in the NT Government (Primary Industries) industry newsletter, *Barkly Beef*.
- Two articles in The North Australian Pastoral Companies' staff newsletter, *NAP News*.
- One article in the Meat and Livestock Australia (North Australia Program) magazine, *NAP News*.

Radio media

- Four interviews with the *ABC Country Hour*.

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