NORTH AUSTRALIA BEEF RESEARCH COUNCIL

Proceedings of the Northern Beef Research UPDATE CONFERENCE

HOLIDAY INN ESPLANADE, DARWIN

3 & 4 AUGUST 2011

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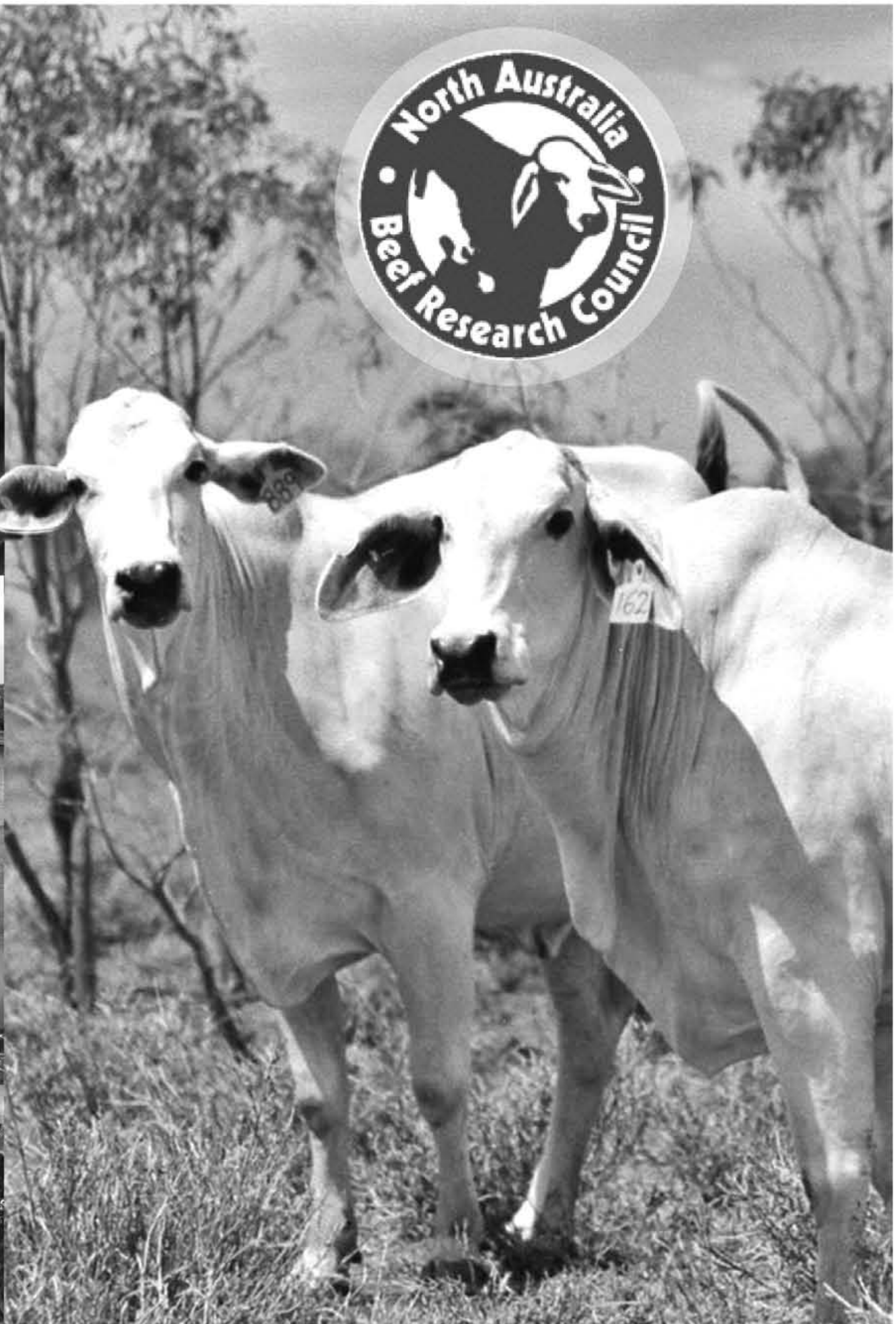

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Foreword

It is a great pleasure for me to write this foreword to introduce the 2011 Northern Beef Research Update Conference. As I do so, there is significant uncertainty about the future of live export, and therefore the industry in northern Australia. Whilst these things are played out in the political arena, R,D & E effort continues to search for and develop ways of making the industry more sustainable in the region. This conference is a celebration of that effort, and a recognition of many wonderful people still committed to a viable northern Australia beef industry. It is my earnest hope that it is an encouragement to producers to keep going against the odds and a suitable recognition of those in the R,D & E community represented in NABRC, to likewise encourage them in the continuing search for improvement.

I applaud all those who will or are already contributing to this conference, and thank especially those whose sponsorship makes it all possible. Thanks also to the Northern Territory for hosting us, to the organising committee for its effort, and to JK Connections for making it happen.

May it make a difference.

Ralph Shannon
Chairman
North Australia Beef Research Council

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Live Export R, D and E – Issues, challenges and progress

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Issues and challenges

Market summary

Live cattle exports during 2010 were down on the record 954,143 in 2009 (Fig. 1). The major reason for this decline was reductions in exports to Indonesia. The decline in cattle exports to Indonesia was due to a number of market access issues including restriction on cattle over 350kg and restrictions of import permits. However, Indonesia is still Australia's largest live export destination and the major market outlet for northern producers.

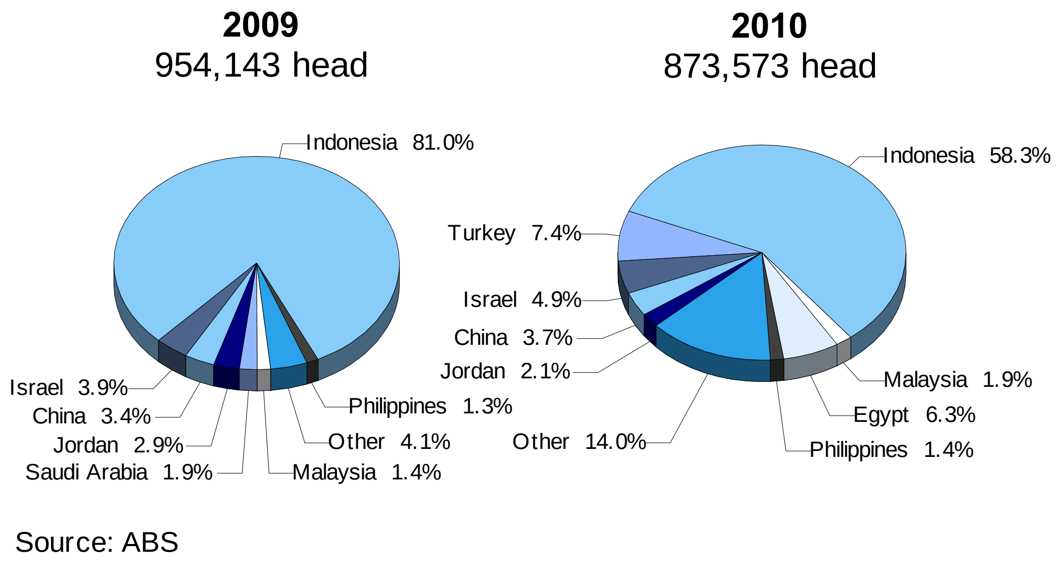

Fig. 1: Australian cattle exports by key markets for 2009 and 2010.

In an attempt to politically and publically demonstrate their commitment to beef self sufficiency targets, the Indonesian Government, from early June 2010 began implementing a series of measures to restrict the supply of live cattle and boxed beef imports. These restrictions have caused considerable market disruption and industry concern.

Indonesian regulations have always specified a weight limit for cattle entering the country, but until 1 June 2010 this limit had not been rigorously applied. From 1 June 2010, however, all import permits issued specifically stated that cattle must be less than 350kg. Random checks are now made by Indonesian authorities. As a result, all animals are now individually weighed up to 72 hours prior to export. This has seen the average weight of live cattle consignments to Indonesia drop from approximately 350kg to between 290 – 320kg.

In July 2010 the Director General of the Directorate of Livestock Services (DGLS) issued a circular to Indonesian cattle importers notifying them that, in line with self sufficiency goals, import permits would only be issued for 452,000 cattle in 2010, a reduction of 318,000 head (41%) on 2009 levels. The reduction in import permits saw a shortage of cattle in feedlots available for peak sales during the Ramadan period. This lead to increase in the price of local cattle and beef sold in wet markets.

In addition to the allocation issues there have been significant delays with the issuing of permits, causing uncertainty within the trade. Cattle imports for 2011 have been set at 500,000 head with a review expected in the middle of the year. The process of issuing permits will be streamlined with these allocated on a quarterly basis, rather than monthly to allow for longer lead-time and better planning of consignments

Many parts of the NT, WA Kimberley region and the Queensland gulf country are 100% reliant on the live export trade. The enforcement of weight restrictions to Indonesia has significantly affected their operations and market options. As a result, heavier cattle have been sold at significant discounts. Disruptions to shipping operations have also occurred. This either caused larger demurrage bills (due to delays), or departing under capacity resulting in reduced efficiencies.

The volume reductions to Indonesia have been taken up to some extent by new markets such as Turkey which is now Australia's second largest market. However, market access restrictions in 2010 significantly disrupted cattle operations in northern Australia and shipping operations of live exporters.

R&D developments

Recent research specific for live cattle exports has primarily focused on long haul animal welfare both on board ship and in market through to point of slaughter. Recently completed or progressing R&D projects are summarised below:

W.LIV.0252 - Developing cattle data collection systems

This project aims to produce valid and credible descriptions of causes of death in long haul cattle exported from Australia and to develop systems that can be implemented by industry to describe causes of death in a sustainable manner. This is a three year project which was instigated in May 2009 in response to concerns regarding elevated mortalities in some cattle voyages to the Middle East that were attributed to bovine respiratory disease (BRD). A preliminary investigation and report (B.LIV.0248) concluded that:

- There is little data describing the major causes of death in live export cattle although a single study on four voyages to the Middle East identified BRD as an important cause of death in live export cattle.
- Risk factors influencing BRD in live export cattle are considered to be the same as in feedlot cattle with additional factors likely to be operating in export vessels in association with pen design on-board ship, ventilation and local (pen, deck and ship level) conditions during the voyage.
- There is insufficient information currently available on which to determine with confidence that BRD risk is sufficiently high across all cattle that are exported to warrant mandatory vaccination in all exported cattle, or to identify a particular vaccine that should be used, or to expect that vaccination with a particular product would be likely to reduce BRD risk.
- There is a need to collect credible information describing causes of death in live export cattle. This means using objective, scientific methods that are carefully designed to ensure high levels of validity and reliability.

W.LIV.0131 - Linking pre delivery factors to post delivery performance of cattle in Indonesian feedlots

This pilot study was completed in 2010 and involved collection of information from consignments of cattle on export vessels travelling from Darwin to Indonesia. The study arose from industry interest in describing the change in liveweight in animals being exported from Northern Australia to South East Asia (particularly Indonesia) and in identifying factors or drivers that may influence liveweight-based performance measures. The longer term outcome of this work is to provide feedback to industry about animal performance that may be useful to guide selection and management and continue to promote a competitive advantage for Australian producers into Asian livestock markets.

The pilot study was specifically designed to test assumptions and methodologies for data collection in order to determine the feasibility of a subsequent larger study that might directly address objectives outlined in the above paragraph.

Consignments of cattle were enrolled into the project from two voyages travelling to Indonesia. Animal weights were collected at multiple weigh points including during the journey from property of origin to the assembly feedlot (ex-property), arrival at the assembly feedlot, on load-out from the assembly feedlot to the vessel and on discharge from the export vessel in an Indonesian port. In addition there were induction and finish weights (and average daily gain estimates) collected from Indonesian feedlots for these consignments. Additional information has been collected on management of animals at the property of origin and on management and environmental factors during the assembly feedlot and voyage periods. Animal weights in Australia were collected in aggregated form (pen, trailer or truck) but because replicates were collected (multiple measurements for each consignment) these aggregated weights were still able to be used to derive unbiased estimates of average weight and variability (standard error and standard deviation).

The findings clearly suggest that it is feasible to design a larger study capable of collecting liveweight and other information on animals being exported and on analysing these data to describe performance and identify drivers of performance in the export process. An important component of any larger study will be appointment of dedicated project personnel within Australia and Indonesia to ensure successful collection of data.

Enforcement of the 350kg limit on animals being exported to Indonesia is understood to have resulted in most or all animals being individually weighed prior to load out. Availability of individual animal weights would enhance the ability of a larger study to achieve objectives by improving precision of weight estimates.

Recommendations from this project included providing a draft design is presented for a 3-year study to address the industry objectives relating to performance of Australian cattle in Indonesian live export markets and that an initial workshop be held to receive background information from the authors of the current report and from MLA/LiveCorp representatives about the proposed project.

Relevant in market R&D activities

Restraining box program

The restraint methods used for cattle have implications for animal welfare, carcass and meat quality, processing efficiency and safety of the stockman. Traditional methods of restraint used for local cattle in the Middle East and Southeast Asia have involved manual handling and casting procedures. However, these methods are not always effective for imported Australian cattle, unfamiliar with human contact. Consequently, there has been a tendency to use inhumane, unacceptable methods of restraint in an attempt to cast the animal whilst avoiding injury to the stockman. Previous research has identified the current casting and restraint processes as key welfare issues and since 2000, three designs of restraining box have been developed (Mark I, II and IV), to replace these methods.

An independent assessment and review of each of these restraining box designs has been undertaken by MLA / LiveCorp. The main conclusions from these reviews were that the use of restraining boxes in the Middle East and Southeast Asia has the following benefits:

- Improved animal handling pre-slaughter and during the slaughter process as it removes the need to incapacitate cattle in an attempt to restrain them effectively.
- Increased processing efficiency and improved safety.
- When operated in accordance with the documented Standard Operating Procedures the Mark IV restraining box satisfies all the requirements outlined in the OIE guidelines.
- Demonstrated commitment to improving animal welfare standards in the export chain.

Future developments in the design of the restraining boxes need to take into consideration the following observations:

- The success of the restraint system is dependent upon the interaction between the stockman, animal and the environment. This can form the basis of a practical welfare assessment of the whole process.
- More sophisticated technology is less likely to be adopted if it does not satisfy production requirements (even if there is a demonstrated welfare advantage).

New technology requires support from knowledgeable and skilled stockmen. The overall acceptance of the restraining box may be reduced if it involves complicated installation, operation and maintenance processes.

Extension material

Animal health, welfare and management are critical parts of the Australian live export industry in both Australia and destination markets. The MLA/LiveCorp live export program is focused on supporting the regional markets by assisting trading partners to become more efficient in the management of their feedlots and beef production enterprises.

In consultation with exporters, consultants and SE Asian feedlot operators, The MLA/LiveCorp live export program (LEP) has contracted a number of expert consultants to produce the following extension materials;

1. Manual for South-East Asian cattle feedlots
2. Manual for SE Asian beef production
3. A guide to dairy herd management
4. Cattle feedlot treatment guide
5. Cattle breeding guide
6. Cattle heat stress management guide
7. Cattle handling and transport guide
8. Cattle nutrition guide
9. Live Export veterinary disease handbook
10. Training DVD for managing Australian cattle in Indonesia

R&D outcomes and gaps

Given the nature of the live export industry there is a continuing shift in R&D priorities as community expectations, markets and political environments change. The current live export industry strategic vision is to ensure all animals exported from Australia are managed through known supply chains (feedlot, transport and abattoir) and treated humanely under endorsed livestock welfare standards from the point of arrival in overseas markets through to the point of processing. Therefore, R&D outcomes will continue to focus on improving animal welfare throughout the live export supply chain.

The opportunity to investigate and optimize cattle pre delivery management strategies to post deliver feedlot performance in Indonesia remains. However, given the current weight restrictions imposed by the Indonesian Government this is seen as a lesser priority.

Knowledge gaps remain in determining optimal breeding programs for Australian cattle in Indonesia. These are in part being addressed by an MLA/LiveCorp breeding cattle demonstration project and Government funded ACIAR projects.

The poor financial performance of the northern beef industry – Its causes and cures.

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"Unfortunately one of the consequences of intensive agriculture and industrial development is an increase in disparity among individuals occupying different positions in the economy" (Bates 2001).

Abstract. There is no shortage of science, knowledge or experience to improve economic, production, and social outcomes in the cattle industry. However it is clearly evident that there is enormous disparity in management systems and outcomes with an industry in its worst financial state since the 1970's beef slump (McCosker *et al.* 2010). The real issue is why? This paper is an early attempt to shed light on this question through three fictitious families.

The data is conclusive that the difference in profitability is not a function of price but is a function of cost of production. The spread between the top and the bottom 20% in return on assets is almost 7% pa.

The paper concludes that the disparity in performance is not due to price or a lack of scientific "fixes", but is rather an outcome of management which in turn is a function of social factors and cultural conditioning which is generational in nature. The R, D & E solution lies in taking a holistic rather than reductionist approach to the industry with a goal of social and cultural transformation.

The numbers

Data below is based on the average results of the last 3 years from ProfitProbe™ for the Top 20%, average and bottom 20% of north Australian beef producers, categorized on return on assets (ROA).

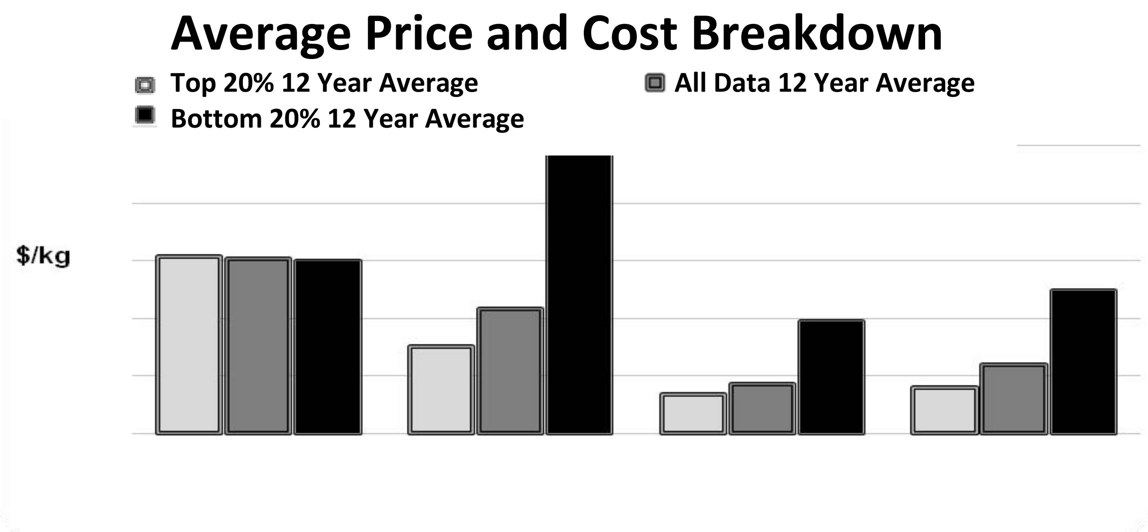

Fig. 1. Average Price and Cost Breakdown ($/kg).

It is clear from Figures 1 and 2 that price does not drive the difference in profit outcomes, but it is instead a function of cost of production (CoP). Profit is the difference between price received and CoP and it is clear that average producers keep CoP below price, but the bottom end have not had CoP below price, in the past 12 years.

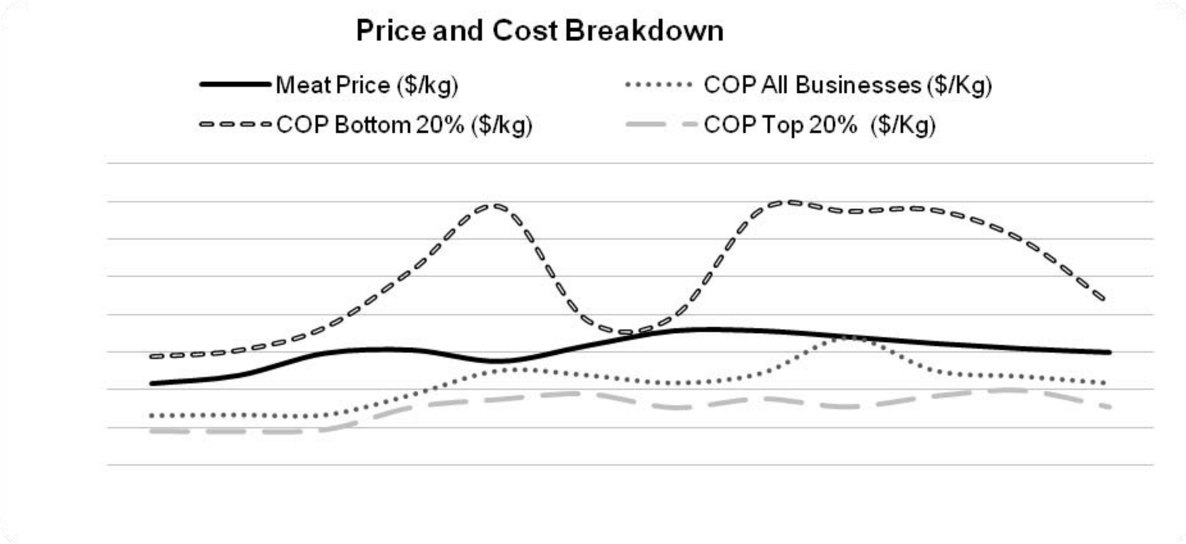

Fig. 2. Cost of production ($/kg Liveweight).

Table 1 below provides a number of key performance indicators, also divided into the three categories. The largest differences between business categories are overheads with plant utilization being significant, gross margin and gross product/FTE. There is no difference in stocking rate.

Table 1. Key Performance Indicators for the Top 20%, Average and Bottom 20%, based on ROA and averaged over 3 years from 2008 to 2010, inclusive.

	Top 20%	Average	Bottom 20%
ROA	4.0%	1.0%	-2.6%
Overhead Ratio	36%	54%	92%
Asset Turnover Ratio	11%	7%	6%
Gross Margin Ratio	53%	36%	-3%
Plant income ratio	41%	65%	121%
Expense Ratio	80%	113%	174%
Liability/AU	$630	$703	$858
Gross Product/FTE	$524,514	$348,028	$145,333
SDH/100mm	14.7	15.7	14.5

The social context

The three families are headed by Below Average, his cousin Joe Average and a neighbour, Top Twenty. They all live in Northern Australia in the same district and run beef herds. It is not my intention to suggest that these characters represent real people, but rather to look at the economics and related sociology of the industry in an understandable way.

Below and Betsy Average.

They are salt of the earth people and have lived in the district all their lives with Below having married Betsy from a neighbouring family. Their son Bruce and daughter in law have come home to the property to help out because there is a lot to do. They are all very proud of how hard they work and believe that sitting in an office is a sign of laziness.

Below has learned a lot from his father and grandfather from whom he inherited the place. They were great cattlemen and horsemen who taught him the value of hard work. Below continues to produce beautiful big bullocks, even if they are a little old for today's' grid. However Below knows that problem is caused by greedy middlemen.

The production system is based around pulling the big calves off at each round, because they make the best bullocks, brand the rest and let the cows take care of them. The steers and bullocks get the best country and the heifers are put back with the herd to get in calf when they are ready. There are plenty of mickey bulls and that saves having to spend too much on buying bulls and keeps the numbers up in case a few of the older bulls don't perform.

Betsy pays the bills and watches the overdraft like a hawk and is always criticizing Below for buying things they can't afford. She has done a basic bookkeeping course but lets the accountant do the BAS and any other fancy things that need doing. But Betsy has a problem. She has this nagging feeling that it is getting harder and harder to make ends meet. Below doesn't want to know about it. It is her problem to make the books balance and it's a good thing because there is no way he is going to pay any tax to those idiots in Canberra to waste. The solution has always been in sending in a few more bullocks so Below knows it can be fixed, especially when the cattle market rises to where it should be.

Junior Below (Bruce) is quite content because dad has told him that one day all this will be his to carry on the family traditions and he loves learning from his dad. However there is trouble in his camp too. Bruce's' wife Beryl is becoming quite disillusioned with the life style. There is never any money, never any time off or to themselves and never any holidays.

Unfortunately for the Below Average family there is more trouble brewing than in the family relationships. The Bank manager is coming for their annual review. He is concerned because 10 years ago there was no debt in the business but now it just seems to be creeping up each year. He has asked for a budget. Below hit the roof "What does that so & so know about grazing? It is impossible to do a budget because you don't know if it going to rain or not and you certainly don't know what you are going to get paid for your bullocks." So the bank manager did his own numbers.

Joe and Julie Average

Joe and Julie are only 150K down the road from Below and Betsy. They have had to work for their place and while they got a bit of inheritance, they have had to buy out the rest of the family. This has left them with a pretty sizeable debt which is hard to cope with at the same time as they have kids in boarding school. While they don't realize it, the debt has sharpened up their management a bit.

Joe is also a very hard worker and also learnt from a young age that hard work lets you win. Julie was a teacher and had another life before going bush with Joe after he did his electrical trade. Joe learnt a lot of good practical bush skills from his parents, which he finds invaluable in his day to day work. However he also takes a lot of notice of what his friends and neighbours are doing.

The production system is breeding and selling 2 year old steers and cull heifers on the boat trade. The calves are weaned at 2 rounds when the steers are around 185 kg and the heifers around 175 kg. The cows are supplemented in the second half of the dry season with a urea based supplement. Joe buys his bulls at the Rocky sales and is prepared to pay good money for well grown, fit looking bulls with a bit of length about them. If they have good EBV's for growth that is a bonus, but the blood lines are more important.

Both Joe and Julie have tasted life off the farm and are engaged in the community and help out where they can. Their learning experiences while doing a trade and going to uni have made them aware of the benefits of knowledge and they go to a few field days and talk to lots of people about what is going on. Julie has handled the transition from teacher to rural wife and mother quite well. Now that the kids are at boarding school she is keen to become involved in the business. To Joe that means helping with the mustering and fencing. To Julie it means understanding the business more. As a good rural wife she pays the bills and does the books; however she does not really understand how to make sense of it and is feeling uneasy. Julie wants to get them both educated in business management but there is never enough time or money to get away.

Because of their level of debt and the fact that it is growing, the bank manager is also uneasy. They have been good customers, they try hard and have generally always paid the interest on time, but the debt is creeping up and he is not sure how much longer this can go on.

Top and Tricia Twenty

Top grew up on the land, did school of the air and went to boarding school. He went on to get a degree and worked off-farm for 6 years. He met Trish, a para-legal secretary at a party in Brisbane after he graduated. They both enjoyed the social life and the money for 5 years but Top's desire to get home and to raise their family on the land eventually won out and after a relatively painless succession process, took on the place and the debt.

Top and Tricia value learning. They seek knowledge and use the skills they learnt in their previous lives to thoroughly analyse their options. They work through them together, make joint decisions and take time out from the children and the day to day activities to work on their business. They plan thoroughly and are quite prepared to re-plan when necessary.

The production system involves a tight breeding herd which is control mated. They market to wherever the best options are and don't always do the same thing each year. They predominately sell to the live trade but will put stock on agistment in good years and will operate a trading operation on agisted country when the numbers stack up. They buy their bulls in the paddock from a very select number of studs because they have found it very difficult to find data on inherent fertility.

Table 2. Summary of key social characteristics.

	Below Average	Joe Average	Top Twenty
Parents attitude	Hard work is the key to success.	Work hard but have a qualification to fall back on.	Get away, get a career, then choose whether you want to return to the land.
Attitude to Learning	Do what has worked in the past. Great cattleman and horseman.	Have spent some time working off farm & learn from neighbours.	Value learning & learn from many sources.
Belief Systems	Our problems are created by others. No time to do anything but work.	Work hard but take time out for the Community.	Together we can learn, make decisions and grow the business while having time for fun.
Family Conflict	Everyone except patriarch unhappy due to no family time and no money.	Concern about debt and lack of profit but patriarch only contributor to decision making.	Limited conflict through good communication in all directions
Female Partner	Under pressure to make books balance. Does not feel valued.	Keen to understand the business but held back by patriarch. Feels included but not valued.	Fully involved at a strategic and business level. Feels valued
Succession	Not discussed but an expectation built in the young generation that they will take over.	Promises made but no action taken.	Often planned for and executed.
Communication Style	Read my mind	Some formal planning but hard issues kept to self.	Open and often.
Production	Poor genetics, uncontrolled mating, heavy, aged turnoff.	Poor reproduction genetics, uncontrolled mating, yearling turnoff.	Focus on fertility, segregated preg tested breeders, variable, flexible turnoff strategy.
Bull Buying	Buys cheaply and breeds own.	Buys "big & beautiful" at sales.	Buys fertility in the paddock.
Bank Manager	Does the budget. Very concerned.	Does the budget. Very concerned	Impressed with understanding of numbers. Not concerned.

Both Top and Tricia's parents raised them to do what they wanted to do. The expectation from Top's parents was that he would leave home, get educated, work in his profession for a reasonable length of time and then decide if he was going to come home. Succession would be organised to allow that to happen if it was needed.

Tricia has found the transition to the bush hard, but her saving grace has been the way Top has made her a part of the business and an equal partner in decision making. She has been able to leave her old life and friends behind because she has something meaningful to replace it with. However she still takes time out to go back to Brisbane for the odd weekend with her girlfriends.

It was time for the annual bank review and the manager was looking forward to visiting Top and Trish. Apart from the enjoyable conversation, he knew that he would find a well considered budget, a thorough analysis of last year's figures, clear goals for next year and the years ahead and a good understanding of how the business was operating and where it was heading. While their debt was higher than most, he was not concerned about cashflowing it.

Obviously this form of categorization is very generalized but in my experience, economic performance is a reflection of many of these characteristics, which have their origins in culture. It is important to note that culture, profitability and outcomes can all be changed with a change of attitude.

"Family land is a cultural patrimony where land tenure and inheritance shape the personalities" Sonya Salomon.

One of the more detailed studies of modern agricultural sociology was carried out by (Salamon 1992) in the US mid west. She has categorized farmers in that area into two groups based on historical community development and culture, adapted below in Table 3.

Table 3. Two divergent strategies that shaped community patterns (from Salamon 1992).

Attitude to	"Yeoman" Approach	"Entrepreneur" Approach
Land	• A sacred trust • Own as much as possible without risk.	• A Commodity • Does not always favour ownership over leasing.
Farming	• Membership of a community	• A business
Family	• Strong hierarchy where the owner has power to make all decisions unilaterally	• Weaker family hierarchy
Inheritence	• Maximize family involvement	• Farming not necessarily the logical thing for an heir to do.
Ethnicity	• German	• Yankee
Debt	• Minimum to reduce risk	• More capital intensive and more debt. • Leasing may be better use of capital.

There are some similarities between my own observations in Table 3 and those of Salamon (1992); however the primary observation about both sets of descriptions is that they are culturally based. Bates (2001) also contends that the two groups are coalescing in the middle as agriculture industrialises even further, which my observations support.

Discussion

Scientific enquiry has evolved into a very reductionist approach, burrowing down into smaller and smaller bits. However it has a tendency to lose sight of the whole and "the unity of science has been obscured" (Bates 2001) by the trend to know more and more about less and less.

The answer to better adoption of existing knowledge lies in a more holistic approach, which is the study of and description of complex systems. These involve human beings who "have a tendency towards stability and continuity" (Bates 2001) which is also evidenced in the "Yeoman" strategy shown above. Change operates against these basic tendencies, where conformity is the rule and innovation is the exception. Being different is therefore difficult to withstand socially.

Behaviour is the result of our culture, which is what the stories above and the work of Salamon (1992) demonstrate. Culture is defined by Bates as shared beliefs, values and customs transmitted from generation to generation. This has more recently been described by Simpson and Cocioppe (2001) as UGR's (Unwritten Ground Rules ie *This is the way we do things around here)*

It is evident from the breakdown of behaviours and attitudes in Tables 2 and 3 that the primary force determining profitability position in the industry, as defined by ROA, is the influence of parental and community culture.

A probable solution therefore lies in a holistic approach to people in the industry, giving more weight to the cultural and social barriers to change than to technical "fixes". Change is achievable but only after attitudinal change is created.

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Recent advances in beef cattle reproduction – how science will improve herd performance

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***Abstract*.** Genetic selection for improved fertility in cattle has historically been considered problematic due to the very low heritability of reproductive traits such as weaning rate. However, the preliminary findings from research conducted by the CRC for Beef Genetic Technologies indicates that critical component traits of fertility such as age at puberty in tropically adapted cattle is highly heritable. Further, CRC researchers have demonstrated that standardised, readily measured male traits such as scrotal circumference and percent morphologically normal sperm are heritable and genetically correlated with the important female traits of age at puberty and interval from calving to first post-partum ovulation. These findings indicate that genetic selection for improved fertility of tropically adapted male and female genotypes is possible and should be utilised particularly in bull breeding herds as a long term strategy to improve herd fertility. In addition, to improve the rate of genetic improvement in fertility and other key traits affecting the profitability of beef herds, producers should consider implementing the routine use of artificial insemination (AI) with semen from high genetic merit bulls in mobs of selected females, particularly maiden heifers. However, there is good evidence that the response of females to hormonal treatments to synchronise ovulation to enable AI at a fixed time is significantly influenced by genotype, with high grade *Bos indicus* female having significantly lower rates of ovulation and hence lower conceptions rates than *Bos indicus* x *Bos taurus* and *Bos taurus* females. Modifications to synchronisation protocols which result in a more physiologically normal hormonal profile during development of the ovulatory follicle in *Bos indicus* heifers have been shown to significantly improve rates of ovulation and subsequent corpus luteum development, and thus the likelihood of conception to AI.

One of the most important nutritional factors affecting the reproductive performance of beef cattle in northern Australia is the body condition of females prior to calving. Preliminary analysis of data from the Cash Cow project has demonstrated that the body condition score (BCS) recorded at the time of pregnancy diagnosis (typically 1 to 6 months prior to calving) was highly correlated with the likelihood of first lactation females re-conceiving. Pre-calving BCS affects not only the interval from calving to first ovulation but also the quality of the oocyte ovulated at first mating.

Losses from pregnancy diagnosis to weaning continue to be a cause of reduced productivity in northern Australia. This is a multifactorial problem; however losses around the time of calving due to dystocia, reduced calf vigour, poor mothering ability and possibly calf and dam dehydration are likely to be major causes of loss. The recent identification of hypovitaminosis A as a cause of significant postnatal loss requires further investigation to determine the prevalence in northern Australia.

Introduction

McCosker *et al.* (2010) identified the major economic challenges facing producers in northern Australia and concluded that producers in the top 20% (based on return on assets) were slightly more productive on a per animal basis, had slightly lower stocking rates and significantly lower overheads. Key recommendations from this report were implementation of strategies to enable sustained improvements in herd reproductive performance. Recent economic modelling conducted by Holmes *et al.* (2009) demonstrated that in a typical north Australian herd of ~8,000 Adult Equivalents (AE), a 5% improvement in the weaning rates of maiden heifers, first lactation females and cows will result in an extra $0.62, $1.09 and $ 3.65 per AE, respectively.

The MLA funded Cash Cow project has demonstrated that there is marked variation in the reproductive performance of breeding herds across northern Australia. This paper will provide an update on some new research findings to improve the reproductive performance of herds.

Genetic selection of females for improved fertility

The genetic contribution to improving fertility has been considered low, thus poorly responsive to selection. For example McKinnon *et al*. (1990) reported a heritability of 0.1 for calving rate in tropical cattle. However a large study by the Beef CRC at four locations in Queensland (Johnston *et al.* 2009) found that age and weight at puberty were highly heritable (0.46-0.57) in Brahman and tropical composites cattle, though there was less genetic variation in the latter. As well, there appears to be few major antagonisms between selection for early age at puberty, and growth, carcass and meat quality traits in heifers and male castrates (Johnston *et al*. 2009). Others documented similar genetic parameters and correlations with other traits. Schatz *et al*. (2010) showed responses to selection at Douglas Daly Research Station in the NT in which Brahman heifers had pregnancy rates 35% higher in a herd selected for fertility, compared to beef industry heifers. Eler *et al*. (2004) reported heritabilities of 0.61-0.68 for pregnancy rate at first mating for Nellore (*Bos indicus*) cattle in Brazil.

Age at puberty is traditionally a difficult trait to measure (Johnston *et al.* 2009) because of the number of repeated measures required to define it. Measuring correlated traits may prove to be a useful alternative strategy. Scaramuzzi *et al*. (2011) concluded that IGF-1 is an important regulator of folliculogenesis at the gonadotrophin-dependent (medium-large antrum) stage of follicle development. Johnston *et al*. (2009) found that age at puberty in tropically adapted cattle was negatively genetically correlated with several fatness traits and IGF-1 (r_g = -0.55 to -0.58) measured at approximately 18 months of age. Prayaga *et al*. (2009) reported that early age at puberty was genetically correlated with sleeker coats (r_g=0.73), which was in turn genetically related to higher body condition scores in heifers (r_g = -0.33 to -0.48).

Other important female reproductive traits include post-partum anoestrous interval and lifetime fertility. Davis (1993) reported a weighted mean heritability estimate for cow lifetime calf output of 0.36, and recently Van Melis *et al.* (2010) reported that in a herd of Nellore cattle, cow survival after culling on failure to conceive had a heritability of 0.17-0.20. Quantitative genetic parameters for post-partum anoestrous intervals and relationships with life-time production efficiency indices are still not finalised from Beef CRC data; however, preliminary estimates would suggest that there is an opportunity to improve reproductive performance of Brahman females through selection for reduced post-partum anoestrous intervals (Johnston *et al.* 2010). Further, preliminary analyses conducted by Beef CRC researchers have identified gene markers for a number of important reproductive traits (Hawken *et al*. 2011). When these markers are validated, they will be used to generate genomic breeding values for reproductive traits such as age at puberty and post-partum anoestrus interval, thus increasing accuracy of selection at all ages, including potentially as embryos.

Recently, Ireland *et al.* (2011) have identified another potentially important female reproductive trait which may be under genetic control. They reported that young adult dairy cattle with a low peak number (≤ 15) of antral follicles (≥3mm in diameter) detected during consecutive follicular waves had smaller ovaries containing a much lower total number of oocytes, a poorer super-ovulatory response, lower concentrations of progesterone and poorer endometrial growth during the oestrous cycle, compared to heifers with a high peak number (≥ 25) of antral follicles. Further, they reported that the peak number of antral follicles observed in individual females was highly repeatable (0.84-0.95).

Interactions between nutrition and female reproduction

The average weight at puberty for both modern Brahmans and tropical composites is approximately 330±45 kg (Johnston *et al*. 2009) which is higher than previous estimates. The average mature weight of these cattle is between 500 and 550 kg and mature height is approximately 140 cm; therefore puberty is reached at an average of approximately 2/3rd of mature body weight (Fordyce 2006). Though both age and fatness are related to age at puberty, this relationship may be driven primarily through weight effects (G Fordyce, unpublished data). This data indicates that heifer groups must attain an average weight of approximately 400 kg to achieve high pregnancy rates (Schatz *et al*. 2008). However, preliminary results from the Beef CRC herds suggest that very high weights and very low ages at puberty may not confer greater lifetime productivity.

Scaramuzzi *et al*. (2011) have recently reviewed how nutrition influences days to puberty and post-partum ovulation. There are direct effects on the ovary, as well as effects on the brain hormone regulators. The period from primordial follicle recruitment to ovulation is at least 5 months and nutrition can influence folliculogenesis and oocyte development throughout. This is part of the reason for the strong relationship between pre- or post-partum body condition or weight, and pregnancy rates (Schatz *et al*. 2008; Schatz *et al*. 2011); e.g., pregnancy rates predicted for cows in pre-calving body condition score 1, 3 and 5 (1-5 scale) were approximately 10%, 60% and 90%. The long period of nutritionally-influenced follicle development also explains how spike feeding (Fordyce *et al*. 1997) improved lactation cyclicity rates without affecting weight or body condition. Because of low weights and poor body condition, pregnancy rates in first-lactation females exceeded 25% in only eight of 11 herds studied in an NT study (Schatz *et al*. 2008). At the other extreme, well-fed first-lactation Brahman heifers aged two years can achieve pregnancy rates of 90% (Fordyce *et al*. 2009). A small study using Beef CRC data showed that few cows cycled when pasture dry matter digestibility (DMD; derived from faecal NIRS) was 50% or less, and that cyclicity rates increased to 50% when pasture DMD was 60% (T Emery and G Fordyce, unpublished data).

Supplementation of female beef cattle with urea-based mixes in the dry season and with phosphorus-based mixes in the wet season remain routine practice across much of north Australia (McCosker *et al*. 2011). Providing high-energy supplements to breeding cattle is not common practice. A detailed north Queensland study demonstrated that such feeding becomes profitable when it can increase income from steer sales, and or can achieve moderate to high pregnancy rates in yearling heifers, with high pregnancy rates during their first lactation (Fordyce *et al*. 2009).

Epigenetics is a heritable change in gene function without change in DNA. Maternal under nutrition or over nutrition during critical stages of gestation may alter DNA methylation or acetylation of histone proteins which in turn may affect gene expression (Sinclair *et al*. 2007). Studies in sheep and cattle have demonstrated depressive epigenetic effects on maternal behaviours and production efficiency of offspring of under-nourished early-pregnant ewes and cows (Bell 2006; Oliver *et al*. 2007). There has been no research to confirm nutritionally-induced epigenetic effects on cow and progeny performance in dry tropical regions where regular severe under-nutrition occurs. Studies with *Bos taurus* cattle in temperate Australia have shown that nutritional restriction early in pregnancy can significantly reduce progeny growth rate to slaughter; however, no information is available on fertility effects (Greenwood *et al.* 2006). In a southern Queensland study using composite heifers, low maternal dietary protein and energy intake during early and mid-gestation affected folliculogenesis and gene expression in the ovary of female offspring (Rodgers *et al*. 2009; Sullivan *et al*. 2009), but the impacts on pregnancy rate and calf output were not investigated.

Use of artificial breeding technology to accelerate rates of genetic gain

The development of effective oestrous/ovulation synchronization protocols to enable fixed-time artificial insemination (FTAI) of extensively managed *Bos indicus* heifers and cows in northern Australia is desirable as a means of accelerating the rate of genetic improvement in seedstock and commercial bull breeding herds. Progestin and progesterone implants combined with prostaglandin $F_{2\alpha}$, oestrogen compounds and equine chorionic gonadotrophin treatment are most commonly used to synchronise ovulation to enable FTAI. However, lower than expected and variable pregnancy rates have been reported after FTAI, particularly in heifers. These poorer pregnancy rates may be partly due to the synchronization protocols were originally developed for use in *Bos taurus*. *Bos indicus* heifers treated with an intravaginal progesterone releasing device (IPRD) and oestradiol benzoate (ODB) had significantly higher serum progesterone during the period of implant insertion, smaller dominant follicle at time of FTAI and lower ovulation rate compared to identically treated *Bos taurus* heifers (Carvalho *et al.* 2008). S Butler (pers. coms.) also observed a relatively high prevalence (39%)

of ovarian dysfunction in Brahman and Brahman cross heifers after treatment with an IPRD and ODB to synchronise ovulation. Sá Filho *et al.* (2009) have examined factors affecting pregnancy rates to FTAI in large FTAI programmes conducted in Brazil. The diameter of the largest follicle measured at the time of FTAI significantly affected the probability of ovulation and subsequent pregnancy rate. Pregnancy rate was affected by genotype (*Bos taurus* 62%; *Bos taurus* x *Bos indicus* 51%; *Bos indicus* 48%) and parity (maiden heifers 40%; 1st lactation females 45%; lactating cows 52%).

Sexed semen is increasingly used to inseminate maiden heifers in the dairy industry. Pregnancy rate per AI at detected oestrus ranges from 35 to 40% for sexed semen compared with 55 to 60% for conventional semen (Weigel 2004). More recently, sexed semen has been used in FTAI programs with reported pregnancy rates ranging from 31 to 44%. There is a real need to evaluate use of sexed semen in AI programs involving tropically adapted beef cattle as this technology can further accelerate rates of genetic gain in beef businesses breeding their own replacement bulls.

Embryo transfer has been widely used in South America to produce customised cross-bred bulls for use in pure bred herds to produce 3-way cross calves. There is some evidence of this approach being increasingly used in northern Australia. The development of efficient large scale embryo transfer operations utilising sexed semen and best practice genetic selection to produce replacement bulls has the potential to significantly improve the rate of genetic gain in northern Australia.

Reproductive losses

Losses from pregnancy diagnosis to weaning continue to be a major cause of reproductive inefficiency in northern Australia. Studies conducted by Holroyd (1987) and more recently by Brown *et al.* (2003) have clearly demonstrated that greatest calf loss is around the time of calving. Many factors can affect calf viability in the first couple of weeks after birth. Dystocia is a well recognised cause of neonatal loss and although calves maybe born alive they may be slow or fail to suckle due to cerebral anoxia which occurs during prolonged parturition. Although the prevalence of dystocia in *Bos indicus* cattle is generally lower than in *Bos taurus* cattle (Rowan 1990), Brown *et al.* (2003) observed that in maiden Brahman heifers mated to Charbray bulls, the prevalence of dystocia was 4%. Also, Fordyce *et al*. (2009) reported a mortality rate of 5-10% due to dystocia in Brahman cross females calving at two years of age.

Recently, hypovitaminosis A has been identified as a cause of perinatal mortality in a beef herd in NW Queensland (Hill *et al*. 2009). Consecutive years of drought can result in severe depletion of liver vitamin A reserves and in pregnant cows can result in characteristic histopathological changes in the brain of the developing foetus. The prevalence of losses due to hypovitaminosis A in northern Australia are yet to be determined. Severe protein deficiency during the last third of gestation can also result in increased perinatal calf mortality.

An eight year longitudinal study of Brahman, Hereford and Brahman X Hereford cross cows conducted by Rowan (1990) in south-east Queensland found that losses from pregnancy diagnosis to weaning were 22.0%, 13.6% and 12.9%, respectively, with nearly half the losses in the Brahman females due to 'weak calf syndrome', defined as failure of calves to stand and suckle after birth or difficulty in locating the teats and failure to suckle. Researchers in Louisiana and Texas have also reported high incidences (up to 27% of calves born) of Brahman calves with suckling problems shortly after birth. These calves were usually full-term and born without difficulty, had no obvious congenital defects, were capable of standing and initiating teat-seeking behaviour, but were incapable of finding and suckling a teat without assistance. Riley *et al.* (2004) examined factors affecting calf vigour over a 40-year period in a Brahman and Brahman cross herd in Florida. They found that purebred Brahman calves were 24.7 times more likely to have poor vigour within 24hours of birth than 2/3 Brahman calves. Also calves born on days with a minimum temperature of ≤5.6°C were 1.97 times more likely to have poor vigour than calves born on days with a minimum temperature of >5.6°C. Estimates of direct and maternal heritability of birth vigour were 0.09 ± 0.05 and 0.10 ± 0.04. In a study of colostrum production, quality and absorption in Brahman and Angus cattle (Vann *et al.* 1995), Brahman cows produced more colostrum than Angus cows, but total immunoglobulin absorbed by calves and efficiency of absorption was not affected by genotype.

Bull selection and management

A BBSE still remains the foundation for selecting replacement bulls and working bulls which are likely to be fertile. It is conducted using standards for each reproductive trait established and monitored by the Australian Cattle Veterinarians (ACV). These traits relate to number of calves that individual bulls can sire. A BBSE generally involves a physical examination of structure, scrotal contents and circumference, a crush side assessment of semen and a laboratory assessment of sperm for percentage of normal and abnormal sperm (morphology), with assessment of serving ability and libido only performed in cases of suspected subfertility or infertility.

A BBSE establishes a baseline for various reproductive traits above which bulls can be regarded as having physical and reproductive traits which are not limiting factors for calf getting ability. In young bulls approximately two to three years of age previous plane of nutrition can significantly affect testicular development and hence scrotal circumference (SC). Analysis of data from 1,958 tropically adapted bulls has demonstrated a highly significant positive relationship (r=0.85) between SC and body weight and led to the establishment of threshold values for SC by body weight (Muller *et al*. 2010). However, we are still at a situation where a thorough BBSE will not identify the highly fecund ('super') bulls in terms of calf output, but will identify sub-fertile and infertile bulls.

A series of field studies (Holroyd *et al*. 2007) have shown that approximately half of the two to three year old bulls purchased and relocated to commercial herds in north Queensland failed a BBSE within 6months of relocation, primarily because their ejaculates contained less than 50% morphologically normal sperm. This occurred irrespective of genotype or nutritional history, and was associated with significant loss of body condition accompanied by decreases in SC and percent normal sperm. However, further studies conducted by Holroyd *et al*. (2007) also demonstrated that yearling Brahman bulls relocated according to best practice recommendations did not experience a significant decrease in proportion subsequently passing a BBSE. These findings are very important given the survey findings from the Cash Cow project which found that most properties introduced replacement bulls in the spring or summer months, and on approximately 50% of properties these bulls were joined after < 2months acclimatisation.

Male phenotypic predictors of calf output

Percent morphologically normal sperm is one of the best predictors of calf output explaining 35-57% of the variation in calf output of multiple-sire mated tropically adapted bulls (Holroyd *et al.* 2002). Percent normal sperm is reasonably repeatable (r = 0.41 to 0.78) once bulls have reached sexual maturity (Holroyd *et al.* 2007), but was lowly or inconsistently correlated with traits such as liveweight, scrotal circumference, testicular tone and motility in tropically adapted bulls (Fitzpatrick *et al.* 2002). However, in *Bos taurus* bulls Waldner *et al.* (2010) demonstrated that percent morphologically normal sperm was lower (P< 0.06) in bulls with a SC ≤34cm compared to bulls with a SC >34cm. SC is highly correlated with daily sperm production (Wildeus and Entwistle 1982) and should be regarded as a threshold trait, above which, selection of bulls with larger SC is unlikely to increase calf output. Finally, although sperm motility is an important determinant for suitability of an ejaculate for freezing it is not a good predictor of calf output.

Early life traits predictive of male and female fertility

Early life predictors of fertility could greatly enhance the efficiency of selection of sires for not only their own reproductive performance but also for the reproductive potential of their progeny. Except for SC there is little genetic information on male reproductive traits and their association with female reproduction. Van Melis et al (2010) reported that survival within a herd of Nellore cattle culled on failure to conceive had a low genetic correlation with scrotal circumference ($r_g = 0.07$), but a high genetic correlation with heifer conception rate ($r_g = 0.82$). The CRC for Beef Genetic Technologies has investigated a range of male traits measured in blood and/or semen from birth through to two years of age that could improve female reproductive performance. Whilst the data analysis is still to be finalised on all of the genetic parameters and genetic correlations, there are some important relationships that can be reported.

Data has been obtained from about 3600 Brahman and Tropical Composite bull calves followed through to two years of age in two locations in central Queensland. A range of traits were measured including, at branding at four months of age, serum inhibin (IN4) and plasma GnRH stimulated luteinising hormone (LH4), and at weaning at six months of age, blood insulin-like growth factor-1 (IGF6). Bulls were repeatedly measured through to two years of age at three monthly intervals for weight and scrotal circumference with a BBSE being done at 12, 18 and 24 months of age. Genetic correlations between the male traits, SC at six and 12 months (SC6, SC12) and percent normal sperm at 24 months (Norm24), and the female traits, age at puberty as defined by the first ultrasound scanned CL (AgeCL) and post-partum anoestrous interval (PPAI), are reported in Table 1.

Table 1. Heritability of male traits and genetic correlations between various male and female reproductive traits

Trait*	Brahman				Tropical Composite			
	h^2	r_g Norm24	r_g AgeCL	r_g PPAI	h^2	r_g Norm24	r_g AgeCL	r_g PPAI
IN4	0.72 (0.13)	-0.42 (0.18)	-0.29 (0.11)	0.08 (0.17)	0.67 (0.07)	-0.35 (0.14)	0.02 (0.10)	-0.05 (0.17)
LH4	0.29 (0.10)	0.27 (0.30)	0.04 (0.19)	-0.17 (0.28)	0.44 (0.09)	-0.33 (0.18)	0.15 (0.14)	-0.17 (0.28)
IGF6	0.44 (0.08)	0.35 (0.22)	-0.61 (0.12)	-0.22 (0.17)	0.34 (0.07)	-0.20 (0.15)	-0.38 (0.09)	-0.11 (0.17)
SC6	0.44 (0.09)	-0.28 (0.22)	-0.34 (0.12)		0.41 (0.08)	0.32 (0.14)	-0.25 (0.10)	
SC12	0.64 (0.08)	0.30(0.20)	0.43 (0.11)	-0.12 (0.14)	0.49 (0.09)	0.35 (0.13)	-0.27 (0.09)	0.34 (0.14)
Norm24	0.17 (0.07)		-0.31 (0.23)	-0.66 (0.24)	0.24 (0.07)		-0.31 (0.23)	-0.13 (0.24)

Data in unshaded cells derived from Corbet et al.(2011); Data in shaded cells from NJ Corbet, unpublished data

* See text for trait definitions

Heritability of male traits ranged from 0.17 to 0.72, indicating that selection for genetic change in these traits is achievable in both Brahmans and Tropical Composites. Genetic correlation of male traits with AgeCL and PPAI offer exciting possibilities for improving reproductive performance, particularly in Brahmans. The next phase of this work will be to have traits such as Norm24 incorporated in Breedplan but this will require validation in other populations of cattle. In addition Beef CRC researchers have investigated whether there are any detrimental effects on male reproductive traits from selecting bulls based on genetic markers for AgeCL and PPAI (M Fortes, S Lenhert and R Hawken, unpublished data). A study of 1115 Brahman bulls demonstrated a 0.6 correlation between the AgeCL marker and puberty in bulls as defined as age at scrotal circumference of 26 cm. There was no significant correlation between the marker for PPAI and bull fertility traits, except a small negative correlation (favourable) with Norm24. Therefore, selecting for fertility traits in cows is not expected to have detrimental effects on male reproductive traits and may actually result in a favourable correlated response.

A number of other potential male traits have also been investigated by Beef CRC researchers. Work conducted by M Fortes and G Bo-Hansen (unpublished data) in Tropical Composite bulls has shown that although the percentage of sperm with evidence of chromatin fragmentation was correlated with percent normal sperm, the percentage of sperm cells with chromatin fragmentation detected at 13 months of age was not a good predictor of the percentage of normal sperm cells at 24 months. In another study of the seminal plasma proteins present in the ejaculates of 75 two-year-old Brahman bulls eight specific proteins and their interactions accounted for 88% of the total phenotypic variation in percent normal sperm (J Crisp, A Moura and M McGowan, unpublished data). Two-dimensional electrophoresis was used to produce protein maps and the identification of specific proteins was done by mass spectrophotometry. For this work to progress beyond the experimental stage there is a need to develop a low cost, accurate method of defining the level of expression of these potential fertility associated proteins.

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Cash Cow- exposing northern breeder herd productivity

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Abstract. The Northern Australian Beef Fertility Project (Cash Cow), funded by Meat and Livestock Australia, began in 2007 and is due for completion in 2012. The project aims to determine the most important factors associated with variation in reproductive performance between north Australian beef herds. Approximately 70,000 cows from 78 commercial properties have been enrolled in the study.

Preliminary mob-level descriptive analyses have been completed on data from the first reproductive cycle from 71 properties. There is wide variation in pregnancy rates and losses from confirmed pregnancy to weaning. The median and inter quartile range for pregnancy rate for mobs across northern Australia was 80 (63, 86)% for maiden heifers, 75 (55, 84)% for first lactation and 75 (62, 88)% cows mobs respectively. The median and inter quartile range for reproductive loss between confirmed pregnancy and weaning was 10 (1, 16)% in first lactation females and 7 (4, 13)% in cows mobs.

Introduction

The Cash Cow project (B.NBP.0382) funded by Meat and Livestock Australia, commenced in 2007 and is now in its final year of data collection. The objective of the Cash Cow project is to define the reproductive performance of selected mobs across north Australia using a range of commercially meaningful measures and to identify typical and achievable levels of performance by broad geographical region and management system. For the purposes of this paper, the achievable level of performance is defined as the upper quartile of recorded mobs.

From the data published between 1990-2010, annual pregnancy rates of 87%, 54%and 90% for maiden heifers, first lactation and cows mobs respectively (Table 1) and (Burns *et al.*, 2010; Hasker, 2000; Schatz and Hearnden, 2008) losses between confirmed pregnancy and weaning of 12% and 8% for first lactation females and cow mobs respectively (Table 2) were calculated as achievable levels of performance for beef herds across northern Australia (Burns *et al.* 2010; Hasker 2000; Schatz and Hearnden 2008).

This paper presents preliminary mob-level performance results by management system from a cross section of properties across northern Australia that have been recorded during the first reproductive cycle of the Cash Cow project. Preliminary typical and achievable levels of performance for northern Australia have been generated from these results.

Materials and Methods

Animal Ethics

This study was approved by an animal ethics committee at The University of Queensland.

Table 1. Summary of published annual pregnancy rates by class of mob from 1990 onwards for beef herds located across northern Australia.

Class	No. of Mobs	Median (%)	Inter-quartile range (%)
Maiden heifers	16	84	74-87
First lactation females	16	17	6-54
Cows/Mixed	13	81	78-90
Overall	45	76	39-86

[1]Achievable performance defined as the median of the upper 25% of mobs.

Table 2. Summary of published losses from confirmed pregnancy to weaning by class of mob from 1990 onwards for beef herds located across northern Australia.

Class	No. of Mobs	Median (%)	Inter-quartile range (%)
First lactation females	15	21	12-32
Cows/Mixed	12	13.5	8-20
Overall	27	14	9-25

[1]Achievable performance defined as the median of the lower 25% of mobs.

Location and Animals

Commercial properties across the Pilbara, Northern Territory and throughout Queensland were recruited into the project and the majority inducted two mobs of breeders: a mob of maiden heifers not exposed to bulls just prior to enrolling into the project and a mob of mature cows. These properties had two annual musters, conducted annual foetal ageing using an accredited veterinarian, and had the ability to weigh weaners.

During 2009-2010, data from a complete reproductive cycle from mating to weaning was recorded for 32,542 female cattle managed in 132 mobs across 71 properties (Table 3). Cattle on the same property, but managed by different collaborators, were treated as separate mobs. The inclusion of individual animal, mob or property data was determined by animals either providing reproductive outcome data or rearing a calf or re-conception.

Table 3. Number of control- and continuously-mated mobs by class and region.

Mating System	Mob Class	Northern Qld.	NT and WA	SE & Central Qld.	Western Qld.
Continuous mated	Maiden Heifer	-	8	-	1
	First Lactation Female	2	8	-	1
	Cow	5	11	-	2
Control mated	Maiden Heifer	8	1	28	8
	First Lactation Female	6	1	21	9
	Cow	12	4	26	8

Data Capture

All females were National Livestock Information System (NLIS) tagged, allowing all animal data to be captured using the AgInfoLink's Beeflink™ crush-side data collection system operated by Outcross Performance Pty Ltd. Crush-side animal data was recorded twice per year, typically at the branding (or weaning round 1) and foetal ageing (or weaning round 2) musters. Lactation status and body condition score (1-5 with half scores) were recorded at both musters by trained and standardised data collectors. Foetal ageing was conducted once per year (preferably in September in continuously-mated herds or 6 weeks after the removal of bulls in control-mated herds). The age the foetus was estimated using half monthly increments between 1-5 months, and thereafter in one month increments.

Definitions

Mobs were constructed from the animal-level by the class of animal, year of induction, and distinct management group. Class was maiden heifers, first lactation females or cows. A maiden heifer was an animal not thought to have calved previously at the time of induction and subsequently become a first lactation female, while a cow was an animal which was thought to have previously calved.

The mating systems of herds were categorised as either being exposed to bulls up 7 months (control-mated) or greater than 7 months (continuously-mated).

The annual pregnancy rate was calculated as the number of females pregnant plus those additional animals not diagnosed as pregnant but rearing a calf at the subsequent muster divided by the number of females assessed at the annual foetal ageing muster.

Females were recorded as having reared a calf if they were previously recorded as pregnant and were subsequently recorded as lactating after the expected calving date at either of the annual musters. Pregnant females were recorded as having failed to rear if they were not lactating at the first muster after the expected calving date, if this muster occurred greater than one month after expected month of calving and were not subsequently recorded as lactating. Breeder mortality has not been accounted for. Hence, the reported losses between confirmed pregnancy and weaning may be an underestimate.

A typical level of performance is defined as the median and achievable level of performance is the upper quartile for key measures of reproductive performance.

Results and Discussion

Annual pregnancy rate

Substantial variation exists between the reproductive performance of north Australian beef herds (Table 4). The median pregnancy rates for maiden heifers (80% v 84%) and cows (75% v 81%) were consistent with previously reported results. However, the median annual pregnancy rates of first-lactation females in the current study was higher (75% *v* 17%) than that in the literature.

Table 4. Annual pregnancy rate of continuously- and control-mated breeders and heifers on commercial properties across northern Australia and a suggested achievable rate.

Class	Mating System	No. of Mobs	Median (%)	Inter-quartile range (%)
Maiden heifers[1]	Continuous	9	63.3	48-82
	Control	45	81.0	71-86
	Overall	54	80.2	63-86
First lactation females	Continuous	8	44.5	37-63
	Control	37	77.0	62-85
	Overall	45	75.0	55-84
Cows	Continuous	16	64.0	57-70
	Control	49	81.0	64-89
	Overall	65	75.0	62-88

[1]The annual pregnancy rate of maiden heifers has not been corrected for the selection of maiden heifers exposed to bulls.

Possible explanations for this are that the annual pregnancy testing in the current study was conducted at the second weaning round in continuously-mated herds and includes conceptions that have occurred following weaning earlier in the year. The results reported in the literature may relate to females that were pregnancy tested earlier in the year. Furthermore, the results documented in the literature for first lactation females were dominated by mobs in the Northern Territory, whereas, the current study has results relating to northern Australia, including the Southern and Central Queensland region (Table 3).

The median annual pregnancy rates recorded for Continuously mated mobs were lower than those recorded for Control mated mobs for maiden heifers (63 v 81%), first-lactation heifers (45 v 77%) and cows (64 v 81%). A possible explanation for this is that continuously mated mobs are typically found in less favourable environments and females that are calving at less favourable times of the year and less likely to reconceive.

Annual pregnancy rate, although a commonly used index to measure reproductive performance, is deficient in reflecting the efficiency in which cows become pregnant and an improvement in this measure is not always of economical benefit to the enterprise. Females that calve at unfavourable times of the year require inputs to meet the requirement demands of the female (Braithwaite and deWitte 1999).

Losses between confirmed pregnancy and weaning

The median percentage of loss between confirmed pregnancy and weaning was lower than that previously reported in the literature for maiden heifers (10% v 21%) and cows (7% v 13.5%) (Table 5).

Table 5. Losses[1] between confirmed pregnancy and weaning of continuously- and control-mated maiden heifers and cows on commercial properties across northern Australia and a suggested achievable rate

Class	Mating System	No. of Mobs	Median (%)	Inter-quartile range (%)
Maiden Heifers	Continuous	9	17.0	15-26
	Control	28	9.0	4-14
	Overall	37	10.0	1-16
Cows	Continuous	15	14.0	7-22
	Control	44	6.5	4-11
	Overall	59	7.0	4-13

[1] These losses are under-estimates as they do not include cow mortalities

The inter-quartile range in mob's losses between confirmed pregnancy and weaning was slightly smaller 1-16% for first lactation females in the current study versus 12-32% in the literature. However, the range in losses between confirmed pregnancy and weaning for cow mobs was much smaller in the current study versus the literature: control-mated was 4-13% versus 8-20% in the literature. Losses between confirmed pregnancy and weaning were generally higher in Continuously mated mobs than Control mated mobs for Maiden Heifers (17 v 9%) and Cows (14 v 6.5%). A possible explanation for this is that mobs that typically control mated are typically found in less extensive areas allowing more intensive management of females. Alternatively, continuously mated mobs are typically found in less favourable environments and females that are calving at less favourable times of the year have an increased risk of calf loss.

Achievable Performance

A commonly stated goal for reproductive efficiency is a female to calve every 12 months. However, in northern Australia this goal is unrealistic due to the nutritional quality of the pasture and the variation in seasons. McGowan and Holroyd (2008) suggested that a realistic weaning rate is 80% for tropically adapted cattle in northern Australia and Burns *et al.* (2010) reported a benchmark figure of 9% loss between confirmed pregnancy and weaning. By extrapolation, it is therefore suggested that an annual pregnancy rate of 88% is a more realistic goal.

For the purposes of this paper, an achievable level of performance is defined as the value which the upper 25% of mobs were able to achieve. The achievable levels of performance in the current study were similar to those from the literature for maiden heifer (86 *v* 87%, respectively) and cow (88% *v* 90%, respectively) mobs. However, the achievable annual pregnancy rate for first-lactation heifer mobs was higher in the current study than that documented in the literature (84% *v* 54%, respectively). As mentioned earlier, a possible reason for this may be due to the current project conducting their pregnancy diagnoses later in the year after the first round of weaning has been done.

The achievable losses between confirmed pregnancy and weaning were lower in the current study compared to that from the literature for both first lactation heifers (1% *v* 12%) and cow/mixed (4% *v* 8%) mobs. Possible explanations for this are the small number of mobs used to estimate these outcomes and the method of estimating losses between confirmed pregnancy and weaning. For the purposes of this paper, the current study has calculated mob averages from the animal-level and as a consequence, the outcome is not corrected for breeder mortality.

Conclusion

These preliminary results from the Cash Cow project demonstrate that the reproductive performance of beef herds across northern Australia varies substantially. A major aim of the Cash Cow project, which is due for completion in 2012, is to identify the major factors associated with this variation. These findings will be critically important for producers to enable management and resources to be directed towards factors which contribute most to these reproductive outcomes.

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Recent research to cost effectively improve heifer fertility

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Abstract. *This paper summarises the findings of 2 recently completed heifer research projects conducted in the Northern Territory (NT). The current state of heifer fertility on NT cattle stations was established through performance recording. Pregnancy rates in 2 year old maiden heifers were generally adequate (>75%) but calf loss rates were often high (average = 22%) in first calf heifers, and reconception rates were often low (<25%). Studies on yearling mating of Brahman heifers found that current NT commercial genotypes are too late maturing to give high pregnancy rates from yearling mating, although pregnancy rates are higher (+35%) in heifers from herds that have been selected for fertility. Tables predicting pregnancy rates from pre-mating liveweights were produced for yearling mated, 2 year old maiden, and first lactation Brahman heifers from strong relationships that were found between these variables. Pre-partum supplementation with high protein supplements was found to be a method of increasing pregnancy rates in first lactation heifers.*

Introduction

It has generally been considered that there is considerable scope to improve heifer fertility throughout much of northern Australia. Two research projects (Schatz 2010a; Schatz 2010b) aimed at better understanding and improving heifer fertility in the Northern Territory (NT) have recently been completed and their findings are summarised in this paper.

Current heifer fertility on NT cattle stations

Performance recording was conducted to document current reproductive rates on NT commercial properties and to determine whether low heifer fertility is still a problem in the NT. Heifer performance was recorded on 13 commercial cattle properties. The findings of this research have previously been reported in detail (Schatz and Hearnden 2008), however a brief summary is:

- Pregnancy rates in maiden heifers were generally adequate (average = 79%, range = 59 – 88%) to produce enough pregnant replacement breeders when they were first mated at about 2 years of age. Low pregnancy rates were recorded in some instances where poor seasonal conditions were experienced or over-stocking occurred.
- Foetal and calf loss between pregnancy diagnosis and weaning in heifers having their first calf was often high (> 30%). The average loss rate of all the herds studied was 22% (range = 4 – 39%).
- Reconception rates in first lactation heifers were often low due to the low liveweight of heifers between calving and weaning. Reconception rates were < 10% on more than a third of properties, and < 25% on three quarters of the properties. However high (> 70%) reconception rates were found on 2 properties, showing that that it is possible to achieve high reconception rates in first lactation heifers on commercial properties in the NT.
- A strong relationship was found between the average liveweight of first lactation heifers at the first round weaning muster (WR1 Wt) and the proportion that had reconceived. Pregnancy rates increased with WR1 Wt and the model produced for the relationship between these two variables was used to produce target WR1 Wts. An average WR1 Wt of around 390 kg is required for a pregnancy rate of 50%, and around 420 kg for a pregnancy rate of 70%.

In summary, the research showed that low heifer fertility, especially in first lactation heifers is still a common problem in the NT and there is large scope for improvement.

Disease studies

There are a number of diseases that can cause foetal and calf loss in first calf heifers in northern Australia and these have been reviewed recently by Burns *et al.* (2010). Studies into 2 of these diseases (vibriosis and Bovine Viral Diarrhoea Disease Virus [BVDV]) were conducted on commercial NT cattle properties. It was found that vaccinating 2 year old maiden heifers against vibriosis once before mating on a commercial property in the VRD increased pregnancy rates at the end of mating by 11% (Schatz 2010b). Also BVDV was found to be widespread throughout the NT and cattle were found to have been previously infected with BVDV on every property (n = 13) on which testing was conducted. Overall, about 63% of animals had previously been infected with BVDV by the time they were 3 years old. More detailed studies were conducted on 2 properties (in the Alice Springs and Sturt Plateau districts) and it was found that 90% or more of the heifers had previously been infected with BVDV (and hence acquired immunity) by the time that they had reached 2 years of age (Schatz *et al*. 2008). However, infection rates vary from property to property and conducting a BVDV serological profile prior to mating is recommended to guide decision making about BVDV control.

Yearling mating of Brahman heifers

Yearling mating is often seen as a way of increasing heifer productivity as it has been shown to increase the lifetime calf output of females and it is a way of identifying heifers that are inherently more fertile. Therefore research was conducted at the Douglas Daly Research farm (DDRF) to investigate yearling mating of Brahman heifers grazing improved pastures.

Each year, for 4 years, about 100 Brahman heifers were purchased from a NT commercial cattle property (a different property each year) and transported to DDRF shortly after weaning. Only heifers weighing 200 – 260 kg were selected as it was considered that heifers that were lighter than this would not have much chance of conceiving during yearling mating at DDRF.

Mating occurred from late December until the end of March, and pregnancy rates averaged 33% over the 4 years (Table 1). Ultrasonic ovary scanning at the end of mating showed that nearly all non-pregnant heifers were not cycling, leading to the conclusion that current commercial genotypes of NT Brahman heifers are too late maturing to give high pregnancy rates from yearling mating. This is supported by recent Beef CRC research which found that the average liveweight and age at puberty in Brahman heifers was 334 kg and 24.7 months (Johnston *et al.* 2009). However it should be noted that pregnancy rates from yearling mating were found to be significantly higher (35% higher) in Brahman heifers from a herd that has been selected for fertility (Schatz *et al.* 2010).

Table 1. The performance of Brahman yearling mated heifers at Douglas Daly Research Farm.

Heifer year group	n	Average weight: Post weaning (kg)	Average weight: Start of mating (kg)	Average weight: End of mating (kg)	Pregnancy rate (%)
# 4	110	216	259	319	27.3
# 5	92	220	252	332	35.9
# 6	98	233	265	350	35.7
# 7	91	228	251	320	35.2
Average	97.8	224.0	256.9	330.1	33.2

Pre-partum supplementation of first calf heifers

Results from pre-partum supplementation of first calf heifers in northern Australia have been variable. Where studies have reported no improvement in reconception rates it has largely been attributed to the supplementation not resulting in higher liveweights, or that the supplementation was stopped before the wet season, resulting in a period of nutritional stress (Fordyce *et al.* 1996). This research aimed to determine whether pre-partum supplementation until the wet season had commenced was a reliable method of increasing reconception rates in first lactation Brahman heifers in the Victoria River District (VRD).

The experiment was repeated with 3 year groups of Brahman females (#4, #5, and #6 year groups) at Victoria River Research Station (VRRS). Each year following maiden joining, heifers pregnant with their first calf were randomly allocated (stratified for stage of pregnancy and liveweight) to either a supplementation (SUP) or control (CON) treatment. The groups grazed in similar adjoining paddocks and both were given inorganic dry lick supplements throughout the year. The SUP group was also fed a high protein supplement twice a week: #4 heifers were fed AustAsia HiPro pellets (28% CP) at a rate of 2.27 kg/hd/day from 17/7/06 to 18/12/06. #5 and #6 heifers were fed Copra meal (22% CP) at a rate of 1.62 kg/hd/day (from 30/7/07 to 16/11/07 for #5s, and from 11/8/08 to 17/11/08 for #6s).

Reconception rate was significantly higher (P<0.0001) in the SUP group in each year, and on average was 42% higher in the SUP treatment (Table 2). Pre-partum supplementation with a high protein supplement from the mid dry season until the wet season had commenced was found to be a reliable method (over 3 years) of improving reconception rate in first lactation Brahman heifers. Despite improving reconception rate, this strategy was not always profitable (Schatz *2010a*). The profitability of such strategies largely depend on the on farm cost of supplement and the length of time that it is fed (which can be extended in years where there is a late start to the wet season).

Table 2. The performance of Brahman first calf heifers at Victoria River Research Station.

Heifer year group	Treatment	Avg. Wt: EM (kg)	Avg. Wt: PC (kg)	n	Re-conc. rate (%)
# 4	CON	391.0	400.0	38	39
	SUP	389.1	424.7	38	82
# 5	CON	401.1	399.3	32	9
	SUP	402.7	415.1	30	63
# 6	CON	380.9	368.3	33	18
	SUP	385.7	394.9	31	45
All years	CON	390.9	389.8	103	23
	SUP	392.1	411.3	99	65
	Difference (SUP-CON)	1.2	21.5		42

EM = end of maiden mating (in May), PC = pre-calving (in September).

The relationship between liveweight and pregnancy rates in Brahman heifers

It is generally accepted that pregnancy rates increase with liveweight in both maiden and first lactation heifers (Entwistle 1983). However, models that predict pregnancy rates from liveweights have not previously been developed for Brahman maiden or first lactation heifers in northern Australia. One of the aims of this research was to meet this need.

Significant relationships (P<0.0001) were found between pre-mating livewight and pregnancy rates in yearling mated heifers grazing improved pasture at DDRF, and 2 year old maiden heifers grazing native pasture at VRRS, and also between pre-calving livewight and pregnancy rates in first lactation heifers at VRRS (Schatz 2010a). These relationships were used to produce tables showing the pregnancy rates likely from different pre-mating liveweights for yearling mated and 2 year old maiden Brahman heifers and from pre-calving liveweights for first lactation heifers (Schatz 2010a). These tables have been combined and condensed to produce Table 3.

Table 3. Predicted pregnancy rates for Brahman heifers at different liveweights.

Yearling mated heifers		2 y.o Maiden heifers.		First lactation heifers	
YPM Wt (kg)	Predicted pregnancy rate (%)	PM Wt (kg)	Predicted Pregnancy rate (%)	PC Wt [c] (kg)	Predicted pregnancy rate (%)
200	11	200	50	260	6
220	16	220	63	300	11
240	24	240	74	340	21
260	34	260	83	380	35
280	46	280	89	420	53
300	58	300	93	460	70
320	69	320	96	500	83
340	78	340	98	540	91

YPM Wt = yearling pre-mating weight, PM Wt = pre-mating weight, and PC^C Wt = pre-calving weight (corrected for stage of pregnancy). Note: If pre-calving weights are recorded in late September and heifers calve in Nov/Dec, then un-corrected weights can be estimated by adding 30 kg to PC Wt.

This information will be a useful resource for cattle managers, consultants and extension officers. It can be used to perform budgeting calculations, cost benefit analyses to work out the most profitable target liveweights for a property, and to calculate the return on investment of strategies aimed at improving heifer fertility through increasing liveweight (eg. supplementation programs).

Recommendations for heifer management

The findings from this and other heifer research in northern Australia have been used to produce the following recommendations for heifer management:

1) Segregation allows targeted management (eg. supplementation and managing the time of calving).
2) Liveweight is the biggest factor affecting pregnancy rates so heifers should be kept in good condition. Also heifers that grow well from weaning to mating reach puberty at younger ages. (Note that stocking rate is one of the main factors determining growth rate).
4) While 80% of maiden heifers weighing >250 kg at the start of mating should conceive, heavier heifers usually conceive earlier in the mating period and this increases the chances of re-conception. Therefore target maiden mating weights are 280kg for Brahman cross and 300 kg for Brahmans.
5) Consider appropriate vaccination programs (definitely botulism and consider vibriosis and BVDV).
6) Supplementation to improve body condition prior to calving increases re-conception rates but the profitability depends on the cost and length of the supplementation program.
7) A target pre-calving weight (adjusted for pregnancy) of 410 kg is required for re-conception rates of 50% in first lactation heifers (490 kg is required for 80%). Where pre-calving weights are not recorded a good pre-calving target BCS is 3.5 (on the 1-5 system).
8) Weaning preserves body condition which results in higher pregnancy rates in future years.

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Recent R&D for improved cattle welfare outcomes

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Abstract. Increasingly, governments, the general community and trading partners are expecting high standards of livestock welfare. The northern Australian beef cattle industry faces challenges meeting these expectations as a consequence of the low-input and extensive nature of production systems. The northern Australian beef cattle industry supports animal welfare-focused research, particularly that relating to practices perceived to be at risk from an animal welfare perspective. This paper summarises some of the recent research on dehorning, spaying, castration, body condition score (as a potential on-farm welfare indicator) and transportation. Research on the inheritance of the polled condition in *Bos indicus* and *Bos indicus* crossbred cattle has resulted in the identification of genetic markers which will assist in the breeding of polled cattle, reducing and, ultimately, eliminating the need for dehorning. Other research into the alleviation of stress and pain of dehorning has demonstrated that a nerve blockade, via 3-point injection of lignocaine, at dehorning attenuated behavioural responses (struggling and vocalising) to dehorning, but did not reduce the cortisol response, which is commonly used as an indicator of pain. These apparently conflicting findings may be explained by a generalised stress response (indicated by cortisol) to the restraint and the additional administration of the local anaesthetic. A comparison of scoop, knife and hot-iron cautery dehorning of calves showed that hot-iron caused least stress and pain during and on the day of dehorning, but wounds were slower to heal and there was an unacceptably high proportion of horn regrowth. A comparison of flank and the Willis dropped ovary technique (WDOT) of spaying showed that, whilst relatively low morbidity and mortality rates in heifers can be achieved with the WDOT, the short-term pain and stress associated with its conduct are similar to flank spaying. However the latter resulted in extended wound healing and inflammatory responses. Thus, producers wishing to retain spaying as a management tool and demonstrate high welfare standards need to practice pain management. It is recognised, however, that R&D is required to determine the practical form that this would take. Preliminary findings from a comparison of surgical and tension-banding castration of weaner bulls suggest that tension-banding causes greater pain and stress than surgical castration on the day of castration. An inflammatory response was also greater in the tension-banded than surgically castrated animals after the first week and to, at least, 4 weeks post-castration. The results of recent transportation research indicates that healthy, mature cattle can be transported using best practice for up to 48 hours duration without major compromise of their welfare.

Introduction

As described previously (Petherick 2005), the northern Australian beef cattle industry is unique from the perspective of its animal welfare challenges, due to the low-input, extensive nature of the cattle production systems used. There is increasing community concern about the welfare of livestock and a need to demonstrate that these concerns are being addressed. This has been recognised by the Australian government with the establishment of the Australian Animal Welfare Strategy (AAWS) and by sectors of the livestock industries, e.g. Australian Pork Ltd's decision to voluntarily phase-out the use of gestation stalls for sows.

The Australian beef cattle industry has also recognised the requirement for demonstrating high standards of animal welfare and to address husbandry and management that would be considered at risk from an animal welfare perspective. Furthermore, the industry appreciates the importance of animal welfare legislation and standards being underpinned by sound science. The industry supports welfare-focused research activities within the Beef Genetic Technologies CRC (Beef CRC) and work directly funded by MLA. The outcomes from some of this research are described below.

Welfare research projects

Dehorning

There are good welfare, management and economic reasons to have hornless cattle (Prayaga 2007). From an animal welfare perspective it is preferable to breed polled cattle than to dehorn cattle, but whilst breeding of polled cattle is relatively straightforward in *Bos taurus* breeds, it may be more complicated in *Bos indicus* cattle, due to the possible influence of other genes (e.g., African horn gene) though no such genes have been defined at the molecular or phenotypic level. Joint research between the Beef CRC and MLA led to the identification of gene markers for polled status in Brahman cattle. Currently, the probability that the DNA test will return an unambiguous result is 85% and, for these, it is 98% accurate in the prediction of polled status (J Henshall pers. comm.). The test will, therefore, improve the efficiency of breeding polled cattle. It appears, however, that the Brahman gene markers are less reliable in other breeds and more research is required to improve the accuracy of the marker-based testing.

Ample research has demonstrated that dehorning is a painful and stressful procedure (e.g. see review by Stafford and Mellor 2005), but there may be ways to conduct dehorning where pain and stress is alleviated. A PhD studentship within the Beef CRC has examined the impact on welfare outcomes of using local anaesthetics and analgesics and the use of different dehorning tools. The assessment of pain is difficult, as pain is subjective, but plasma cortisol concentration has been widely used as a key indicator in livestock pain research. Previous research on the dehorning of young (typically less than 2 months-old) *Bos taurus* calves has indicated that optimum pain and stress relief can be achieved through the administration of a local anaesthetic to the base of the horn/horn bud in conjunction with a long-acting non-steroidal anti-inflammatory drug (NSAID) (Stafford and Mellor 2005); this regime reduces the cortisol response so that it is similar to that of calves handled and blood-sampled, but not dehorned (control animals). When a nerve blockade, via 3-point injection of 2% lignocaine hydrochloride and an NSAID (meloxicam) was applied to 5-7 month-old *Bos indicus* weaners, there was no reduction in the cortisol response compared to controls and it was no different to weaners dehorned without anaesthesia/analgesia (Fig. 1). Significantly, however, the behavioural responses of the treated calves at the time of dehorning were attenuated; they performed significantly less struggling (mean ± s.e., 1.9 ± 0.9) and vocalising (1.6 ± 0.9) compared to weaners dehorned without local anaesthetic and NSAID (6.3 ± 1.5 and 12.1 ± 2.3 for struggles and vocalisations, respectively; Sinclair *et al.* 2009). This suggests that they actually felt less pain, but still displayed a stress response, perhaps as a consequence of the handling, restraint and injection of the local anaesthetic.

This project also compared the responses of calves (2-6 months old) to dehorning with scoop dehorners (S), a dehorning knife (K) or hot-iron cautery (C) using specially constructed irons of different shapes and sizes to fit round the horn base. Calf age was found to be positively related to horn-base area, which was positively related to the size of the dehorning wound, supporting the recommendation that calves be dehorned as young as possible. Cautery (C) calves vocalised significantly less during dehorning (mean ± s.e., 4 ± 1.2) compared to the other treatments (S: 9.8 ± 1.9, K: 10 ± 1.9) and plasma cortisol concentrations were at levels similar to controls (which were sham-dehorned) at 5 hours post-dehorning (C: 38.8 nmol/L), whilst the S (57.3 nmol/L) and K (61.3 nmol/L) group concentrations remained significantly elevated (Sinclair *et al.* 2010). These results indicate that hot-iron cautery for dehorning caused less stress and pain than scoop dehorners and the knife, but assessment of wound healing indicated significantly (P = 0.038) slower healing in the cautery group; at 4 weeks post-dehorning, 82% of C wounds had a discharge, compared with 38% for K and 30% for Sc . Furthermore, at this time, wound area was significantly ($P<0.001$) larger in the C treated calves than in the Sc and K calves. At 8 weeks post-dehorning there was, however, no difference between treatments in the extent of healing or wound size. Additionally, cautery was largely ineffective, with 68% of horns showing signs of regrowth when assessed 3 months post-dehorning. Whilst hot-iron cautery for horn removal is recommended only for calves up to 2 or 3 months of age, both effective and ineffective cautery dehorning was found across the age range of 2-6 months.

In summary, breeding and using polled cattle is the preferred option for assuring high animal welfare standards, but it is recognised that it will take some years for polled cattle to be the norm for the northern Australian herd. In the meantime there is a need to manage the pain and stressors associated with dehorning and whilst there appear to be methods that mitigate pain, their application and effectiveness require development. Ideally, calves should be dehorned as young as possible to minimise the adverse impacts of dehorning.

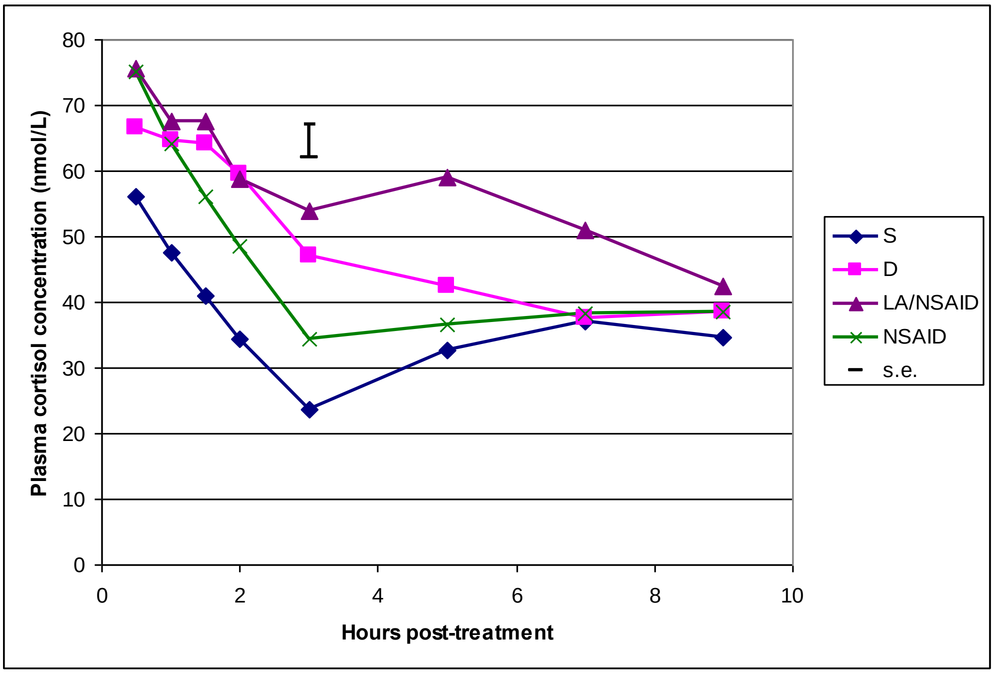

Fig. 1. Mean plasma cortisol concentrations in 5-7 month-old *Bos indicus* weaners post-treatment (S, sham-dehorn; D, dehorned without anaesthesia or analgesia; LA/NSAID, dehorned with local anaesthetic and NSAID; dehorned with NSAID.

Spaying

There are production and welfare advantages of controlling the fertility of female cattle in northern Australia and the only reliable and permanent method of preventing pregnancy currently available is surgical spaying. During the last 20 years, flank spaying has been increasingly replaced by the Willis dropped ovary technique (WDOT) which was perceived as being less invasive and painful; result in less complications, morbidity and mortalities; and, with skilled operators, offered high processing rates compared to flank spaying. An evaluation of the impacts on welfare of WDOT spaying had, however, not been conducted. In cooperation with Heytesbury Beef and support from MLA, 3 studies were conducted comparing the welfare outcomes of flank and WDOT spaying using measures of physiology, behaviour, productivity, morbidity and mortality to assess welfare status (McCosker *et al.* 2010; Petherick *et al.* 2011).

The studies showed that, in heifers, morbidity and mortality rates tended to be non-significantly lower with WDOT than flank spaying and with skilled operators and good animal management, mortalities of 0.5% can be achieved with WDOT spaying (McCosker *et al.* 2010). Flank and WDOT spaying adversely affected liveweight gains of heifers to 6 weeks post-spaying to a similar extent compared to non-spayed animals and 5% of flank wounds had not fully healed after 6 weeks (McCosker *et al.* 2010). Plasma cortisol concentrations peaked 3 to 4 hours post-procedures and were similar for Flank (1603 nmol/L) and WDOT (1290 nmol/L) and significantly higher than non-spayed heifers (519 nmol/L) indicating that the different methods induced equivalent levels of short-term pain and stress. Haptoglobin, which indicates inflammation, remained elevated to 96 hours post-procedures in flank spayed heifers, whilst concentrations had returned to levels similar to control heifers by 24 hours in WDOT heifers suggesting that the adverse effects were shorter-lived with WDOT compared to flank spaying (Petherick *et al.* 2011).

In summary, whilst WDOT spaying provides better welfare outcomes for heifers than flank spaying, the procedures cause similar short-term stress and pain. If producers wish to retain spaying as a management tool and demonstrate high welfare standards then some form of pain management should be practiced. Further research is needed, however, on the most suitable and practical form of anaesthetic or analgesic and its application.

Castration

Male cattle that are not required for breeding are usually castrated because it is perceived that bulls are difficult to control and manage, although the difficulties probably rise with increasing bull age (Kilgour and Campin 1973). In northern Australia, castration is generally done surgically but the tension-bander (sold as the Callicrate Bander) has gained favour in some regions due to its perceived ease of application and superior outcomes in terms of mortalities, particularly in older bulls. Although there have been studies on castration using the tension bander (Fisher *et al.* 2001; González *et al.* 2010) they were not conducted under northern Australian conditions with *Bos indicus* cattle. In recent work supported by MLA a comparison was made of the welfare outcomes for two age groups (7-10 months and 22-25 months of age) of Brahman bulls between surgical castration and castration using the tension-bander with and without an analgesic (Ketoprofen). As with the spaying studies, a range of indicators were used to assess welfare status post-castration. Whilst the data from the older animals are still to be examined, preliminary analyses of the data from the 7-10 month-old bulls suggest that tension-banding causes greater pain and stress immediately post-castration than surgical castration and that the Ketoprofen had little effect. Inflammation (as determined by concentrations of plasma haptoglobin) was greater in the surgically castrated than tension-banded animals to 1 week post-castration but inflammation then increased significantly in the tension-banded cattle and remained elevated relative to the surgical animals to at least week 4. There appears to be no difference between the methods on liveweight gains over a 3-month period.

Until all data are thoroughly analysed, final conclusions about the animal welfare outcomes of surgical and tension-banding castration cannot be made.

Body condition score

Cattle in extensive systems are often subject to periods of reduced feed availability due to the normal seasonal cycles in pasture growth or more extreme conditions, such as drought. When nutrient intake fails to meet metabolic requirements in the animal, an adaptive response is initiated resulting in catabolism of fat and muscle tissue and subsequent reductions in liveweight and body condition. During prolonged periods of under-nutrition, the losses in body mass can be significant and this in turn, negatively affects productivity (e.g. reduced reproductive function). Whilst the productivity losses have been well characterised, very little is known about the impacts on animal welfare during moderate and sustained under-nutrition in livestock.

Body condition score (BCS) has been used as a practical and effective means to monitor changes in body mass and composition in cattle on-farm. It potentially may also provide an indication of welfare status and whether this is achievable has been the subject of joint investigations between Australian (MLA and CSIRO) and New Zealand (AgResearch and Meat and Wool New Zealand) research agencies. This research is in the final stages of completion and will be released to industry in the near future.

Transportation

The welfare risks associated with the transport of livestock in extensive farming systems have been recently reviewed by Fisher *et al.* (2009). These authors contend that the overall impact of transport on animal welfare ultimately depends on how well these risks are managed or avoided.

The livestock transport practices conducted in Australia are different to those in other countries (e.g. transport duration). Although Australian livestock may be well adapted to our environmental conditions, there are discrepancies between our transport practices and those of other countries and there is a lack of research that demonstrates equivalence of outcomes. In view of this, a joint CSIRO and MLA research project was undertaken with the goal to deliver scientifically defensible quantification of the animal welfare outcomes of Australian livestock transport practices. A focal point of this research was transport duration given the distances cattle can be transported particularly in northern Australia. Under the then Model Code of Practice (Land Transportation of Cattle and Land Transportation of Sheep), the current maximum duration was 36 hours with the option to extend to 48 hours (if the animals are not displaying obvious signs of fatigue, thirst or distress and if the extension allowed the journey to be completed within 48 hours).

For the study, mature *Bos indicus* crossbred cattle were transported 6, 12, 30 or 48 hours and a range of physiological and behavioural measures were recorded. The results showed that healthy mature cattle with no pre-transport feed or water curfew and transported in accordance with accepted good practice generally coped with transport durations up to 48 hours (Ferguson *et al.* 2006). It was concluded that the current Code maximum duration of 36 hours with the option to extend to 48 hours was acceptable on animal welfare grounds. This maximum duration of 48 hours which specifically relates to the total period of water deprivation was subsequently adopted in the Australian Animal Welfare Standards and Guidelines for the Land Transport of Livestock for the class of cattle used in the project.

It is important to emphasise that these results cannot be extrapolated across all transport events of this duration. The condition and physiological state of the livestock and the prevailing journey conditions are key variables that will influence the animals' response to transport. These and other welfare risks must be considered in the transport planning phase.

Conclusions

Whilst recent R&D on cattle husbandry procedures that cause pain, such as dehorning, spaying and castration, have confirmed that current practices may require modification in order to demonstrate high standards of animal welfare, it is evident that effective and practical pain management solutions are currently not available. Thus, further R&D is needed on anaesthetics and analgesics and particularly their method of delivery in order to consider effective and practical delivery of pain management on property. In the meantime, such procedures should be conducted on animals as young as possible in order to minimise restraint, tissue damage, pain and stress and promote rapid healing. Clearly a better strategy is to develop alternatives so that these procedures do not need to be performed. Certainly breeding polled cattle appears to be a viable alternative to dehorning, and this can now be accelerated through the use of gene marker technology. It is recognised, however, that it will take time for polled cattle to be the norm in northern Australian herds. Fertility control seems to be more problematic; leaving bulls intact is an option that will likely enhance their welfare, but if this means that bulls are difficult to control, it may result in a greater requirement for spaying, to the detriment of the welfare of females. Non-surgical research approaches to both male and female immuno-castration are now being pursued by researchers world-wide. With regard to transportation, specifically duration, research has shown that healthy cattle that have unrestricted access to food and water prior to transportation, can be transported, using best practice, for up to 48 hours without major compromise of their welfare.

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New R and D for better herd health and productivity

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Abstract. Herd health and productivity are integrally linked and maximum productivity can not be achieved where sub optimal levels of health are a confounding variable. Other presentations at this conference will specifically cover reproduction, nutrition and genetics. This paper will attempt to identify current and proposed research activities that may not be identified in the above. Historically, gains to reproductive efficiency and live weight gain have been hard to achieve. While efforts along traditional lines are continuing, new research projects such as developing tools to determine calf wastage are exploring opportunities outside the square while others such as phosphorus supplementation over the wet season and improving response to artificial insemination are seeking to address poor adoption of old and proven technologies. Similarly, the research on eating quality of young entire males is a blend of both old and new thinking that is designed to respond to market trends and welfare concerns. The first step in addressing the key profit driver of breeder mortality for beef producers in the far north is to get acceptance of the problem and funds are now being directed in this area. In animal health, the big three issues of cattle tick, ephemeral fever and buffalo fly are all being tackled while the activities at the Australian Animal Health Laboratory are focused mainly on improving capacity and responsiveness in the ASEAN region and developing better diagnostic tests.

Introduction

The R and D initiatives that address better herd health and productivity are directly aligned with the Red Meat Co-investment committee (RMCIC) strategic imperative of "Increasing cost efficiency and productivity (including adaptability and risk management). Enormous synergies exist between productivity and herd health and although the two disciplines are often separated on budget, scientific and research lines, they are integrally linked (Fig. 1).

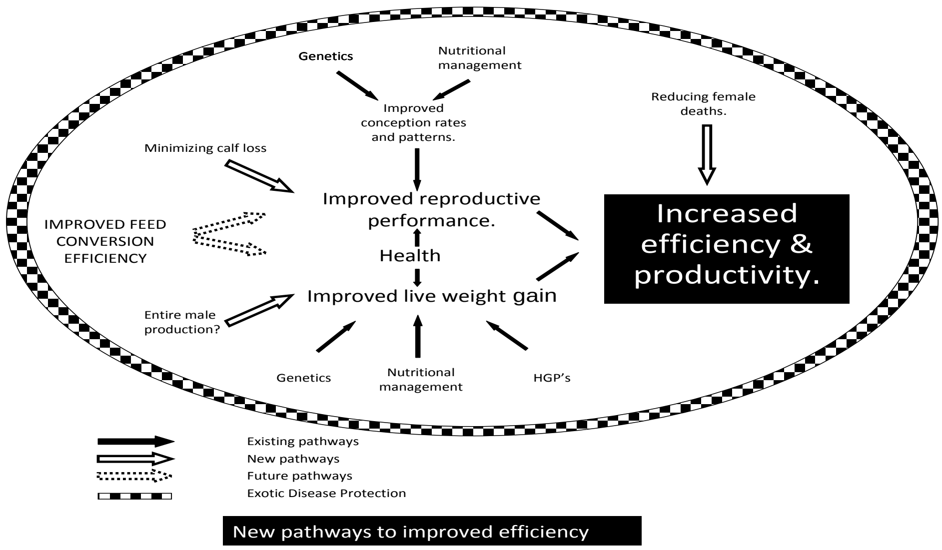

Fig.1. The pathways to improving health and productivity in the beef industry.

Maximum productivity can't be achieved where ill health is a confounding variable. The financial gains achieved in any beef production system whether it be from pastures, forage systems or in a feedlot can be represented simply by the cost of producing a kilogram of beef relative to its net worth times the total number of kilograms produced. While marketing, price received, management efficiencies and indirect operational costs are all important factors in the economic equation, this paper will focus purely on the animal components that influence the beef system's outputs, i.e. the efficiency of converting the feed consumed into beef (FCE) and the quantity of kilograms produced. The conversion of feed into beef occurs at two levels: – the direct increase in liveweight gain (production) and the increase in the number of units available to convert feed into beef (reproduction). Animal health impacts directly at both levels as disease decreases FCE and lowers liveweight gain and reproductive efficiency. The specific reproductive aspect at this conference will be covered by Michael McGowan, the specific nutrition component will be presented by Stuart McLennan while the important genetic advances will covered by David Johnston.

Improving reproductive efficiency

The broad focus of research and development in the reproductive area has historically been directed at improving pregnancy rates and decreasing the intercalving interval. While this has generally been accepted as the correct and best pathway to adopt, the results to date have sometimes been unspectacular. At a national level, the best data (Australian Bureau of Statistics (ABS)) on which to access reproductive efficiency is to examine the annual sales in relation to the national breeder herd as sale numbers which can be accurately calculated are a direct reflection of the numbers weaned. In the late eighties the male turnoff rate, when expressed as a percentage of the breeding herd, was 32.89% compared to 31.37% for the period 2005 to 2010. While endeavours that focus on decreasing days to calving (DTC) and lowering the age of puberty should continue (the genetic route is showing promise) other aspects of breeder cow efficiency are now being explored.

Table 1. A comparison of reproductive efficiency and female turnoff in the national herd.

6 year period of time in comparison	**1985-1990**	**2005-2010**
National herd size start of period in millions	22.72	27.78
National herd size end of period in millions	23.16	26.55
Total turnoff/total females>1 yr of age 2 yrs earlier	56.77%	57.69%
*** Male turnoff/total females>1 yr of age 2 yrs earlier**	**32.89%**	**31.37%**
Average female turnoff in millions	2.795	3.892
Average male turnoff in millions	3.846	4.634
% females slaughtered	42.09%	45.65%
Total turnoff as % of national herd	28.95%	31.39%

NB: Data includes dairy cattle as well & and it assumes 35% of live exports are female

* Male sales reflect males weaned & therefore best indicator of reproductive efficiency

Calf alert (CSU)

This project is designed to develop a tool to allow future research into causes of neonatal calf losses in extensive herds in northern Australia. Results from recent studies into calf losses, (Brown *et al.* 2002), heifer fertility (Schatz 2008) and the CashCow project (M. McGowan *et al.*, unpublished) have shown that calf losses in excess of 20% are occurring in maiden heifers in field situations. Losses at calving represent significantly larger economic impacts than failure to conceive. While calf wastage has been recognised as a major problem for many years, the tools to study the causes have not been available. The work at Brunchilly in the late 1990s highlighted the difficulty of monitoring births under commercial situations. The extent of losses detected on research stations, while significant, do not accurately reflect the extent or issues being experienced in the field. To date, the cost of labour and surveillance has restricted progress in this important area. The development of a calf alert device will represent a major breakthrough in the research efforts in this area.

Wet season field trials into P supplementation (U of Q)

It is estimated that approximately 90% of the cattle (representing approx. 5.68 million head) located in acutely P deficient regions of Australia are not being supplemented with phosphorus over the wet season despite the long history of research and awareness of the problem (Theiler 1928). Adoption of wet season P in acutely deficient regions may provide the single biggest achievable boost to productivity in breeding females. The lack of adoption of P supplementation in northern Australia has been the most disappointing aspect of efforts to improve both reproductive performance and liveweight gain. The reasons for the lack of adoption are poorly understood. The varying responses between marginal and deficient regions, the lack of certainty of a suitable diagnostic tool, suitable delivery systems, confidence in the cost benefits on offer and conflicting advice emanating from producers, extension officers and researchers have all impacted on the level of adoption. This project should resolve most of the underlying hurdles and open the way for enormous gains in productivity for many north Australian beef producers.

Strategies to increase adoption of AI in northern Australian beef herds (U of Q)

This project will provide a cost effective strategy to disseminate superior genetics to *Bos indicus* beef producers in northern Australia and to capitalise on the investment in the Australian Genetic Breeding Unit (AGBU) and previous and current CRC research. Important genetic traits such as Days to Calving and the polled gene are not readily available to the majority of the commercial *Bos indicus* breeders and a practical tool to accelerate adoption could rapidly change the face of the northern beef industry. The lack of genetic gain in northern Australia continues to frustrate funding bodies and research providers alike. In addition, fixed time AI offers increased opportunities to exploit hybrid vigour through the use of terminal sires that don't readily acclimatise in dry tropics. Although artificial insemination has been available for several decades, it has never been widely adopted in management systems in northern Australia because poor results have plagued the technology when previously applied to *Bos indicus* females.

Assessing property-level female mortality rates in northern Australia (private consultant)

Recent analysis of property benchmarking data suggest that breeder death rates are the biggest factor limiting profitability for many properties in the Alice Springs, Katherine and Pilbara regions (McCosker *et al.* 2010). In the Northern Territory an assessment of regional turn-off data between 2002 and 2008 (G.E. Niethe unpublished data) found the percentage of annual female turnoff averaged approximately 41.5%. However beef producers estimate average breeder and heifer mortality rates at 3% (Oxley *et al.* 2004). In the Pilbara and Kimberley, Quirk and Niethe (2008) estimated regional breeder cow mortality was greater than 10%; however losses reported to the Pastoral Lands Board in West Australia average 3.6% for the period from 1985 to 2007. Property-level mortality rates are particularly difficult, if not impossible to measure directly. This may partially explain the disparity between general industry estimates and emerging regional evidence. This project aims to quantify property-level breeder cow death rates by developing simple but robust indirect methods of retrospectively estimating breeder mortality over a period of at least 3 years using property-level herd and turnoff data combined with simple herd modeling. This project is only the first step in addressing the major determinants of the key profit driver for many northern breeder herds.

Understanding vibriosis (QAAFI)

An integrated genomics approach to improve our understanding of the biology of genital campylobacteriosis in beef cattle is required since the newly developed PCR test has been able to establish that the Campylobacter organism is much more prevalent than first thought. The high prevalence of *Campylobacter fetus* subspecies *venerealis* in Australian cattle does not correlate well with reproductive performance. The current research will firstly confirm the genome differences between closely related subspecies and field isolates using vaccination and animal infection models. An epidemiological study will associate results with reproductive status of Australian herds.

Improved liveweight gain

Similarly, when it comes to improving liveweight gain, the attention has been largely centered on finding methods to achieve improved growth rates in the steer portion of the herd but the fact remains that in any breeding enterprise, almost 50% of the stock sold is female. Furthermore Lean *et al.* (2011) in a meta-analysis of the research into liveweight gain from 1959 to 2000 gain found little or no evidence of improvements in the ADG of cattle in studies conducted over that period (Fig.2). Nevertheless, there may be opportunities to achieve liveweight gains by exploring other options such as production of young entire males as market forces driven by welfare concerns and cultural preferences start to emerge and improvements in adoption of phosphorus supplementation to steers and heifers over the growing season.

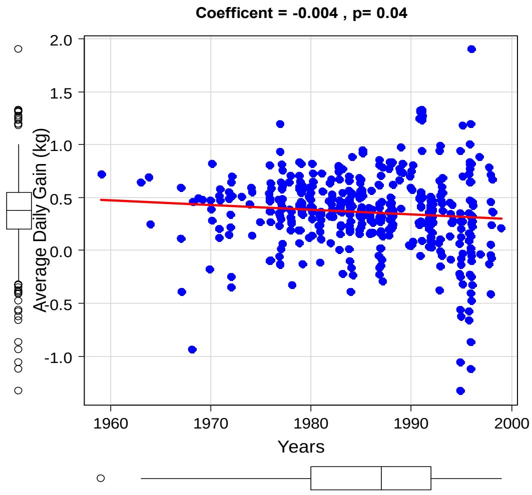

Fig. 2. The trend of ADG in all classes of cattle, breeds and during dry and wet seasons from 1959–2000 (Lean *et al.* 2011).

Wet season field trials into P supplementation (U of Q)

This research has already been mentioned under reproductive efficiency but it needs re-emphasising again here as it could provide the single biggest boost to liveweight gain for growing animals in acutely P deficient regions.

Growth and meat quality of grain finished entire male Bos indicus cattle (JCU)

This project will establish the eating quality and superior production characteristics of young entire males and could lift meat production in northern Australia by 5-7%. It also has two major side benefits. Firstly it could create an acceptable alternative for HGP's, should their use meet with consumer resistance. Secondly, it will help address animal welfare concerns associated with castration of males without analgesia or anaesthesia. The chances of success are good from both the production side and the meat quality angle. There are enormous economic advantages for producers and live exporters when young entire males attract a premium. Furthermore, it will open up opportunities for future research projects that address management, feed conversion efficiencies, and bull control.

Hi output forage systems (DEEDI)

This is a project based in the Fitzroy basin that aims to provide better predictive outcomes on the various forage and improved pasture options available on those properties with arable land. The predictions will incorporate estimates based on the computer simulation model APSIM (Agricultural Production Systems Simulator) used for cropping.

Health

The report by Holmes and Sackett (2006) "Assessing the economic cost of endemic disease on the profitability of Australian beef cattle and sheep producers" provided a framework for funding and research activities in the northern beef industry since 2006. Apart from undernutrition, the big three have been tick (and tick fever), bovine ephemeral fever and buffalo fly (Fig 3.). The latter appears to be progressively moving south and causing increased concern as it spreads. In 2011 it was recorded as far south as Maitland on the coast of NSW and Dubbo and Narromine in central NSW (P. Freeman, pers. comm.).

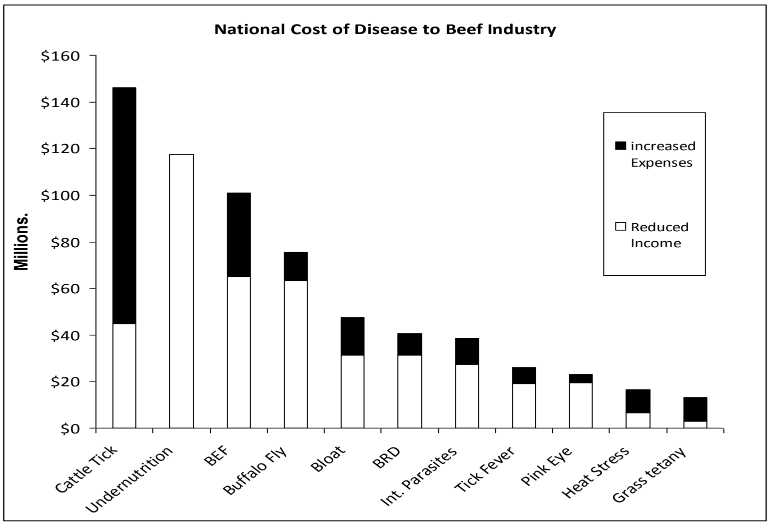

Fig.3. National cost of disease to the beef industry (Holmes and Sackett, 2006.)

Tick vaccine (QAAFI)

The Holy Grail in the battle against the nation's most costly health issue has to be an effective tick vaccine. The original vaccine showed promise but the immunity produced was very short lived and multiple repeat injections were not suitable for beef producers. The work continues and antigens have been identified that require further development in order to have a 'product'. Continued development will occur if there is an extension of the Beef CRC however it may be sufficiently advanced to be of interest to a commercial company in the event that this does not occur. The current trials give an idea of antigen activity to reduce tick numbers but not an indication of duration of immunity as special adjuvants aren't being used and optimised doses have not been derived but this is the next step.

Alternate treatments for the control of Buffalo Fly (U of Q)

The current research has focused on *in vitro* culturing of the buffalo fly and infecting them with *Wolbachia*. To date, no natural *Wolbachia* species have been identified in the Australian buffalo fly population so research efforts are now being directed to test experimentally if *Wolbachia* infection can be established in buffalo fly. Further work will progress if the in vitro cultures are successful. This will include characterising the nature, lifecycle features and pathogenic effects on cattle of *Stephanofilaria* nematodes (carried by buffalo fly), defining the insecticide resistance status of Australian buffalo flies, investigation of management strategies to ameliorate resistance in the laboratory before conducting large scale field trials or making management recommendations, assessing the potential of vaccine targets and indirect selection criteria for breeding for increased resistance.

Improved Bovine Ephemeral Fever vaccine (Private Company)

A private drug company is currently attempting to develop a single dose BEF vaccine under an MLA donor company (MDC) project agreement. Because of the commercial sensitivities of such work project details and results to date are not available. Developing an animal health product (drug, or vaccine) for registration by the Australian Pesticides and Veterinary Medicines Authority prior to its release on the market is a lengthy process which follows a strictly specified path. If there is a successful outcome at the completion of the final milestone in July 2014, a registration application will be submitted to the APVMA. The approval process is expected to take a further 18 to 24 months, meaning that a new vaccine would not be registered until 30 June 2016.

Epidemiology and management of bovine respiratory disease in feedlot cattle (QAAFI)

The aim of this work is to provide the Australian feedlot sector with improved management strategies and tools to minimise the economic impact of bovine respiratory disease on feedlot cattle performance. By the end of 2013 it will have conducted an epidemiological study to identify and quantify the impact of BRD and the critical risk factors associated with its development and it will have determined the role of bovine virus diarrhoea virus, *Mycoplasma bovis* and other infectious agents in the occurrence of BRD. It will also have developed a support tool for feedlot managers and advisors that determine the economic benefits of management practices that reduce BRD incidence and delivered to industry a best practice manual to minimise the impact of BRD on the feedlot sector.

Exotic Disease research (AAHL)

Multiplexing technology

The Australian Animal Health Laboratories has initiated test R&D on "multiplexing" strategies to enable multiple tests on the one sample. The idea, while not new will potentially lead to a more comprehensive diagnosis more rapidly, and when more fully developed will potentially lead to more comprehensive and cost effective testing in support of surveillance.

Agent characterisation

The agent characterization team is developing capabilities for rapid whole genome sequencing and, for diseases like AI, BTV and FMD, specific SOPs. The idea is that surveillance in the foreseeable future will not only be for specific disease agents or serotypes, but also to detect new forms of viruses such as reassortants and also to detect genetic markers of particular concern, such as virulence markers or markers that would indicate transmissibility by specific types of hosts. These might include markers for transmissibility among mammalian hosts in the case of influenza viruses, or by specific vector species in the case of BTV.

Increased capacity and surveillance in the ASEAN region

The AAHL Regional Program is working with international agencies OIE, FAO and even WHO to a certain extent to do two things in general; Firstly to develop laboratory capacity in the ASEAN countries so the region is better placed to manage transboundary animal diseases and emerging infectious diseases to the benefit of us all, and secondly in the process is making a significant contribution to pre-border biosecurity by being active in the region and consequently providing animal disease intelligence that is of use in a number of ways. These include national awareness of emerging threats and also, more specifically, the ability to fine tune our diagnostic testing to be matched to the strains of disease agents that are circulating in the region.

Improved Foot and Mouth Risk Management

The FMD Risk Management project is designed to (i) gain comprehensive knowledge about FMD virus strains that pose a geographic high risk to Australia and their comparable likely behaviour in Australian livestock species, (ii) devise control strategies tailored to Australian circumstances and store appropriate serum derived bulk reagents for future Australian use, (iii) improve laboratory diagnostic capability for FMD virus to rapidly isolate or detect FMD virus and confirm a primary diagnosis by providing AAHL staff the opportunity to work with live virus offshore and so gain experience with FMD clinical signs, culture and recognition of cytopathogenic effects (CPE), (iv) validate diagnostic tests (including DIVA) for use in local animal species and breeds, and to conduct genetic 'fingerprinting' (sequencing) on the virus(es) isolated in support of molecular epidemiology and vaccine selection, (v) field validation of at least two commercially available pen side assays in an endemic region, and (vi) enhance the epidemiological and virological understanding and thus help model virus spread.

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Grazing management options for improving profitability and sustainability. 1. New insights from experiments

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Abstract. Results from experiments studying aspects of grazing management (paddock and water point development, stocking rates, pasture resting/spelling and fire) were collected and synthesised.

In areas with large paddocks and few water points, additional water points can enable grazing of previously under-utilised areas, increasing carrying capacity, while smaller paddocks enable cattle to be more evenly distributed over the available area. Increasing the number of water points lowers the number of cattle per water point reducing localised degradation but grazing sensitive species may be lost from previously water-remote and thus ungrazed areas.

Stocking rate is the major driver of both production and environmental impacts. Moderate stocking rates give better overall performance than high stocking rates with season having a marked effect. In a long-term trial at Wambiana, the heavy stocking rate had higher gross margins than the moderate stocking rate in above-average years but the reverse was true in poor years; overall the moderate stocking rate had a higher average gross margin. There is little experimental evidence that variable stocking performs better than set stocking at a moderate rate.

Pasture resting can improve pasture condition with most response in the early growing season; rest periods should be a minimum of 8 weeks from the start of effective growth. However, a full wet season rest may be more practical to manage in some situations. There is low confidence in predicting the rate of recovery and cost effectiveness of using resting to improve land condition for many land types. However, our current "best-bet" guide is that pastures need two growing season rests to improve by one ABCD condition class. Where growing conditions are poor, more rest periods will be required. The stocking rate used in conjunction with resting is critical for success.

There has been a lot of research on fire in northern Australia providing general conclusions (e.g. relationships between tree height and mortality, and between fuel load and fire intensity) and showing that fire can be used to influence tree/grass balance. However, it is difficult to apply the general conclusions to a particular situation as there are many factors to consider – tree species, fuel loads, weather conditions, pre- and post-grazing, etc. Where fire is used it is essential there is a clear understanding of the purpose of the fire. One-off low-intensity fires generate costs, both direct control costs and foregone grazing due to lost forage, which may not be offset by benefits.

The combination of experiments with bio-economic modelling is a potentially powerful tool enabling the longer term consequences of management to be predicted, and the impacts of a range of seasonal conditions to be explored. Despite this, there will always be a need to test and demonstrate any recommendations locally to ensure they are appropriate.

Introduction

Beef producers in northern Australia face continuing challenges to increase their incomes to offset rising costs and a recent analysis concluded that the industry is generally unprofitable (McCosker *et al*. 2010). Increasing productivity has been a traditional means of meeting this challenge but there is survey information indicating that productivity has declined or remained steady in recent years (Nossal *et al*. 2008). At the same time as increasing productivity, producers must maintain or improve the natural resource base and there is evidence that much of the north Australian pasture lands have suffered some decline in condition (Tothill and Gillies 1992).

Grazing management influences both production and the environment. What information does past research on grazing management provide that can assist producers increase profitability and/or maintain their resource base? A recent project (MLA B.NBP.0579 Enhancing adoption of improved grazing and fire management practices in northern Australia: Synthesis of research and identification of best bet management guidelines) conducted a synthesis of past research relevant to this topic. The project was limited to paddock and water point development, stocking rates, pasture resting/spelling and fire, and this paper draws on the report from that project (McIvor 2010).

Paddock and water point development

Paddock and water point development by creating smaller paddocks and/or installing additional water points is most relevant to extensive areas where large paddocks (>40-50 km^2) with few water points mean animals are unable to reach the distant parts of the paddock during daily foraging activities. Cattle need to drink regularly (usually once a day) under the hot conditions experienced in northern Australia. Since there is a limit to how far they can walk between drinks they can only travel a limited distance from water to forage, leaving areas of pasture beyond the usual foraging distance from water.

Establishing more water points in formerly ungrazed areas enables cattle to use these areas and this has been an important part of property development since the grazing industry commenced. However, understanding the optimum number and distribution of water points to make best use of available forage and the associated response of livestock, productivity and land condition for a region can be informed by research. Most research on these issues has occurred in the more extensive regions (e.g. central Australia and the Top End).

Although a number of studies have reported the maximum distance cattle will walk from water to forage in northern Australia (e.g. up to 11 km on the Barkly Tableland and usually no further than 5-8 km from water in central Australia), most grazing by cattle occurs much closer to water. Grazing pressure usually declines markedly beyond about 3 km from water, although where water points are sparse cattle will use areas further from water. Thus, a general recommendation to improve the effective use of available pasture is for the majority of a paddock to be within 3 km of water and the distance between water points not to exceed approximately 6 km.

The Pigeon Hole project in the Victoria River District (Northern Territory) is the only project to have specifically investigated the effect of paddock size on grazing distribution and pasture use. Using GPS collars to record cattle distribution in paddocks, the research at Pigeon Hole indicated that cattle generally use a greater proportion of a paddock if paddock size is reduced. Confining cattle to smaller paddocks appears to have some effect in 'forcing' them to use areas they may not have used had paddocks been larger (although they still may not use areas that contain few palatable plants). This effect means that having more smaller paddocks results in grazing being distributed more widely across the landscape as a whole, and should improve the effective use of available forage. Cost is a major consideration when reducing paddock size. Fencing costs per km^2 escalate rapidly for paddocks smaller than about 30-40 km^2, and developing paddocks smaller than this may be hard to justify solely on the grounds of improving grazing distribution.

For more productive areas with higher carrying capacities, smaller paddock sizes are likely to be warranted in order to better manage stocking rates and have mobs of a manageable size. Smaller paddocks facilitate the use of other management options (e.g. controlled mating, supplementing particular animal classes) and in some circumstances may reduce operating costs. Having a greater number of smaller paddocks increases the opportunities for pasture spelling, makes mustering easier and facilitates the use of prescribed fire.

Smaller paddocks do not result in completely even use within a paddock. Some areas may still not receive much use, and some areas will be heavily used due to the presence of preferred species and land types, or shade. However, the rate at which overgrazed areas increase in size should be slower with smaller paddocks.

Conclusions

- Additional water points can enable the grazing of previously un- or under-utilised areas, increasing carrying capacity.
- Smaller paddocks enable cattle to be more evenly distributed over the available area.
- Increasing the number of water points lowers the number of cattle per water point reducing degradation around each water point
- Grazing-sensitive species may be lost from previously water-remote and thus ungrazed areas.

Stocking rates

Stocking rate is the major driver of both production and environmental impacts. There are two important aspects – the overall level, and the amount of variation through time.

There have been many stocking rate trials and the general response of animal production to stocking rate is well known (Jones and Sandland 1974) although there are debates (Ash and Stafford Smith 1996) about how relevant this is to rangelands. As stocking rate rises, production per head declines; production per hectare initially increases but reaches a maximum and then declines. In most trials the highest stocking rate used has been below the stocking rate giving maximum animal production per hectare.

Production per hectare is a major component of financial returns and hence stocking rate is related to financial performance. The results from a large, long-term grazing trial at Wambiana near Charters Towers show how growing season affects the financial response to stocking rate (Table 1). In Years 1-4 and 11-12 with high rainfall, gross margins were greater at the heavy than the moderate stocking rate. However in the low rainfall Years 5-10, the gross margins were higher at the moderate stocking rate and this was also true for the whole 12 year period.

Table 1. Gross margins ($/ha) for grazing strategies at Wambiana (from O'Reagain *et al*. 2011).

	Years 1-4	Years 5-10	Years 11-12	Years 1-12
Annual rainfall	776	434	1073	654
Heavy stocking rate	34	-17	20	6
Moderate stocking rate	21	11	15	15
Variable stocking rate	30	4	16	14

Detrimental environmental effects [lower ground cover, loss of 3P (palatable, perennial and productive) grasses, etc.] increase as stocking rates increase and there is a need to balance production increases and environmental impacts.

Even if stock numbers are near the long-term carrying capacity there can be a need to adjust stock numbers in response to poor seasonal conditions. There are two broad approaches - stocking conservatively to rarely run out of feed but potentially foregoing income in above-average years, or varying animal numbers to match expected forage supply with greater associated risks. There are few experimental data on the relative merits of these alternative approaches as most experiments used either fixed stocking rates (variable utilisation) or variable stocking rates (fixed utilisation) and only the Pigeon Hole and Wambiana projects compared the two approaches. There was little difference between the two approaches at Pigeon Hole. There was only a small financial benefit (a return on invested capital of 8.7% versus 8.1% respectively) and no benefit for land condition and pastures (although this may reflect the short duration of the trial). In the variable treatment at Wambiana, animal numbers were changed each year at the end of the growing season. The variable stocking rate strategy did not produce any better financial return than moderate set stocking (Table 1) and there was a high risk (both financial and ecological) in the transition between good and poor years (O'Reagain *et al*. 2011).

Conclusions

There is evidence that moderate stocking rates give a better overall performance than high stocking rates. There is little experimental evidence that variable stocking performs better than set stocking at a moderate rate. Modelling provides further information on the relative benefits of variable and set stocking rates (Scanlan *et al*. 2011).

Pasture resting or spelling

Pastures in poor condition produce less herbage than pastures in good condition. There has been some decline in pasture condition in many regions and there is a lot of interest in the role of pasture resting in restoring condition. There are three aspects of rest – season, duration and frequency (number of rest periods).

Season

Grasses are susceptible to heavy grazing when they are regrowing at the start of the growing season. Ash and McIvor (1998) showed that plots that were heavily grazed in the early growing season produced only 60% of the yield of plots that were only lightly grazed at this time. In contrast, level of utilisation (i.e. the percentage of the forage grown that is eaten) during the dry season had no impact on yield and composition while effects of utilisation during the late growing season were intermediate.

A number of studies have shown that resting during the growing season can produce desirable pasture changes. For example, in the Ecograze trial near Charters Towers, resting for 8 weeks at the start of the growing season each year led to higher yields (and proportions in the pasture) of the 3P grasses compared with continuous grazing (Table 2). Yields with 50% utilisation and pasture rest were similar to those with 25% utilisation and no rest.

Table 2. Yields (kg/ha) of 3P grasses on continuously grazed and rested plots in the final year of the Ecograze project for plots grazed to utilise 25 or 50% of the forage on land initially in good or fair condition (from Ash *et al*. 2011).

Pasture condition	Utilisation (%)	Continuous (no rest)	Rest
Good	25	2060	[A]
	50	1250	1730
Fair	25	1910	2010
	50	600	1720

[A]There was no treatment of 25% utilisation and pasture rest for the good condition plots.

The experimental data, although limited, indicate that resting during the wet season and particularly during the early growing season when grasses are most susceptible to heavy defoliation is important for encouraging 3P grasses. Rest during the dry season may also be useful for maintaining ground cover, improving rainfall infiltration for the following growing season, preventing repeated grazing of regrowing shoots, and preventing the removal of aerial buds on grasses.

Duration

The duration of a rest period is a balance between the benefit to the pasture (greater benefits with longer rests) and the loss of grazing combined with the lower quality of the accumulated herbage (greater losses with longer rests). Most trials have not compared different durations of rest. One of the few that did was the study by Orr and Paton (1997) where 4 and 6 months wet season rest gave a greater response (more spear grass and less wire grass) than no rest or 2 months rest.

Frequency (number of rest periods)

Like the duration of rest periods, the number of rest periods is a trade-off between the benefit to the pasture and the amount of foregone grazing. There is limited experimental evidence but general agreement that as land condition declines, pastures need more rest if land condition is to be improved. Responses to rest are much less in below-average rainfall years compared with average or good years, perhaps not unexpectedly, so cost-effectiveness is likely to be greater in better years.

There are no experiments in northern Australia that have examined the number of rest periods needed to achieve a particular goal. However there is a body of evidence from the experiment of Orr and Paton (1997) and short-term and long-term exclosure studies that provides some guidance. The limited evidence indicates that two or more consecutive rest periods results in a greater improvement than a single rest period; this may be linked to the time required for previously overgrazed plants to recover, set seed and for those seeds to establish and grow into new tussocks.

Conclusions

Most response to resting seems to occur in the early part of the growing season, so the duration of rest period should be a minimum of 8 weeks from the start of effective growth. However, a full wet season rest may be more practical to manage and, perhaps, more cost-effective in some situations.

There is low confidence in predicting the rate of recovery and cost effectiveness of using resting to improve land condition in many land types. However, our current “best-bet” guide is that pastures need two growing season rests to improve by one ABCD condition class. Where growing conditions are poor, more rest periods will be required. This topic is being studied in a new experiment that commenced in 2010 (MLA B.NBP0555 Spelling strategies for recovery of pasture condition).

The stocking rate used in conjunction with resting will be critical for success. If stocking rates are not matched to feed supply and pastures are overgrazed, minimal gains will be made with resting. The benefits of resting must be balanced by the foregone grazing on the rested area and impacts of increased grazing on the pastures where stocking rates are increased to carry the animals from the rested pastures. Most experimental studies do not consider the whole system - only the pastures being rested - but this issue is explored in Scanlan *et al*. (2011).

Fire to manage tree/grass balance

There are concerns about increases in the density of trees and shrubs in many areas of northern Australia. Interactions between trees and grasses are influenced by many factors but fire is one of the few under the control of management. There has been a lot of research on fire in northern Australia (>800 papers) providing general conclusions (e.g. relationships between tree height and mortality, and between fuel load and fire intensity) and showing that fire can be used to influence tree/grass balance. However, it is difficult to apply the general conclusions to a particular situation as there are many factors to consider – tree species, fuel loads, weather conditions, pre- and post-grazing, etc. Fire-grazing-weather interactions remain a major knowledge gap and local knowledge will always be important in successful implementation of fire regimes.

Where fire is used it is essential there is a clear understanding of the purpose of the fire, and that the cost of fire both in terms of direct costs and foregone grazing (both pre- and post-fire) is considered. One-off low-intensity fires generate costs, both direct control costs and foregone grazing due to lost forage, which may not be offset by benefits. Excess forage grown in high rainfall seasons may provide an opportunity to implement a planned fire with reduced impact through loss of forage.

Discussion

There is a lot of experimental evidence on grazing management but this information is sometimes difficult to apply (e.g. relevance of stocking rate results from small plots) and often does not apply to whole systems (e.g. pasture resting). Experiments always have limitations (plot size, duration, one sequence of seasons, local conditions, limited treatments, replication, etc.). The combination of experimentation with bio-economic modelling is a potentially powerful tool enabling the longer term consequences of management to be predicted, and the impacts of a range of seasonal conditions to be explored (Scanlan *et al*. 2011). While these offer promise of better information for grazing management in the future there will always be a need to test and demonstrate any recommendations locally to ensure they are appropriate.

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Grazing management options for improving profitability and sustainability. 2. Modelling to predict biological and financial outcomes

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***Abstract*.** A bio-economic modelling framework was developed to examine biophysical and economic impacts of several grazing management practices at a property level. These practices were: stocking rates and their adjustment; pasture resting and burning to manage unwanted woody growth.

In general, stocking at or slightly below the long-term safe carrying capacity gave good pasture condition and good economic performance, compared to high stocking rates. Systems which limited annual changes in stock numbers to a modest increase (~10%) and a larger decrease (~40%) appear to give better economic performance and still maintain good pasture condition. However, a protracted sequence of poor years can lead to a large drop in animal numbers and with a slow build-up, the economic performance can be unsatisfactory. Pasture resting simulations showed that frequent and long rests were the most beneficial to pasture condition. Resting paddocks for 6 months, once every 4 years, was profitable and allowed pasture to improve if cattle were agisted. If cattle were 'loaded up' into other paddocks on the property, then some paddocks can suffer long-term damage. At moderate levels of woody cover and moderate rates of tree growth in reasonably productive land types, burning improved economic performance. A burn every 4 years may be sufficient to maintain woody cover at an acceptable level and maintain animal production and economic performance.

This work has supported the findings of the review of literature by McIvor *et al.* (2011). More thorough analyses of completed trials and improvements in the ability of the framework to analyse real-world management practices are needed to gain further insights.

Introduction

Key challenges facing north Australian beef enterprises are discussed by McIvor *et al*. (2011). While many of these issues have been subject to field research, the results can be difficult to extrapolate beyond the location and the climatic window over which the trials were undertaken. Simulation modelling can extend the findings to assess the impact of different climatic conditions, location and land type on those results. Compared to undertaking additional field trials, modelling is inexpensive. MLA project B.NBP.0578 (Enhancing adoption of improved grazing and fire management practices in northern Australia: Bio-economic analysis and regional assessment of management options) has examined the biological and economic impacts of stocking rate, wet season resting and burning for a wide range of land types across northern Australia (Scanlan and McIvor 2010). This paper summarises key findings from that work.

Methodology

Biophysical responses

The GRASP pasture model has been used to explore a wide range of issues from assessing safe carrying capacities for properties (Johnston *et al.* 1996) to examining effects of climate change on extensive grazing lands (McKeon *et al.* 2008). GRASP was modified to investigate 3 key practices - stocking rate strategies, resting and use of fire:

- Simulating different degrees of change in annual stocking rate, to enable simulation of all possible combinations from fixed stocking rate to a fully responsive strategy (where stock numbers were set after the wet season to consume a fixed proportion of feed on offer);

- Simulating changes in grass basal area on a monthly basis to determine the impact of resting or heavy grazing during the growing season;
- Including a simple woody plant growth model; and
- Relating the impact of burning on woody plants to the fuel load (as an indicator of fire intensity).

Several major land types were examined at seven locations: Mitchell, Longreach, Duaringa and Charters Towers in Queensland; Barkly Tablelands and Victoria River District in the NT; and Fitzroy Crossing in the Kimberley Region of WA. For each land type, we simulated the effect of:

- a range of fixed stocking rates;
- a range of flexibilities in annual adjustments of stocking rate;
- different lengths and frequencies of wet season rests; and
- stocking rate on likely frequency of fires and their impact on woody plant basal area.

Simulations of biophysical responses used 20 different climatic windows (each of 30 years duration) to ensure that results are not specific to a particular climate sequence.

Economic assessment

Producer and technical workshops in each location developed a representative beef breeding enterprise consisting of a number of paddocks (≤ 20 each with one land type per paddock) and an animal production system (e.g. selling all weaners or selling bullocks). No steer trading businesses were simulated. A variant of the ENTERPRISE herd economic model (MacLeod and Ash 2001) was calibrated to represent the range of production systems developed at regional workshops. This provided total animal numbers and turnoff rates for each year of a simulation and estimated a number of profitability measures, including gross margins, net profit and year-to-year variability for a property for simulation runs over a selected period (~30 years). Key inputs to the economic model are stocking rate and potential liveweight gain per animal, derived from GRASP which was run separately for each paddock with paddock-specific management parameters for each stocking rate, resting and/or burning regime.

Results and Discussion

Stocking rate

Stocking rate is the fundamental management issue for any grazing enterprise. If this is not appropriate for the conditions (seasons, land condition and land types), then other management options are unlikely to overcome the resulting problems. For both practical and financial reasons many landholders in northern Australia do not vary their stock numbers from year to year by a large amount, except during drought periods. While absolutely fixed stocking rates are rarely practiced, it is useful in modelling to examine what happens at the extremes i.e. from fixed stocking to a fully responsive strategy where numbers are changed each year in direct proportion to forage availability.

Fixed stocking rates have to be low enough for adverse impacts of poor seasons to be limited so that pastures can recover. Under a fully responsive strategy, stock numbers can vary widely from year to year (e.g. by an order of magnitude). This may be achievable for a trading operation (e.g. annual purchases of steers) but is typically impractical for breeding enterprises. Some variation could be achieved by buying breeders to take advantage of season feed surpluses but this is not often done. Rather than changing the herd genetics by introducing new breeding animals from another genetic source, any shortage in breeders would most likely be met by keeping the oldest breeder cohorts (instead of culling) and not culling dry cows. In extreme cases (a very good year after a drought period), this would not be sufficient to meet the increased potential carrying capacity of the property in that year. Therefore, some year-to-year variation in herd numbers typically occurs. An important question is how much should numbers be varied from one year to another to maintain pasture condition and give good financial returns.

Using simulations for the VRD (NT) as an example, increasing flexibility led to greater changes from initial stocking rates over the experimental period, especially for very high and very low initial rates (Fig. 1a). This resulted in the percent perennials being higher when initial stocking rates were low (7 AE/100ha) and flexibility was higher (Fig. 1b). The economic performance also showed improvement with increased flexibility (Table 1). In simulations for some other regions across northern Australia, the fully flexible stocking strategy had a poorer economic performance than in the VRD, due largely to the economic impact of the herd dynamics issues during poor seasons. Further simulations undertaken suggest that a promising strategy may be a flexible stocking regime based on limiting annual increases to 10% per year and allowing annual decreases to be up to 40% (Pahl *et al*. 2011). This maintains good pasture condition with a better financial return than fixed stocking and is also better than either low flexibility or very high flexibility.

a) b)

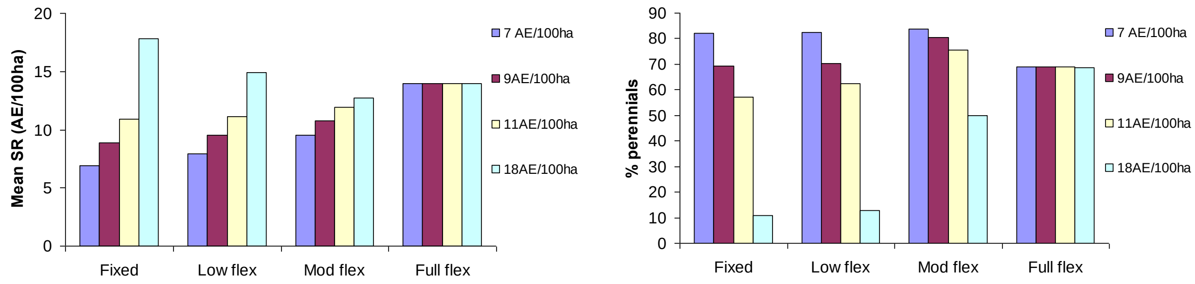

Fig 1. Simulation results for the influence of initial stocking rates and flexibility strategies on (a) mean stocking rates and (b) percent perennials for a clay soil land type in Victoria River District, Northern Territory. (*Low flex* ± 10% annual variation with maximum ± 30% over experimental period; *Mod flex* - ± 40% annual variation with maximum ± 80% over experimental period. Means are for 20 different climate windows each of 30 years).

Table 1. Simulated gross margin per adult equivalent for the VRD representative property (NT) under various stocking rate flexibility strategies (1981-2006).

Gross margin $/AE	Fixed	Low flexibility	Mod flexibility	Full flexibility
Average	$60.86	$72.72	$123.84	$152.22
Minimum	-$1.37	$15.08	-$12.81	-$22.39
Maximum	$124.41	$177.53	$458.94	$913.22
No. years negative	1	0	2	3

Pasture resting

Key questions relating to pasture resting are how long and how often (McIvor *et al.* 2011). The simulation results from all regions suggest that the longer the resting period, the greater the improvement in pasture condition, as shown for the Burdekin region (Fig. 2a). Similarly, the more frequent the rest, the greater the improvement (Fig. 2b). Property-level simulations of a resting regime from another region (Maranoa - 4-paddock rotation with a 6-month rest) showed an overall improvement of 15% in gross margin (Table 2). Further modelling (data not shown) has indicated that shorter, more frequent rest (e.g. a 4-year system with consecutive years with 3-month rest, followed by 2 years of normal grazing) may give greater improvement than longer, less frequent rests (1 rest of 6 months every 4th year), even though the total rest period is the same.

An additional question examined by simulation is what happens when the cattle from the rested paddock are spread to the other paddocks that are also part of the resting regime. These pastures risk being damaged by heavier grazing pressures during the summer period when tropical grasses are most sensitive to overgrazing. A 4-paddock system was simulated where each paddock received a 6-month rest from 1st December each 4th year and the stock were evenly distributed across the remaining three paddocks. All paddocks started with 20% perennials (poor condition) with the simulation run from 1976 to 2005. The results (Fig. 3) highlighted a potential problem - pasture condition in the last paddock to be rested (pdk4) suffered deterioration because it initially received 3 years of heavy summer grazing pressure before its first rest period. Scanlan *et al.* (2011) suggest a possible solution may be to agist cattle during the first 4-year cycle. Regardless of how resting is implemented it is essential that the stocking rate be chosen carefully - too high between rests, pasture condition will not improve (21 AE/100ha; Fig. 1a); too low, then even paddocks that are never rested will improve in condition and resting may not be needed.

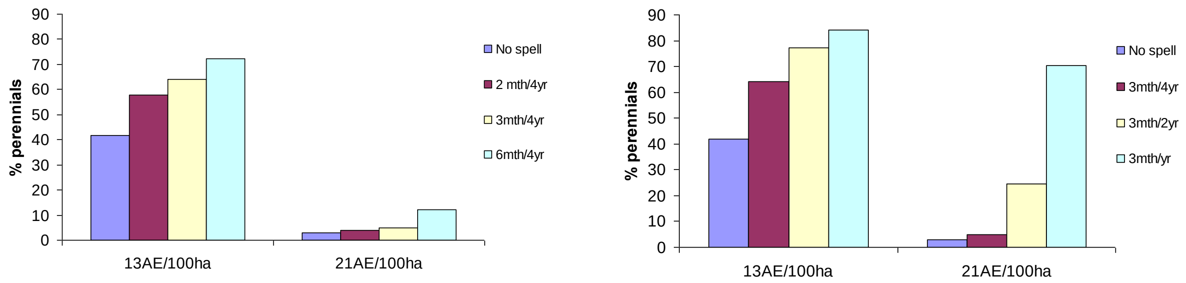

Fig 2. Simulated mean percent perennials showing the influence of (a) stocking rate and length of resting period for a 1 in 4 year rest, and (b) stocking rates and frequency of a 3-month rest for a goldfields land type in Burdekin region of north Queensland. (Means are for 20 different climate windows each of 30 years).

Table 2. Gross margin and property profit for the Maranoa property in southern Queensland without resting and with 4 of 7 paddocks receiving a 6-month rest every 4 years during 1981-2006.

	No rest	Rest 1 in 4 years
Average gross margin/ha	$24.16	$27.62
Minimum gross margin/ha	$14.17	$15.51
Maximum gross margin/ha	$47.16	$60.67
Profit (Net Present Value @ 4%) per property	$3.26m	$4.39m

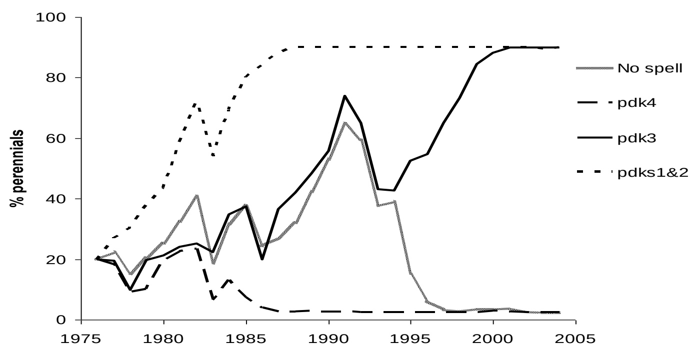

Fig 3. Change in % perennials in a 4 paddock resting system, each receiving a 6-month rest every 4th year. Cattle from the rested paddock are evenly distributed across the remaining 3 paddocks during the rest (for a Mitchell grassland at Longreach, Qld.)

Burning

McIvor *et al.* (2011) highlight the difficulty of generalising the response to burning for reducing woody plant cover. The more productive the land type, the greater the opportunity for a hot fire that will damage woody plants. As grazing pressure increases, opportunities for obtaining a hot fire reduce. For a given stocking rate, presence of trees reduces the potential burning frequency. All these responses are due to reduced potential fuel loads and, therefore, reduced fire intensity.

Simulations for a representative property in the Burdekin region of Queensland (where 4 paddocks were in a fixed-rotation burning regime of once in 4 years) indicate a small improvement in financial return when stock numbers were not altered during the simulation period ($9.81/ha for no burning compared with $10.21/ha when burning implemented - Table 3). Burning may reduce woody plant cover; another simulation allowed the stocking rate to increase to take advantage of the increased pasture production. This showed further improvement in gross margin (up to $14.60/ha).

Table 3. Average, minimum, and maximum values of gross margin/ha under nil burn and burn strategies applied to 4 poor condition paddocks for a representative property in the Burdekin region of north Queensland, 1980 to 2005.

	No burn+Fixed SR	Burn+Fixed SR	Burn+SR increase
Average	$9.81	$10.21	$14.60
Minimum	$3.59	$4.03	$3.03
Maximum	$14.76	$15.00	$27.70

Conclusions

Simulation experiments have supported the findings of field trials and observations made by land managers that getting the overall stocking rate right is critical to managing land condition, animal production and economic performance. While conservative stocking at the long term safe carrying capacity can give good financial returns, there is scope for improvement by practicing some year-to-year variation in stock numbers. One promising strategy appears to be an annual maximum increase in response to good pasture growth limited to 10% and a maximum annual decrease of 40% in response to poor conditions; another is to make stocking rate decisions more than once per year (O'Reagain and Scanlan 2011).

Pasture resting improves poor condition pastures and combined with modest increases in stock numbers to use the additional forage produced, also improves economic performance. Appropriate stocking rates during the non-rest period are essential. The resting regime used for simulations was rigidly applied, and the paddock that was last to receive a rest deteriorated further. Astute managers could overcome this problem by allocating the stock that must be moved during the resting of one paddock to other paddocks on the capacity of those paddocks to carry the additional numbers during the rest period. Additionally, resting would not necessarily start on a fixed date, although logistics may require cattle to be moved before the start of the wet season. In years when the outlook for the following wet season is also poor, the resting regime might be suspended for a year.

The impacts of burning on woody plant cover vary with land type, climatic conditions, stocking rate and the species of woody plants to be managed. Modelling can suggest the feasibility of burning as a management option. The difference between ecological thresholds in relation to woody plant cover and the economic thresholds are being explored, and it is likely that the threshold at which control is required from an ecological perspective will be much lower than the threshold at which economic factors dictate the need for control.

Limitations to modelling

Modelling is useful in investigating management options, but there are methodological limitations to the current bio-economic framework. Fixed rules are employed for the whole of simulation period, so that for the same set of conditions, the same 'decision' is made every year. Usually there is only one decision point per year e.g. stocking rate is determined on 1st June and set for the following 12-

month period. Modelling of pasture rest used rigid rules for when resting started; producers can do better by advancing/delaying resting depending on the season, and not undertaking the resting program in poor years. The biophysical model is presently run for the complete period and the economics/herd modelling then uses that output. Ideally, each model would directly inform decisions made in the other model each year. Despite these limitations, modelling is a very useful tool to complement field experiments in the study of grazing management options.

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Grazing systems - insights from studies in northern Australia

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Abstract. A range of grazing systems from continuous stocking to intensive cells is practised across the northern beef industry in attempts to improve environmental and economic performance. Producer initiated research into the inputs and outcomes of the three broad systems of continuous with spelling, rotational (including wet season spelling) and cells on commercial properties has been conducted within 9 commercial properties in Queensland and within a large-scale research trial in the Northern Territory.

Across all sites there was negligible effect of the grazing system on pasture attributes such as production, composition and cover or on soil surface conditions. Trends in pasture were dominated by seasonal conditions, with pastures in all systems responding well to better rainfall conditions. There was no consistent difference in grazing days per ha due to grazing system. Diet quality measured by faecal NIRS was lower in the more intensive systems, especially during the growing season. Intensive systems did not lead to improved pasture condition, ecological services, or increased carrying capacity. In the NT study there were no consistent effects of grazing system on livestock production.

The integrated management of paddocks across systems, on each of the commercial properties studied, suggests that key management principles, such as matching stocking rate to carrying capacity, were applied to all paddocks. This may help explain the lack of impact of grazing system per se and suggests stocking rate management and seasonal conditions, and not grazing system are the major drivers of pasture and animal productivity in northern Australia. Because of the apparent lack of livestock production improvements from the use of intensive rotational grazing systems, the higher capital and operating costs associated with these systems may reduce profits. However, it may be possible in some cases for these increased costs to be offset by other management improvements.

Introduction

Beef producers face increasing environmental and financial pressures to remain productive and viable. While some past cases of deteriorating condition of grazing land have been clearly linked to poor management of stocking rate, there has been increasing interest and investment in intensive grazing systems, especially cell grazing, which provide greater control of the location, duration, intensity and timing of grazing. Part of the attraction of such systems is their perceived potential to increase stocking rates (relative to continuous grazing), improve land condition, and enhance animal performance due to factors such as improved spatial distribution of grazing, long spell periods, and maintaining pasture in a vegetative state. While interest in more intensive grazing systems has grown, there are mixed views over their benefits and their suitability for different environments, levels of property infrastructure, management capacities and lifestyle preferences.

The management and infrastructure requirements of grazing systems can be viewed as a continuum from low-input continuous grazing, through rotational systems, to intensive 'cell' systems. Where along this continuum is the most appropriate place for any particular enterprise? There have been many studies of grazing systems in many countries. Briske *et al.* (2008) reviewed the results of research on rotational grazing systems and found there was no evidence of superior plant and animal production from rotational systems compared to continuous systems. Two recent studies in northern Australia conducted on commercial properties provide some information and are described in this paper. In the first, a range of commercial grazing systems (continuous, rotational, cell) were compared on 9 properties in Queensland, and in the second, four grazing systems were compared in a large experiment in the Victoria River district of the Northern Territory.

Methods

In Queensland, 9 properties were monitored, with each operating at least two of the broad systems – continuous, rotational and cell. Sites were located in both north and south Queensland (regions), including both brigalow (more fertile soils) and eucalypt (lower fertility) land types. There was 12,660 ha monitored in 74 paddocks (54 cell, 13 rotation and seven continuous) across 21 grazing systems (eight cells, six rotational and seven continuous) from 2005-06 to 2008-09. The property owners made all management decisions and conducted all operations. The intensive grazing systems have been in place for up to 13 years prior to the study. Paddocks were monitored for pastures using Botanal techniques (Tothill *et al.* 1992), soil surface conditions (based on Tongway and Hindley 2004) and animal grazing records. Diet quality from systems was analysed by faecal NIRS (Coates 1999) from approximately monthly samples. At all sites monitoring covered two drought years followed by two average to above-average rainfall years. Site locations are shown in Fig. 1.

The NT study was on the Wave Hill land system (predominantly cracking black clay soils) at Pigeon Hole Station and compared the performance of set stocking, set utilisation (20% annual utilisation), wet season spelling and cell grazing systems over four years. Pastures were a mix of perennial and annual grasses and forbs. The set stocking and set utilisation treatments occurred in single paddocks of approximately 21 km2. Wet season spelling used a group of three 5 km2 paddocks with the herd being rotated amongst the paddocks to allow spelling. Cell grazing used an area of 33 km2 subdivided (by electric fencing) into 25 paddocks each of 1 to 1.5 km2. The paddocks were stocked with Brahman breeder cattle. Pasture and livestock performance and effects on biodiversity were assessed twice yearly. Seasonal conditions were moderate to good for the duration of the study.

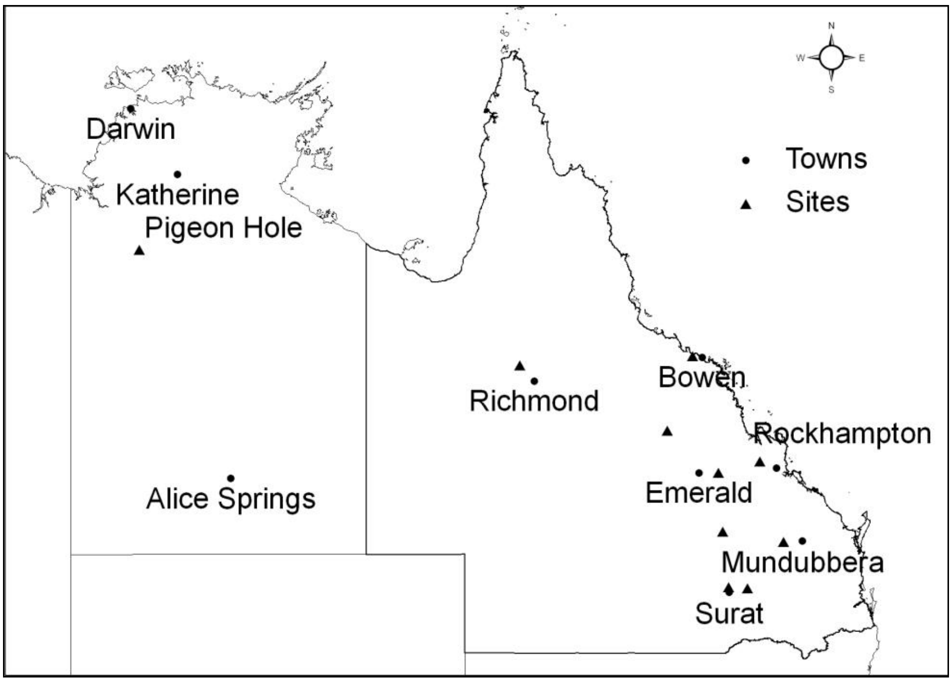

Fig. 1. Location of grazing system project sites in Queensland (GSP) and Pigeon Hole, Northern Territory.

Results

Queensland

Pastures. Over all sites in Queensland, there were few significant effects of grazing system on pasture attributes, soil surface conditions, land condition or annual grazing imposed (Table 1). However, there were land condition improvements at some sites over the four years which were related to the higher rainfall seasons of the final two years. These changes were not related to the grazing system. Differences in pastures were primarily driven by variation in year-to-year rainfall. After two years of higher rainfall, there were increases over all sites in pasture yield (by 69%), ground cover (24%) and litter cover (47%) in all pasture types, across all systems, compared to those measured in the autumn of 2006.

There were only small differences in pasture diversity among grazing systems with the cell systems being less diverse, with fewer species per quadrat, than rotational and continuous systems. The buffel grass-dominated sites were less diverse than native pasture sites. The continuous paddocks had more variable utilisation than other systems, with most uniform utilisation in the cells. However, this did not translate into any consistent effects on paddock uniformity in the LFA indices for stability, infiltration or nutrient cycling across paddocks, between systems, vegetation types or regions.

Table 1. Mean pasture, animal and land condition parameters in three grazing systems on nine properties over four years in Queensland.

Measurement	Cell	Rotation	Continuous	Difference*
Pasture				
Yield (kg/ha)	2519	2403	2307	ns
Perennial grass (%)	97	93	95	*; Rot<Cell
Diversity (no spp 90% yield)	2.3	3.3	3.6	ns
Dominant spp contrib'n. % to yield	83	75	76	*; Rot<Cell
Ground cover (%)	61	64	59	ns
Litter cover (%)	21	22	18	ns
Animal				
Grazing days per ha (SDH)	87	69	86	ns
Grazing pressure (GD/1000 kg)	41	33	45	NA
Utilisation (0-30%)	93	90	83	ns
Land condition				
LFA stability	61	61	60	ns
LFA infiltration	39	40	39	ns
LFA nutrient cycling	31	32	31	ns
Land condition (% in LC1+LC2)	67	65	63	ns

*This across site analysis presents main effect results ignoring any system * year interactions.

Cattle grazing. Over nine sites there was no significant difference between systems in the grazing pressure imposed, with and av. of 80 stock days per ha per year (SDH). However, there was a wide range of grazing imposed between systems, sites and years (Table 2). Within 4 properties, there were some large differences in grazing pressure between systems but the ranking of systems in SDH varied across sites. The average grazing of rotational pastures over all sites was 81% of that in the cell and continuous systems. This is the same percentage difference as the calculated LTCC difference (82%) between the rotation paddocks and the average of the cell and continuous system paddocks. The grazing in rotation systems was reduced at two sites due to drought management strategies and woody regrowth control. There was a significant difference in average grazing between years at seven of the nine sites in Queensland.

Table 2. Average grazing pressure (SDH) in three grazing systems over four years at nine sites in Queensland (back transformed means).

Sites	1	2	3	4	5	6	7	8	9	Mean
GS signif.	ns	ns	**	ns	*	ns	*	ns	**	ns
Cell	107	83	80	107		146	23	146	87	87
Rotation		96	156	99	66		12		36	69
Continuous	103	87	175	85	92	91		138		86
Year signif.	*	ns	*	*	ns	*	**	**	**	ns
2005-06	97	78	187	76	80	154	11	57	83	75
2006-07	103	95	89	95	86	102	33	181	90	88
2007-08	130	114	159	97	62	81	14	185	16	72
2008-09	94	73	108	125	89	137		209	82	89
GS x Year signif.	P=0.08	ns	*	**	ns	ns	**	ns	**	ns

Diet quality. The faecal NIRS analyses showed that cattle in continuous systems had higher diet quality (crude protein and digestibility) than those grazing cell pastures, with the diet in rotations intermediate. Diet quality differences were greatest between systems during periods of good pasture growth (growth index>0.5) (Fig. 2).

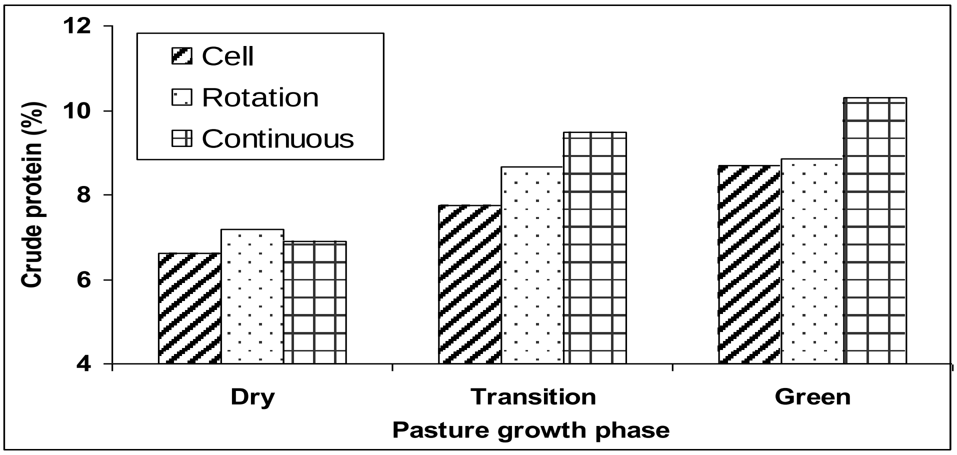

Fig. 2. Faecal NIRS crude protein (%) in three systems at three pasture growth index (GI) levels (means of 565 samples over four years).

Northern Territory

There were no marked differences in the performance of the four grazing systems with respect to pasture yield (measured post wet season) and perennial grass basal area, but there was a trend of increasing ground cover under wet season spelling (although this might be confounded with a pre-study fire at the site). Pasture species composition appeared to be unaffected by grazing system. There were significant differences in yield and ground cover amongst years in all systems which were attributed to rainfall.

Although there were year-to-year differences in the relative performance of the grazing systems in terms of livestock production (i.e. liveweight gain, mortality and various reproduction parameters) the systems did not show any consistent differences in livestock production.

Set pasture utilisation (at ~20% annual use) was the best performing system in economic terms with a return on invested capital of 8.7% (marginally better than set stocked; Table 3), and had no apparent adverse effects on land condition. Cell grazing was the least profitable system due to higher capital and operational costs.

There was no detectable effect of grazing system on biodiversity, although some fauna increased in ungrazed exclosures (Hunt *et al.* 2010).

Table 3. Financial comparison of grazing systems at Pigeon Hole Station in the Victoria River District, NT.

Financial indicator	Set stocked	Set utilisation (20%)	Wet season spelling	Cell grazing
Total capital costs ($/km2)	$15,915	$16,014	$18,038	$25,681
Stocking rate (AE/km2)	14.7	14.7	14.5	18.1
Operating costs ($/AE)	$49	$51	$49	$65
Gross returns ($/AE)	$152	$158	$158	$147
EBIT ($/AE)*	$93	$95	$97	$71
ROIC (%)**	8.1%	8.7%	6.8%	5.3%

* Earnings before interest and tax.

** Return on invested capital (before interest, replacement capital and tax).

Discussion

In all environments in the Queensland studies, we found that the grazing system had no consistent effect on pastures, soil surface conditions or carrying capacity. The between year differences were related to improved rainfall conditions and were not affected by the system. This supports other studies that have shown stocking rate management to be the major driver of pasture and animal productivity, rather than grazing system per se. In these studies, our ecological results suggest all systems on each property were managed equally well with respect to stocking rate and monitoring of pasture, soil and stock. In addition, the operation of each system varied over the four years as managers reacted to changing seasons and circumstances, and livestock were often grazed across different systems within a year, especially during dry periods. This would reinforce the extent to which all systems were 'well managed', although often at marginally higher rates than the calculated LTCC.

Although there was improved spatial distribution of grazing in the cell systems, this did not translate into any effect on the grazing days per ha per year imposed on paddocks. There were, however, instances of lower grazing days from rotational systems due, in part, to extraneous factors. Overall, there were similar numbers of stock days per hectare per year for paddocks within the cell and continuous systems (87 SDH over all sites). The within site system differences were not consistent. On average, cell and continuous paddocks were grazed above their objectively assessed long-term carrying capacity.

Grazing system did affect diet quality as estimated via faecal NIRS on some pastures, particularly on the native grass pastures. The more intensive systems had the lowest diet quality. Over all sites and seasons, the continuous system had 1-2% higher crude protein and digestibility than the cells, with diet estimates for the rotation systems consistently between those systems. These differences were largest during the growing season and likely reflect higher individual liveweight gains.

Overall, the results obtained on the relative performance of the grazing systems in the Northern Territory study were similar to those in Queensland, with no consistent effects of grazing system on land condition, livestock production or biodiversity. However, it should be acknowledged that this was a relatively short-term study so it is not known how the grazing systems might compare in the longer term. Nevertheless, seasonal conditions appeared to be the dominant influence on the productivity of each system, whilst capital and running costs determined the overall economic performance of the systems. Despite carrying more animals, higher costs made cell grazing the least profitable grazing system.

Part of the attraction of more intensive systems, such as cells, is their perceived potential to improve pasture and land condition, at a recognised lifestyle cost (Hall and Hall 2008), increase stocking rates and improve animal performance. This can happen, but is not necessarily due to the grazing method. Ecological benefits are mainly related to management of stocking rate and related factors that can be adequately controlled in less intensive systems. Other suggested benefits of intensive systems, such as quieter cattle, fewer labour units required to manage herds, the ease of supplementing or water medicating centralised trough systems and ease of feed-budgeting were not quantified in these studies. However, in the NT study the difficulties in managing the cell grazing system on the black clay soils (especially during the wet season) did result in increased operating costs for this system.

Conclusions

Grazing systems as used in northern Australia, are not specifically defined, but are variable and flexible between seasons and operators. All systems can be used similarly for all herd classes, with pasture and land condition improvement possible irrespective of the system, with seasonal conditions and stocking rate having an over-riding effect. Benefits of increasing intensification are, therefore, not directly related to the system influence on land condition, but accrue from better management of the whole beef business. Intensive systems need a different level of pasture knowledge, skills and training than more traditional management systems. Matching stock numbers to annual feed supply is the most critical decision in managing pastures and cattle performance and this applies equally to all systems. Seasonal conditions had a more dominant effect on pasture and land condition and on grazing capacity and diet quality than the actual grazing system. Initial capital outlays and ongoing operating costs will have an important influence on the financial performance of a particular grazing system.

Acknowledgements

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Genomics for the northern beef industry – past, present and future

ME Goddard

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Abstract. Genetic improvement of cattle is an important source of gain in the productivity of beef production. This improvement relies on genetic variation in our cattle and this variation is caused by differences between individual cattle in their DNA sequence. Recent advances in genomics has increased our ability to find differences in DNA sequence that cause differences in traits or are closely linked to such causal sequence variants. For some traits caused by a single gene, such as many genetic abnormalities, the change in sequence is known and can be used to select cattle carrying the desired alleles. For complex traits, controlled by many genes and by environmental factors, we can use genetic markers covering the whole genome to predict the genetic value of cattle for each trait. This method, called genomic selection, is very successful in dairy cattle but the accuracy in beef cattle is not as high as in dairy cattle because, to date, insufficient cattle that have been measured for the trait of interest and genotyped with a high density panel of markers or SNPs. The Beef CRC is currently undertaking a large experiment which will genotype 8000 cattle and estimate prediction equations for carcase traits, feed conversion efficiency and fertility. The predictions of genetic merit made from genetic markers will be incorporated into Breedplan EBVs so that cattle breeders can use the most accurate estimates of genetic merit when selecting bulls and cows.

Introduction

The genetic merit of cattle is an important determinant of profitability in beef cattle production. For instance, we have seen Shorthorns replaced with Brahmans in northern Australia because of their adaptability to the tropical environment and Herefords replaced by Angus in southern Australia due, in part, to their higher marbling. However, continuous improvement in productivity is necessary to keep up with the cost-price squeeze and to generate competitive returns to capital and labour. On-going genetic improvement is an opportunity to achieve some of these yearly productivity gains. The value of year after year genetic improvement is most clearly seen in the chicken meat industry. Broilers reach the same market weight at 5 weeks of age that they used to reach at 12 weeks (Havenstein *et al.* 1994). This gain in efficiency has transformed the chicken from a luxury product to the cheapest meat available. Genetic gains have also been very valuable for the dairy, lamb and pig industries. Beef cattle in Australia increase each year in profitability, on average, by about $2 per cow-year but some individual studs achieve yearly gains of $6 per cow-year. Unfortunately the rate of genetic gain in northern Australia is below the national average.

Genetic gain in all industries is generated by selecting the best animals as parents of the next generation. Here “best” means those with the most profitable offspring. The value that animals pass on to their offspring is called their breeding value and so the aim is to select those bulls and cows with the best breeding values for traits that determine profit. Breeding value can be estimated from records of each animal’s performance (eg weight gain) and pedigree and the resulting estimated breeding values (EBVs) are published by Breedplan.

Genetic differences between animals are due to differences in their DNA sequence. In a few cases we know which change in sequence causes a particular trait. For instance, the mutation that causes Pompe’s disease in cattle is known. However, most traits are not controlled by a single gene but are influenced by variation in the DNA sequence of many genes and by environmental factors. Unfortunately, we know few of the genes affecting these complex traits such as growth rate and fertility. In the cases where we do know variations in DNA sequence that affect a trait, this knowledge can be used to assess the breeding value of potential sires and dams and select the best.

For instance, if we know a bull is a carrier of Pompe's disease we know he will pass the mutant allele on to half his progeny. In this case the DNA test is particularly useful because the mutation causing Pompe's disease is recessive. This means that you can't tell be looking at a bull whether or not he is a carrier. DNA tests for complex traits are also most useful when it is difficult to assess an animal's breeding value from its own performance or appearance. For instance, bulls pass on genes for the fertility of their daughters but you cannot see the affect in the bull himself, so it would be very useful to have a DNA test that predicted the breeding value of bulls for cow fertility. Similarly, it is difficult to select for traits that can only be observed after the animal is dead (e.g. tenderness), or late in life (e.g. longevity), or are very expensive to measure (e.g. feed conversion efficiency).

Although we still don't know most of the genes affecting these complex traits, we now have a method, called genomic selection that allows us to predict the breeding value of animals from DNA tests. Recently, it has become possible to genotype cattle for many thousands of genetic markers. These markers, called single nucleotide polymorphisms (SNPs), cover the entire genome and so they allow us to track the genes for traits, such as fertility, even though the important genes are not known.

In this paper I will review DNA tests for single genes, then tests based on a small panel of genes and finally genomic selection based on thousands of SNPs. Finally I will discuss the use of these DNA tests and speculate about the future of the technology.

DNA tests for single genes

Mutations that are detrimental, or even fatal, occur frequently when sperm and eggs are produced. Natural selection will tend to eliminate these mutations but, if the mutation is recessive, it will initially occur only in carriers and so escape selection until a calf inherits a mutant allele from both its dam and sire. This can only occur if the dam and sire share a common ancestor. Therefore we see these abnormalities where a carrier bull was used widely so that the mutant allele now occurs in many of his descendants. When two carriers are mated, one quarter of the calves carry two copies of the mutant allele (i.e. are homozygous) and show the abnormality. DNA tests for these abnormalities, such as Pompe's disease (Dennis *et al.* 2000), are usually only developed after the mutant allele has become common. In that case, they are a useful way to identify carriers and eliminate the mutant allele from the population. An even more useful strategy is to minimise inbreeding because this keeps all recessive abnormalities rare.

In *Bos taurus* cattle, polled is predominantly due to a single gene and the polled allele is dominant to the allele for horns. In the past it has been hypothesised that this simple model did not apply to *Bos indicus* cattle. However, recent research shows that the same mutation causes polled in both subspecies. The actual mutation and gene causing polled has never been identified but markers linked to this mutation are known (Prayaga *et al.* 2009). The recent research has found a marker that is useful in Brahmans and some Brahman cross breeds. It is not a perfect guide to the polled gene but in 85% of polled animals the test will correctly distinguish between a homozygous or true poll and a heterozygous carrier of horns. This research has also discovered, in Brahmans, many heterozygotes that carry one horned allele and one polled allele, have scurs. Thus selecting against animals with scurs will also help to identify true polled Brahmans.

Several mutations in the myostatin gene are known to cause double muscling. For instance, in Belgium Blue cattle there is a mutation that deletes 11 nucleotides from the gene for myostatin causing the myostatin protein not to inhibit muscle growth as the normal protein does (Grobet *et al.* 1997). Consequently cattle carrying this mutation get excessive muscle growth. This is beneficial in that the yield of saleable meat from the carcase is increased but it is detrimental in that the double muscled cattle have a high incidence of calving difficulty. The mutation is partially recessive which means that the full double muscling phenotype is seen in homozygotes but heterozygotes have some increase in muscling. The same mutation that occurs in Belgium Blue cattle also occurs rarely in Angus, Shorthorn and Santa Gertrudis (O'Rourke *et al.* 2009). Therefore selection for increased muscling in these breeds can accidently select carriers of the double muscling mutation. Limousins have a different mutation in the myostatin gene that causes a less extreme form of double muscling

(Sellick *et al.* 2007). This mutant allele in heterozygous form might be useful. Heterozygotes could be produced by crossing bulls carrying the mutation to cows that are homozygous for the normal allele. There are DNA tests for 7 known mutations in the myostatin gene.

DNA tests for small panels of genes

Only 5 years ago it was hoped that 5-10 genes might explain half of the genetic variance in many complex traits. This caused researchers to look for a small panel of DNA tests that might be useful to select cattle for complex traits. We now know that most complex traits are controlled by 100's or even 1000's of genes and so, not surprisingly, small panels of DNA markers usually do not work. An exception is for tenderness (Johnston and Graser 2010). Pfizer Animal Genetics market a panel of 4 tests. The Beef CRC evaluated the test and found that the correlation between the test and genetic merit for tenderness in Brahman cattle was 0.3. Two of the genes in this test are calpastatin and calpain 1 which code for proteins controlling the breakdown of muscle fibres post-mortem and therefore effect tenderness. Cattle carrying favourable alleles at all 4 genes have a shear force 1 kg less than cattle that carry all unfavourable alleles. This in not a huge effect but it could make a difference to eating quality when cattle are near the border for acceptability.

Genomic selection

The availability of tests that genotype 1000's of SNPs at once has made genomic selection (Meuwissen *et al.* 2001) possible. Genomic selection relies on SNPs covering the whole genome densely enough so that all genes affecting a trait are close to one of the SNPs. If a trait gene and a SNP are close together on the chromosome they are likely to be in linkage disequilibrium (LD). LD is illustrated in Fig. 1 where chromosomes that carry the '+' allele at the trait gene usually carry the 'T' allele at the SNP and chromosomes that carry the '-' allele at the trait gene usually carry the 'C' allele at the SNP. Therefore it is possible to select for the '+' allele by selecting cattle carrying the 'T' allele at the SNP. This association between trait genes and SNPs may be repeated 1000's of times across the genome, so genomic selection uses all the SNPs to predict the combined effect of all the trait genes, that is, the breeding value of the animal. This prediction equation is derived from a large sample of animals that have been genotyped for the SNPs and measured for the trait (Hayes and Goddard 2010).

Breed 1			Breed 2
common	+	T	rare
rare	+	C	common
rare	-	T	common
common	-	C	rare

Fig. 1. Linkage disequilibrium in two breeds between a SNP with alleles T and C and a QTL with alleles + and -. Each line represents a chromosome type. Chromosomes carrying the +T haplotype are common in Breed 1 but rare in Breed 2.

In dairy cattle genomic selection has been spectacularly successful and the whole world's dairy industry is switching from progeny testing to genomic selection as the main method to evaluate bulls and cows. Several features of the dairy industry have assisted the development of accurate prediction equations based on SNPs. Large numbers of Holstein bulls exist that have an accurately known breeding value for milk production traits based on a progeny test. For instance, the USDA prediction equation is based on 14,000 progeny tested Holstein sires that have been genotyped for 50,000 SNPs. Their prediction equation predicts breeding value for milk production with an accuracy of 70%. That is, the correlation between the DNA prediction and true breeding value for milk production is 0.7.

The need for very large samples of animals in the reference population arises because most genes have very small effects on complex traits. Therefore very large sample sizes are needed to estimate these small effects with any accuracy. The small size of the effects is best illustrated from research in human genetics. Hana Lango *et al.* (2010) genotyped 180,000 people for 300,000 SNPs and discovered 180 genes affecting height. Collectively these genes explained 10% of the variance in height and the largest genes affected height by 3 mm.

So far it has been harder to derive accurate prediction equations in beef cattle than in dairy cattle for well understood reasons. In beef cattle it is difficult to obtain a reference population of the same size within one breed as in dairy cattle. Even in the USA there are probably not 14,000 Brahman bulls progeny tested for all important traits. The lack of progeny tested bulls has forced researchers to use the performance of individual animals instead of progeny test results to derive the prediction equation. Unfortunately, individual performance is not as good a guide to breeding value as a progeny test and so even larger samples sizes are necessary. To achieve the same accuracy as 14,000 progeny tested sires we would need 50,000 to 100,000 individually recorded cattle. We cannot achieve this within one breed and so the strategy of the Beef CRC has been to combine data from many breeds. However, this has another drawback. When 50,000 SNPs are used the association between trait genes and SNPs varies from breed to breed (deRoos *et al.* 2009). This is illustrated in Fig. 1. Consequently, a different prediction equation must be estimated for every breed. The problem arises because the SNPs are not dense enough and so the distance from a trait gene to the nearest SNP is too great to conserve the same association across breeds. Fortunately, an 800,000 SNP chip has become available and at this density of SNPs we expect to find associations between trait genes and SNPs that are consistent across breeds. This will allow us to use data on multiple breeds to derive a prediction equation that is useful across a range of breeds.

Commercial DNA tests based on the 50k SNP chip are currently available for Angus cattle from Pfizer in USA and Australia and from Igenity in USA. The American Angus Association reports the correlation between these tests and breeding value for a range of traits on its web site. The correlations are in the range 0.3-0.6. In Australia, AGBU has evaluated the Pfizer test in Angus and report correlations with breeding value ranging from 0.2 to 0.45 across a range of traits. The prediction equations were trained on USA data so it is not surprising that they perform better in USA than in Australia. No commercial 50k test is available for Brahmans or any beef breed other than Angus.

The Beef CRC has estimated predicted equations based on 50k SNP genotypes for many traits. For instance, a test based on 50k SNP genotypes to predict length of postpartum anoestrus in Brahman cows had a genetic correlation with pregnancy rate of approximately 0.3. Attempts to derive prediction equations that work in all breeds based on 50k SNP genotypes have not been successful and the analysis of the 800k data is just commencing as this paper is written.

Finding genes for complex traits

The same data that we use to derive prediction equations can also be used to map genes for complex traits in what is called a genome wide association study (GWAS). Since we have genotyped SNPs located across the whole genome we can detect places in the genome where SNPs are associated with a trait. When an association is found it implies there is a gene affecting that trait near to the SNP and in LD with it. For instance, in Brahmans we have found a gene that affects a large number of traits. One allele causes an increase in height and weight, reduction in fatness, increase in feed conversion efficiency and delay in puberty in both heifers and bulls. Thus the desirable allele at this gene might depend on whether it is in a cow herd or a terminal sire and whether or not you wanted to mate the heifers as yearlings or not.

Fig. 2 shows some of the data from a GWAS. Chromosome 1 is spread out across the x-axis and the y-axis shows the strength of the association between a SNP and the trait. Each spot on the graph represents one SNP. The results show that there are many genes affecting P8 fat depth in the carcase of Angus cattle even on this one chromosome. Each of the other 29 chromosomes presents a similar picture so the number of genes affecting fat depth must be large.

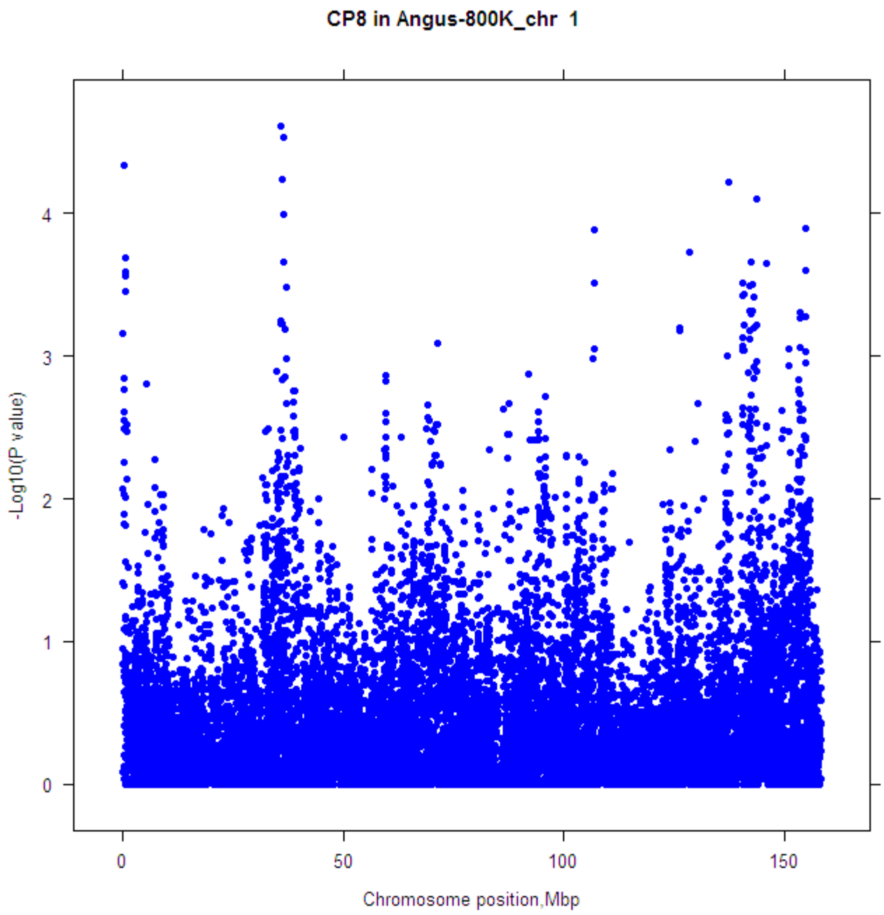

Fig. 2. SNPs on chromosome 1 affecting fat depth at the P8 site on the carcase. The x-axis is the position of the SNP on the chromosome and the y-axis is -log(p-value) so that a value of 3 means that the SNP effect was significant at p<0.001.

Using SNP genotypes in selection

The purpose of genetic markers such as SNPs is to estimate the breeding value of potential selection candidates. If a traditional EBV exists for the trait it is undesirable to have two imperfect estimates of the same breeding value. Therefore the most useful strategy is to combine the DNA data and the traditional data on performance and pedigree into a single EBV. This is the strategy that Breedplan is pursuing. In cases where a DNA test has been shown to be useful for predicting breeding value it is being incorporated into the EBV of the animal. This already occurs for tenderness and for several traits in Angus.

DNA tests are quite expensive and so the question arises as to whether the extra accuracy in EBVs is worth the cost. Van Eenennaam *et al.* (2010) investigated this and concluded that it would be profitable for a stud to DNA test young bulls provided the price of bulls fairly reflected their genetic merit. The best bulls could then be kept as stud bulls and the next best sold as herd bulls and the worst castrated. As the price drops or as the accuracy of the test improves it would be profitable to test stud heifers but the price would have to drop further to be attractive for commercial cattle.

The future

Prediction equations based on 800k SNP genotypes will be available shortly and should be more accurate and useful across more breeds than the 50k prediction equations. However, the 50k SNP chip (or a cheaper 6k SNP chip) will probably remain the commercial product because it is less expensive and it is possible to deduce or impute 800k genotypes from 50k genotypes within a breed provided that a sample of the breed has been genotyped with the 800k SNP chip. Even the 800k SNP chip is not perfect because it still contains genetic markers rather than the actual gene traits. Full genome sequence does contain all genetic variants including those that actually cause variation in complex traits and fortunately the cost of genome sequencing is dropping rapidly. Therefore future experiments are likely to use genome sequence data rather than SNP genotypes to find genes causing genetic variation and to use them to predict breeding value more accurately. This will greatly expand our understanding of the biology underlying economically important traits.

Stud herds could use DNA based tests for purposes other than estimation of breeding values. They already use them for confirming pedigree and to test for genetic abnormalities such as Pompe's disease and could use them to test for single genes such as polled. It is desirable that all these tests are performed on the same DNA sample by the same laboratory for the one low price. This should be possible in the near future and will make DNA tests more attractive to stud breeders.

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The genetics of whole herd profitability

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Abstract. Steer carcass performance and heifer age at puberty are moderately heritable in tropically adapted genotypes of beef cattle, and represent key drivers of profitability for beef production enterprises in Northern Australia. This study examined the degree to which selection to improve these traits would impact the genetics of cow body composition at the commencement of their second mating (M2), a critical period for benchmarking cow reproductive performance. Body composition measurements comprised liveweight, scanned P8 and 12/13th rib fat depth, scanned eye muscle area, body condition score and hip height collected at M2 for Brahman (BRAH) and Tropical Composite (TCOMP) cows. Corresponding steer carcass traits were measured in their half-sib brothers following feedlot finishing for 119 days. Cow data were limited to animals which would successfully wean their first calf and had age at puberty measurements. M2 traits were moderately to highly heritable (h^2 = 0.25 to 0.81). Least squares means contrasting M2 traits across genotypes showed that TCOMP cows were heavier than BRAH (430.6 and 390.2kg respectively), and that significant differences in eye muscle area (40.8 and 43.8cm^2 for BRAH and TCOMP respectively) and hip height (138.9 and 137.4cm for BRAH and TCOMP) were likely to be the key drivers for the liveweight difference. Genetic relationships between cow M2 body composition traits and age at puberty showed that TCOMP heifers which reached puberty earlier tended to be genetically fatter, with superior condition score and greater eye muscle area (r_g = -0.16 to -0.29), while M2 liveweight and hip height were not significantly correlated with age at puberty. For BRAH, only M2 eye muscle area had a significant genetic relationship with age at puberty (r_g = -0.30). Genetic correlations between M2 liveweight and eye muscle area, and the corresponding steer carcass traits were high for TCOMP (0.77 and 0.63 respectively). For measures of M2 fat depth in TCOMP, and all of these relationships for BRAH, genetic correlations were moderate though consistently positive (r_g = 0.11 to 0.43). These results show that selection to improve steer carcass traits and heifer age at puberty may influence the genetics of M2 body composition traits, and do so differently for BRAH and TCOMP.

Introduction

A components of the CRC for Beef Genetic Technologies research (Burrow and Bindon 2005) has sought to identify the degree to which commercially important carcass and meat quality traits and heifer age at puberty were subject to genetic control, and to examine the genetic relationships between these and descriptors of early steer and heifer performance in tropically adapted Brahman (BRAH) and Tropical composite (TCOMP) cattle. A key step in improving our understanding of the genetic influences on whole herd profitability is to examine the genetics of cow reproductive performance and the relationships of this with other commercially important heifer and steer traits. Barwick *et al.* (2009b) examined the genetics of heifer traits measured at the end of their first wet season following weaning (ENDWET) and the subsequent dry season (ENDDRY), and the genetic relationships of these with the steer traits described by Barwick *et al.* (2009a). BRAH heifers were faster-growing in the wet season, slower-growing in the dry season, lighter at ENDDRY, and taller and fatter at both ENDWET and ENDDRY than TCOMP. Genetic relationships between body composition measurements at ENDWET and ENDDRY were strong and positive for TCOMP, but tended to be low for BRAH, suggesting that the mechanisms controlling body condition under more stressful conditions (ENDDRY) may be different in BRAH than under the more benign conditions at ENDWET.

Johnston *et al.* (2009) examined the genetics of heifer puberty in the same females, and the relationships of this trait with the other heifer and steer measurements previously described. Age at puberty (AGECL) was moderately heritable. For BRAH, AGECL was moderately negatively genetically related to heifer measures of bodyweight, fatness, body condition score and IGF-I, at both ENDWET and ENDDRY, but was positively correlated with ENDDRY growth rate. BRAH also displayed a genetic correlation between age at puberty and steer net feed intake which described a significant antagonism between the two. Johnston *et al.* (2009) concluded that selection to improve AGECL could be undertaken effectively, but that evidence that different biological mechanisms controlled the trait would require separate genetic evaluations for BRAH and TCOMP. Subsequent research (Johnston *et al*. 2010) showed that the time from the commencement of the cows second mating to cycling (PPAI2) was also heritable and positively genetically correlated with AGECL in BRAH (0.34).

Wolcott *et al.* (2009) examined the genetics of carcass and meat quality traits in BRAH and TCOMP steers, and their relationships with earlier steer, and heifer measurements. As was observed by Barwick *et al.* (2009a) for steer feedlot exit traits, TCOMP displayed generally strong and positive genetic relationships between carcass measures of body composition and those assessed in steers through the grow-out and finishing phase, and heifers at ENDWET and ENDDRY; where this was not the case for BRAH. There were few strong genetic relationships between meat quality traits (tenderness, cooking loss and percent intra-muscular fat) and live steer and heifer traits. It was concluded that selection to improve meat quality in BRAH and TCOMP could be undertaken with little negative impact on steer and heifer production traits measured in the live animal.

Beyond the ENDDRY measurement time, the heifers examined for the studies described above remained at their respective research stations where they were joined to first calve as three year olds, and their reproductive performance and body composition monitored for a further 6 years. This study examined the genetics of female body composition at the key stage, as cows rear their first calf, and commence joining for the second time, and the genetic relationship between these traits and corresponding steer carcass traits and heifer age at puberty.

Materials and methods

Animals used for this study were from the Co-operative Research Centre for Beef Genetic Technologies northern breeding project (Burrow and Bindon 2005). Breeding and management of animals, and experimental treatments imposed was described by Barwick *et al.* (2009*a*) and Barwick *et al.* (2009*b*). Briefly, animals of two tropically adapted genotypes, Brahman (BRAH) and Tropical Composite (TCOMP: comprising approximately 50% tropically adapted *Bos indicus* or African Sanga, and 50% non-adapted *Bos taurus* genetics) were bred over a 4-year period (2000 to 2003) on 8 co-operating properties. Following weaning heifer progeny were transported to 1 of 4 research stations where they were joined to first calve as 3 year olds, and records of reproductive performance and body composition (described below) assessed through to the 6th weaning. This study examined measurements collected at the commencement of the second mating (M2) for BRAH and TCOMP cows of 1111 and 1123 days of age, and 384 and 398kg liveweight respectively, for the subset of females which would go on to successfully wean a calf from their first mating (N = 636 of 1041 and 868 of 1097 respectively). M2 measurements examined for this paper were: liveweight (M2WT), hip height (M2HH), body condition score (M2CS), scanned eye muscle area (M2EMA), scanned P8 fat depth (M2P8) and scanned 12/13th rib fat depth (M2RIB), and were carried out following the protocols for ENDDRY measurements described by Barwick *et al.* (2009b). Age at puberty (AGECL) was determined by regular real time ultrasound scanning of heifers for ovarian function to identify the heifers' first corpus luteum, as described by Johnston *et al.* (2009). After weaning, steer progeny were transported to allocated grow-out properties, with management and treatments described by Barwick *et al.* (2009a). Following feedlot finishing for 119 days, steers were slaughtered, and measurements of hot carcass weight (CWT), cold P8 fat depth (CP8), cold rib fat depth (CRIB), and eye muscle area (CEMA) were measured, as described by Wolcott *et al.* (2009).

The genetic analysis methodology for steer, heifer, age at puberty and carcass and meat quality traits were described by Barwick *et al*. (2009*a*), Barwick *et al*. (2009*b*), Johnston *et al.* (2009) and

Wolcott *et al.* (2009) respectively, and apply to the M2 traits analysed for this experiment. Least squares means (LSM) for M2 traits were estimated for a subset of the animals which had been born and managed together at a single location from birth to M2 (N = 270 and 292 for BRAH and TCOMP). Variance components were estimated using a 3 generation pedigree, with a total of 54 BRAH and 51 TCOMP sires represented, and genetic correlations were estimated from bivariate analyses.

Results and Discussion

Least squares means for the subset of cows born and managed at the same location since birth showed a significant difference between BRAH and TCOMP for M2WT (BRAH = 390.2 and TCOMP = 430.6kg), M2P8 (BRAH = 2.9mm and TCOMP = 2.0mm), M2EMA (BRAH and TCOMP = 40.8 and 43.8cm^2) and M2HH (BRAH and TCOMP = 138.9 and 137.4cm). LSM for M2RIB were not significantly different (BRAH and TCOMP both = 1.7mm). These results suggest that differences in M2 liveweight between genotypes for cows which would successfully wean their first calf were likely to be largely due to differences in M2EMA and M2HH.

Heritabilities for M2 body composition traits were moderate to high (h2 = 0.27 to 0.81), and very similar to those reported by Barwick *et al.* (2009b) for the corresponding ENDDRY measurements. Table 1 presents genetic correlations between cow M2 traits and heifer age at puberty. For cows which would go on to successfully wean a calf from their first mating, those with genetically lower age at puberty tended to have genetically higher M2EMA, fat depths and M2CS, though these were only significantly different from zero for M2EMA in BRAH, and M2EMA and M2P8 in TCOMP. These results suggest that selection to improve AGECL will not negatively impact body composition in wet females measured at commencement of their second mating, and were very similar to those reported by Johnston *et al*. (2009) for ENDDRY measurements of body composition. Given the positive correlation between AGECL and PPAI2 reported by Johnston *et al.* (2010) for BRAH, similar genetic relationships may exist between M2 body composition traits and PPAI2 as observed here for AGECL. This will represent a key area of investigation for subsequent studies.

Table 1. Genetic correlations (r_g) and standard errors (se) of mating 2 (M2) liveweight (kg), eye muscle area (cm^2), P8 and rib fat depth (mm), body condition score and hip height (cm), with age at puberty (days) for wet BRAH and TCOMP cows.

Cow M2 traits	BRAH r_g	BRAH se	TCOMP r_g	TCOMP se
M2 Liveweight	-0.07	0.08	-0.06	0.07
M2 eye muscle area	-0.30	0.11	-0.29	0.08
M2 P8 fat depth	-0.10	0.08	-0.21	0.09
M2 rib fat depth	-0.13	0.08	-0.16	0.08
M2 body condition score	-0.15	0.09	-0.21	0.12
M2 hip height	0.05	0.09	0.14	0.06

Table 2 presents the genetic correlations between comparable body composition measurements from cows at M2 and steer carcasses. For weight measurements, the relationship for TCOMP was strong and positive (r_g = 0.77), consistent with the correlations reported by Wolcott *et al*. (2009) between CWT and ENDDRY WT (r_g = 0.69 for both genotypes), which were assessed approximately one year prior to the M2 traits. For BRAH, however, this relationship was weaker (r_g = 0.25), suggesting that the genetics controlling carcass weight from feedlot finished steers may differ from those acting on the trait in reproductively active females managed under pasture conditions. A similar difference existed for EMA, with BRAH displaying only a moderate and non-significant relationship between cow M2EMA and steer CEMA (r_g = 0.34), while for TCOMP this relationship was relatively strong (r_g = 0.63). For BRAH, the genetic relationship between M2RIB and the corresponding carcass measurement was moderate and positive (r_g = 0.43), where neither of the genetic correlations between cow M2 and steer carcass fat depths were significantly different for zero for TCOMP. These results were suggestive of differences between BRAH and TCOMP in the genetics controlling body composition traits for steers under feedlot conditions and reproductively active females managed under extensive pasture conditions at their second mating.

Table 2. Genetic correlations (r_g) and standard errors (se) between M2 and steer carcass weight (kg), P8 and rib fat depth (mm) and eye muscle area (cm^2) traits for wet BRAH and TCOMP cows.

Steer carcass traits	Cow M2 traits	BRAH r_g	BRAH se	TCOMP r_g	TCOMP se
Carcass weight	M2WT	0.25	0.21	0.77	0.14
P8 fat depth	M2P8	0.25	0.24	0.11	0.25
Rib fat depth	M2RIB	0.43	0.18	0.16	0.27
Eye muscle area	M2EMA	0.34	0.31	0.63	0.18

Conclusions

These results demonstrated that there was a genetic basis for variation in body composition traits measured in tropically adapted females at the commencement of their second mating. Significant differences in the liveweight, fatness, hip height and eye muscle area between BRAH and TCOMP cows suggest that there may be differences in how body reserves are utilised in times of energy deficit between these genotypes. This was supported by differences in the genetic relationships of cow body composition measurements and those of corresponding traits in the carcasses of their feedlot finished steer half-sibs, which showed strong genetic correlations between liveweight and eye muscle area measurements for TCOMP but not for BRAH. The relationship between body composition traits measured at the commencement of their second mating and age at puberty demonstrated that eye muscle area was more strongly related to age at puberty than liveweight and fatness, particularly for BRAH. Future analyses will examine the important relationship between cow body composition measured at the commencement of their second mating and reproductive performance in tropically adapted females.

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Accelerating gains- practical application of selection of cattle for northern Australia

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Abstract. Genetic differences between breeds, and animals within a breed, are powerful resources that beef producer can use to increase productivity and profitability. Commercial beef producers can use these genetic differences to better meet market specifications and to match cattle to particular production environments. The seedstock or bull breeding sector can exploit the genetic differences through selection to improve our breeds. Selection allows a breed to respond to changing productions systems or market requirements. Through continuous genetic gain for profit it is possible to counter the negative effects of the cost-price squeeze in agriculture. Most importantly selection is an effective way of improving reproduction rates, particularly in tropically adapted breeds.

Performance recording and genetic evaluation enables the genetic differences that exist in a breed to be described across a range of economically important traits and this is done using estimated breeding values or EBVs. The key to making genetic improvement is to identify the superior animals based on EBVs then use them to be the parents of the next generation. Most genetic progress comes from using superior sires. However for northern Australia the challenge is to conduct effective performance recording in extensively managed bull breeding herds. Limitations also exist in the ability to use artificial breeding technologies such as AI which is an important tool that enables increased intensity of selection, leading to greater rates of genetic improvement. Therefore to make genetic progress in northern Australia it is important that breeds and breeders have clear breeding goals and that performance recording is targeted at collecting the key traits relevant to those goals. For northern Australia there is a clear need to focus on recording female reproduction. For commercial producers the key to improving profitability through genetics is to ensure that replacement bulls are genetically better than previous years and that heifer-replacement strategies are retaining the high reproductively performing genetics.

Genetic progress

There is considerable potential to increase the rate of genetic progress in all beef breeds and those in northern Australia are no exception. The estimated current rates of genetic progress are relatively low for tropically adapted breeds, with the exception of early growth traits (e.g. 200d) which in all breeds are showing positive trends. Genetic progress in a population is achieved through selection such that the average genetic merit of each calf drop is increasing compared to the previous drop. Potential exists to increase rates of gain across a range of economically important traits in the major tropically adapted breeds (e.g. Brahman, Santa Gertrudis and Droughtmaster) given their large size and in some cases the capacity to use overseas genetics. Recent Beef CRC results have shown large amounts of genetic variation within breeds for key female reproduction traits of heifer age at puberty (Johnston *et al.* 2009) and return to cycling of lactating first calf cows (Johnston *et al.* 2010). A long term selection experiment in a Northern Territory research herd has reported impressive improvement in female reproduction in Brahmans through selection on the days to calving EBV (Schatz *et al.* 2010). However in bull breeding herds across northern breeds the levels of recording are low, particularly for reproductive traits. Therefore there is a lack of EBVs available for selection in northern Australia, particularly for traits other than early growth.

Current levels of recording

In northern bull breeding herds the levels of recording are low compared to southern breeds. This can certainly be improved and would be assisted by better price signals from bull buyers to encourage increased levels of recording in the seedstock sector. Increased recording for a trait is reflected in the accuracy figure for the EBV. Greater levels of recording lead to higher accuracies and the less likely the EBV is to change with the addition of new information. The average EBV accuracy of the young Brahman and Santa Gertrudis bulls are reasonable for growth (60%) but very low for reproduction (25%). The reasons for the low accuracies are that too few herds are recording the reproduction traits and the heritability (i.e. amount of genetic control) of female reproduction traits are lower thus requiring more records to achieve higher accuracies.

The amount of recording possible will be very much dependent on the individual herd. However it is important to measure as many traits as possible and most importantly to measure all animals. For most northern breeds the key profit drivers (those under genetic control) are sale weight, retail yield and reproduction. Basic recording requires permanent (unique) animal identification, a set of weigh scales and a scrotal circumference tape. Additional key measures would require access to an accredited ultrasound scanning technician and a flight time machine for objectively measuring temperament. Listed below is a simple 4 step recording strategy aimed at collecting data for these key traits for northern breeds.

1) For all cows at start of mating each year record (especially the maidens and 1st calf cows)
- start of mating date
- type of mating (if AI details required)
- mating group (paddock, bull ID)

then
- record pregnancy test results (especially if culled for being empty)
- record calving outcome (date of birth, sex, pedigree)

2) At weaning
- weigh all calves and do flight time test (a temperament score is also possible)
- weigh all cows

3) For young bulls about 15-18 months of age
- weight
- measure scrotal circumference (also BSSE examination at this time)
- can also do a ultrasound carcass scan (but fat depths likely to be low)

4) For young heifers

i) if calving at 2 years – measure into mating (at 15 months)
- weight and carcass scans
- mating group details (dates, bull, paddock)

ii) or if first calve at 3 years - measure at 18 months (at same time as bulls)
- weight and carcass scans

For each of these it is critical to also record the date, management group information for each animal and trait (paddock, treatments, show groups etc). Periodically records should be submitted to BREEDPLAN, usually through your breed society. Each society has different fee structures but for all breeds submission of female mating records has no additional charge.

More comprehensive recording could include birth weight, calving difficulty scores and AI date for gestation length. Future recording may include additional traits for heifer age at puberty scans, and additional bull reproduction (e.g. semen morphology) and cow measures (e.g. teat and udder scores). DNA samples can also be taken for genomic predictions e.g. shear force.

Key selections strategies – Bull breeder

For the bull breeder, EBVs should be used to select replacement males and females. However to make genetic progress (particularly for commercial profit) the breeder requires a clear definition of the breeding goal. In most breeds $EBVs are available that combine each of the EBVs into a single figure based on economic importance to the commercial producer through knowledge of the production system and target market. The $EBV ensures correct emphasis on each of the individual traits and simplifies them into a single EBV for profit to compare animals. A lot of work by breeders and breed society technical staff has gone into the development of these specific $EBVs.

Genetic progress occurs in the seedstock herds through the selection of genetically superior sires. Higher rates of progress can be generated by increasing the intensity of selection of superior sires. An effective way to achieve this in a breed is to select from as large a number of genetically evaluated males as possible. Commonly in a breed this would require comparisons of bulls across herds. This is where EBVs are important because unlike raw figures they have been computed to remove environmental effects, thus allowing the genetics of different animals to be directly compared across herds and years within a breed.

Replacement females can also be selected using EBVs and the $EBV but they will have low accuracies, though the same principles apply. It is also critical to put additional pressure on reproduction by culling all cows that don't calve. In some breeds and productions systems this may not be possible but recent Beef CRC results suggest, not doing so will result in the multiplication of poorer genetics for reproduction.

Breeds joining BREEDPLAN or those breeds commencing recording of a new trait must understand that it takes several years of recording to generate the depth of information across generations and herds to partition accurately all of the effects. Pivotal to this is the establishment of genetic linkage across all herds in a breed for each trait. This is commonly achieved through the use of popular AI sires but in some breeds may require swapping of sires to generate progeny in more than one herd. Genetic linkage allows the effects of herd (i.e. your environment) to be removed from the raw records. Low levels of genetic linkage across herds is an ongoing issue for many northern breeds and needs to be continually addressed to ensure accurate across herd comparisons using EBVs. Therefore in the early years of BREEDPLAN for a breed it is important to realise that the EBVs on individuals may change more and this be taken into account when making purchase or culling decisions.

All breeders need to manage inbreeding in their breed and breeding programs. Genetic disorders occur sporadically in all breeds and can be increase in a breed through high usage of bulls. To minimise the impact of a genetic disorder it is critical to record any abnormalities (get vet diagnosis if possible). This allows a problem to be indentified early before it is multiplied in a population.

Key selections strategies – Commercial breeder

For commercial breeders there are 2 key decisions where you can use genetics to improve the bottom line.

a) Selecting new herd bulls

The question when comparing potential new bulls is "which ones will produce the more profitable progeny"? And for most traits that affect profit you can't "see" these traits and their genetics in the young bull. This is where EBVs are powerful tools to allow you to compare the genetic merit of bulls. List below are some key considerations when purchasing your next sires:

Key bull selection consideration:

- be clear on what you intend to do with the female progeny. Will they all be slaughtered? Or kept are replacements? This will affect which EBVs and $EBV you should use for selection
- source bulls from breeders with EBVs for the traits that are important for your system., including female reproduction if you intend retaining heifers

- use the $EBV to simplify selection decisions
- avoid raw figures - they don't allow you to compare bulls across groups, herds or years
- benchmark growth EBVs (e.g. 600d and cow weight) for your country
- as well good EBVs the bull must be functionally sound (e.g. feet, scrotal size and temperament)
- consider using a polled bull (if so, consider DNA testing to know if the bull is homozygous polled)
- if no female reproduction EBVs select using the scrotal size EBV and if possible check the calving history of his dam and sire's mother

b) Selection of replacement females

Selection of replacement heifers will depend on your herd's weaning rate. However there may be opportunity to apply simple selection to ensure your cow herd is steadily improving (or at least not getting worse). If possible cull all non-calvers or as a minimum avoid keeping replacement heifers out of cows that have skipped calving the previous year. Without records for individual cow reproductive performance each year in such a herd the likely scenario is that heifer calves off cows that have skipped will be older and heavier at weaning (Jeyaruban *et al.* 2011) and thus more likely to be kept as replacements. In doing so poorer reproduction genetics will continue to be multiplied through your herd.

Conclusions

To improve our breeds in northern Australia there is an opportunity to increase the levels of performance recording and to use of EBVs for selection. Bull breeders needs to increasingly focus on the profit drivers in commercial production and provide genetically improved bulls for the key traits. Without reproduction EBVs (days to calving and scrotal size) it is unlikely a breed is making any improvement in female reproduction, in fact it is likely to be getting progressively worse. Commercial breeder needs to buy genetically described bulls for traits important to their systems and provide clear signals to the bull breeding sector on what traits are important.

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Strategies for measuring and reducing methane emissions from beef cattle in northern Australia

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Abstract. Methane is a greenhouse gas (GHG) produced as a by-product of rumen fermentation. The northern cattle industry produces about 4.5% of Australia's total GHG emissions. Livestock methane emissions can be reduced through adoption of changed management and new technologies. If the Carbon Farming Initiative (CFI) is passed through parliament, there will be financial incentives to reduce emissions. A major challenge in Australia's north is simply measuring methane emissions. However in recent years, significant advancement in this area has been achieved. A range of methods are now available experimentally and are being developed specifically for extensive grazing conditions. In particular the use of open-path laser techniques to measure methane concentration in the atmosphere down-wind of grazing cattle can be used to estimate emissions from cattle on pasture. By validating these data with intensive techniques from animals in chambers we now have a viable approach to measure emissions from cattle under extensive grazing conditions. Currently, the laser technique is being used in a number of commercial situations in northern Australia to assess the variability in methane emissions across different production systems and land types. These data will inform new models that will give more accurate predictions of methane emissions per animal, per hectare and per unit product. Such information is critical if we are to quantify the effects of management and mitigation technologies on methane emissions. These developments will ensure that management decisions can be made to optimise productivity and carbon outcomes. A range of options exist for mitigating methane. Some can be implemented today, but these usually have low impact on emissions, others are further into the future but may offer real hope of a genuine reduction in methane emissions. Mitigation options fall into four broad categories; management changes, dietary manipulation, rumen manipulation and genetic improvement. Not all these options are suitable in every circumstance and for the northern cattle industry many potential mitigation practices are simply impractical. For the producer currently, the most promising options for abating methane emissions focus around sound management decisions that also improve profitability through increased growth and reproductive rates. While these options will reduce the amount of methane produced per kg saleable product, they may not reduce total emissions form the property. While methane emissions from the northern cattle industry represent a challenge, there are also potential opportunities if we have the means to reduce methane emissions. Recent research is providing answers to the measurement and mitigation of methane from the northern cattle industry.

Introduction

The beef industry in northern Australia is a significant contributor to the economy of the region, ranked third behind mining and tourism in terms of economic value. The Northern Australia Land and Water Science review (2010) recommended that the industry has capacity to expand and indeed this is happening. At the same time the industry is also challenged by its environmental impact, in particular the greenhouse gas emissions associated with cattle production. Methane is a by-product of feed digestion in the rumen and accounts for about 4 to 8% of the energy ingested by the animal. It is therefore a significant loss of energy that could otherwise be used for productive purposes. Today, however, methane is significant to the industry because it is a potent greenhouse gas, having an atmospheric warming potential about 23 times that of CO_2. This is becoming a bigger issue for the industry, firstly because it casts beef in a poor light with consumers, which may eventually impact on sales. Secondly, and ultimately more significantly, it could carry a "carbon tax". Clearly, there are good reasons why the industry should strive to reduce their methane emissions; reduced feed energy loss, improved consumer acceptance and the option to earn "carbon credits" for reducing the level of emissions. This latter aspect is central to the "Carbon Farming Initiative" (CFI; Commonwealth of Australia 2011) which if passed by Parliament would allow producers to earn carbon credits that can be sold to offset emissions in other industry sectors. This paper discusses the challenges specifically for the northern Australian cattle industry around methane.

The scale of the problem

The Australian beef herd amounts to about 25 million head and, depending on how you define northern Australia, about half of these cattle are in the north. The majority of the northern herd is a grass-based industry with breeders and most finishing cattle raised predominantly on grazed forages. Although forage-based beef systems are often deemed "clean and green" and utilize land unsuitable for other purposes, they do have an Achilles' heel. Because forages, and particularly tropical or northern forages, are lower in feeding value than grain-based diets, cattle grow more slowly, and reproductive performance in breeders is often lower than in beef systems of our southern counterparts. While this has always represented a productivity challenge for producers, it also carries a methane impost. Less efficient cattle take longer to reach market weight and may only breed two seasons out of three, for example. Every day a cow or steer is in the paddock it is producing methane – about 200 g/day. So the longer a beast takes to get to market and the more often a cow does not get bred, then that animal is producing methane with very little beef being marketed in return (Charmley *et al.* 2008). This so-called methane intensity is markedly higher for northern cattle than cattle raised in more intensive systems. Although estimates vary widely, depending on the methodology used, emissions intensity values of around 25 to 40 kg CO_2 equivalents per kg saleable beef produced are typical (Eady *et al.* 2011). In contrast, intensive systems, such as in Europe may have values between 15 to 20 kg CO_2 equivalents per kg saleable beef.

The northern cattle industry is also large and estimates suggest that about half the enteric methane (from digestion in ruminants) produced in Australia comes from the northern herd. This equates to 4 to 5% of Australia's total greenhouse gas emissions (Table 1). However, it has to be stressed that these figures are only estimates (DCCEE 2008). Actual data is scarce and difficult to collect in extensive systems. For inventory purposes the National Greenhouse Gas Inventory system uses census data to estimate cattle numbers, an equation based on just 8 tropical grasses to estimate feed intake and an equation based on just two tropical forages to estimate methane emissions from the diet (Kurihara *et al.* 1999). Algorithms based on that data imply higher methane emissions from tropical diets than temperate diets. However, more recent data (PM Kennedy, unpublished) has demonstrated that this is not the case. Current methane estimates for the northern industry are appropriate for inventory reporting purposes but are not sufficiently detailed, accurate or precise if the industry enters into abatement methodologies or carbon trading scheme.

Table 1. Agricultural emissions from Australia and northern Australia as a percentage of Australia's total emissions

	Whole of Australia	Northern Australia
Total emissions (T CO_2 equiv. x 1000)	576	
Agricultural emissions (% of Australian emissions)	15.2	7.6
Enteric methane emissions (% of Australian emissions)	9.6	4.5

The challenge of measurement

To measure emissions from every animal in northern Australia is obviously impossible, but it is important to get better estimates of emissions than we currently have. Historically, measurements have been made on cattle in highly controlled conditions and extrapolated to the industry (e.g. Kurihara *et al.* 1999). Yet we know that under controlled conditions animals behave differently, eat differently and the results cannot be realistically applied to the grazing animal. Therefore a hybrid approach is being adopted where we combine information from a small number of highly controlled but precise measurements with a broader range of in-field data. Models can then be used to get better estimates of methane emissions at the regional, property and even paddock scale. Ultimately these models will be used to quantify methane mitigation methodologies under an incentive scheme such as the CFI.

Table 2 details many of the methods that are currently available. There is no perfect method, all have advantages and drawbacks. However by selecting methods most appropriate to what is trying to be accomplished and by strategically combining methods, many of the drawbacks can be minimized. In northern Australia, for example methane chambers have been instrumental in providing data on methane emissions from cattle fed tropical diets (Tomkins *et al*. 2011). These data will help inform for inventory purposes. The extreme field conditions preclude the use of the SF_6 method, but the laser method can be used. However validation of the laser method can be difficult. In research by CSIRO at Lansdown Research Station, Townsville, we use a variety of methods and are able to validate the field techniques by cross referencing our results. Results collected by laser in the paddock are validated by feeding the same feeds in methane chambers and by running field chambers in the same paddock.

The options for reducing methane emissions

A range of options exist for mitigating methane. Some can be implemented today, but these usually have low impact on emissions, others are further into the future but may offer real hope of a genuine reduction in methane emissions (Fig. 1). Mitigation options fall into four broad categories:

- Management changes
- Dietary manipulation
- Rumen manipulation
- Genetic improvement

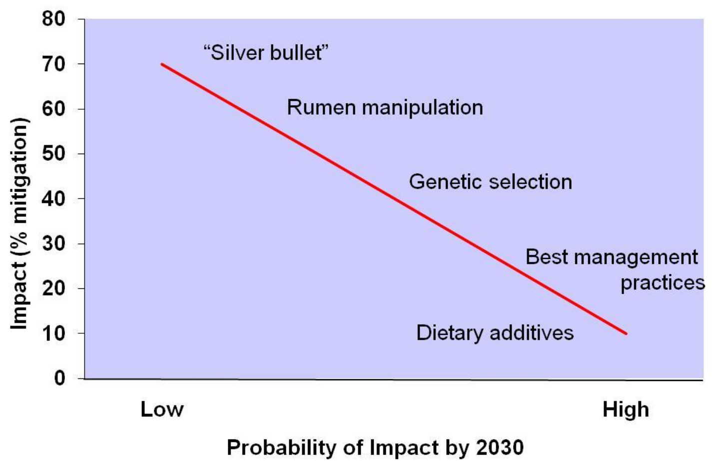

Fig. 1. The relationship between the impact of a methane mitigant and the probability if will be an option within 30 years

Table 2. Methods for measuring and estimating methane emissions from cattle

	Type	Positives	Negatives
In vitro gas production	Laboratory scale using rumen fluid incubated in small glass jars	• Useful for rapid screening of many feeds • Cheap and repeatable	• Results are often not supported by animal experimentation
Methane proxies	Blood methane concentration Faecal NIRS spectra	• Both method offer cheap methods for widespread measurement	• Neither method has been developed sufficiently and significant work is needed to validate these techniques.
Methane chambers (Calorimeters)	Whole animal or a small number of animals held in total confinement to estimate gas balance. Animal(s) is held in a chamber for normally 24 hours and the composition of air entering and leaving the chamber is measured for methane, CO_2 and sometimes hydrogen.	• Considered the "gold standard" against which other methods are compared. • Useful for precise measurements of methane emissions from ruminants fed different feeds. • Measures the individual animal • Can replicate measurements • Chambers exist for both cattle and sheep	• Method is expensive and cannot be used on large numbers of animals. Although shortening the duration of measurement have got round this issue to some extent • Animal behaviour is severely compromised • Feed intake is reduced
Field-scale chambers (Poly tunnels)	Similar to above but larger and the principals are the same. These can be placed in the paddock and accommodate several animals. A half-way system between methane chambers and field-scale systems.	• Allows some grazing behaviour • Can be used to look at a range of species not suited to chambers • Is portable and can look at different sward types	• Less accurate than above method • Cumbersome to move and set up
SF_6 methods	A tracer gas (SF6) is released slowly from a capsule in the rumen. Gases escaping from the mouth and nostrils are samples into an evacuated yoke or cylinder mounted on the animal. The relative proportions of tracer gas and methane in the gas sample are used to estimate methane emissions	• Can be used in the field • Gives data on individual animals • Can be used on large numbers of animals, e.g. for genetic selection • Is widely used and accepted • Does not markedly interfere with grazing behaviour • Suited well to dairy cattle	• The method is difficult to set up and results can be variable • Not suited to extensive grazing due to equipment damage/failure and the need to corral animals daily to collect sampling devices, although some methods now allow for 7 day collections. • Repeatability of measurements has been questioned
Laser methods	A laser beam is shot across or downwind of a group of cattle. The concentration of methane in the bean is measured. Windspeed, direction and turbulence is measured and used to estimate the concentration of methane in the airspace above the animals	• Measures methane from the production system (e.g. paddock or feedlot) • Can be set up in commercial situations • Minimal interference to the animal • Works well in extensive conditions	• Cannot be used on individual animals • Dependent upon weather • Need a sufficient concentration of cattle to record accurately above background levels • In large paddocks cattle have to be concentrated around water or supplement points • Cannot separate enteric methane from other sources
Indwelling rumen bolus	A sensor in the rumen records methane and CO2 concentration and relays data to a computer n real time via radio. Algorithms developed to relate rumen methane concentration to emissions using chambers.	• Potentially low cost and can be used on large numbers of animals. • Measures the individual animal and useful for genetic selection	• Still experimental • Retrieval issue for the sensor • Needs to be validated and tested • Only measures rumen methane not hind gut methane

Animal models	A range of models are available based on simulating the digestive processes of the animal. They range from simple to complex	• Cheap and relatively easy to apply. • Can be used to simulate many scenarios • Animal models can be incorporated into systems models	• Good input data is reliant on direct experimental study • Output only as good as the input • Models can give spurious answers
Systems models	Similar to above but at a higher scale to include the animal in the paddock or the herd in a region for example	• Can simulate farm systems, regional scenarios. • Good for "what if" scenarios can test management options without the risk • Ideal for inventory purposes and estimating carbon abatement potential	• Input data is often sparse and not applicable to all systems • Models can give spurious answers • Credibility issues if used for policy
Life cycle analysis models	A well defined discipline that assesses the flow of components through the whole (or part of) the value chain (e.g. carbon, water, Nitrogen)	• Standardized processes and procedures allows for valid comparisons among supply chains • Relatively cheap and easy to run. • Ideal for assessing the "carbon footprint" of foods.	• Highly dependent on the quality and quantity of input data • Comparisons between studies are difficult when system boundaries are not clear and consistent • Results can vary depending on the nature of the question being asked.

Management

Not all these options are suitable in every circumstance and for the northern cattle industry many potential mitigation practices are simply impractical. Today, the most effective means to reduce methane from northern herds is to increase productivity. Reducing days to market, either through increased growth rate or selecting markets with lower LW thresholds shortens the lifespan of slaughter cattle and consequently reduces the methane emissions per kg saleable product, the methane intensity (Eady *et al.* 2011). Similarly, increasing weaning rate spreads the methane "overhead" of the dam across more productive offspring and again reduces the methane intensity (Charmley *et al.* 2008). Ironically, such practices often increase daily methane emissions per head and if improving a herd's efficiency means herd size increases then emissions per hectare will also increase. Charmley *et al.* (2008) modelled a hypothetical property with 3000 adult equivalents. The impact of using tactical energy supplementation at pasture to maintain a LW gain in growing steers of at least 0.5 kg/d was considered. Supplementation reduced age at turn off from 4 years to 2.3 years. This allowed the property to carry more breeders, thus increasing methane emissions from the breeder herd. However, this was offset by increased sales of finished cattle without increasing their lifetime methane emissions. Overall, methane emissions from the property remained unchanged at 6700 tonnes CO_2 equivalent per year but herd emissions per kg saleable beef declined from 21 to 15 kg CO_2 equiv/kg shrunk carcass weight.

Dietary manipulation

Dietary ingredients affect the amount of methane produced per kg feed consumed. For example, a feedlot diet produces about half the methane per kg DMI than does a northern pasture diet (Johnson and Johnson 1995). So a simple means of reducing methane emissions is to finish cattle in feedlots. The gradual trend to increased lot feeding is therefore helping to reduce emissions intensity.

Dietary additives have been widely studied and there are many supplements that have shown efficacy. This paper will only discuss those that could have application for the northern cattle industry. For an excellent review on dietary supplements see Beauchemin *et al.* (2008).

Oilseeds can reduce emissions as the lipid inhibits the activity of some methane producing micro-organisms (methanogens). While the options for feeding these in the rangelands are limited, they do exist in some localities. Cotton seed, for example, is rich in oils and has an antimethanogenic effect (Klieve *et al.* 2009). An alternative option for the northern cattle industry is the introduction of legumes into the diet. Many legumes contain tannins and other secondary plant compounds which have some antimethanogenic activity. Some tropical legumes are agrononically adapted to parts of the north and are grown successfully. P.M. Kennedy (unpublished) fed a number of legumes in methane chamber studies. Leucaena reduced methane production by about 20% when fed at 100% of the diet. Field data collected using lasers from cattle grazing either Rhodes grass or Rhodes/leucaena paddocks showed no difference in methane emissions but we speculated that feed intake was higher for the leucaena-fed cattle, thus implying lower methane emissions intensity (McGinn *et al.* 2011). Recent work has screened 8 tropical legumes for their antimethanogenic activity *in vitro*. Four of the 8 species showed marked reduction in methane production when the legumes were incubated with sheep rumen fluid (CA Ramirez-Restrepo, unpublished).

Anti-methanogenic dietary compounds could be delivered to grazing cattle in the water or as a component of concentrate blocks. While no products are currently on the market, these delivery systems could be effectively used to deliver various compounds in extensive grazing systems.

Rumen manipulation

Manipulation of the rumen microbiota to reduce methane emissions has been the subject of several reviews which provide a broad analysis of the options that are available and the practical strategies that might be employed (Attwood and McSweeney 2007). Research has focused on directly inhibiting the methane producing microorganisms or increasing the utilization of hydrogen (precursor for methane formation) by stimulating bacteria that produce energy yielding products from hydrogen for use by the animal rather than yielding wasteful methane. Many chemical agents such as ionophores, unsaturated fatty acids, sulfate, nitrate, fumarate, and halogenated methane analogues (e.g. bromochloromethane) are able to reduce methane production from ruminants. Although some of these compounds are effective in reducing methane production, individual compounds have potential adverse side effects which limit their current practical use while others are prohibitive in cost. Ionophores including monensin and lasalocid are effective rumen modifiers for improving productivity but can also abate methane emissions from cattle fed concentrate diets (Rumpler *et al.* 1986). Although monensin does not appear to improve productivity in cattle grazing northern Australian pastures, recent unpublished research by Tomkins and co-workers indicated that methane production was reduced in cattle fed a roughage hay diet. Elimination of ciliate protozoa from the rumen with commercially available chemicals is being investigated, since methanogens that adhere to protozoa as a source of hydrogen may contribute 9-25% of rumen methanogenesis. However the long term impacts of protozoal removal are not known in (sub-) tropical production systems. New approaches for methane reduction such as vaccination of ruminants against methanogens (Wright et al. 2004) is being actively pursued by Ag Research New Zealand, and the inoculation of kangaroo gut microbiota (Klieve and Hegarty 1999) that produce much less methane than the microbiota of cattle rumen are still at a "proof of concept" stage.

Genetic improvement

For the northern cattle industry, genetic selection for low methane cattle offers an elegant solution. Such a trait is embedded in the genetic code of the animal and is progeny. There is no need for mustering to administer the treatment, there is no need to feed expensive supplements, there is no requirement to change the production system and the mitigation lasts for the lifetime of the animal. Because of these potential advantages, programs have been established in beef cattle and low emitting individuals selected. However the process is by no means straight forward and animals that are found to be ranked as low emitters on one diet may in fact rank higher on another diet. Selecting for higher net feed efficiency may be more effective as there seems to be a relationship between net feed efficiency and methane (Alford *et al.* 2006). Even though methane is produced by the microbiota in the rumen and breeders are selecting genes in cattle, it would appear, based on sheep data, that the trait is heritable. Consequently there is hope that genetics, particularly marker assisted genetic improvement, if a marker can be found, can offer a solution.

The role of models

Models play a significant role in understanding and estimating methane emissions from cattle at the rumen, whole animal, herd, property, regional and national scale of organization. Models are developed to simulate the system in question and can only be as good as the data they are based upon. Where there are rich data sources, such as in intensive production systems, the uncertainty around model predictions can be manageable. However, for the northern cattle industry, the main difficulty in estimating emissions at the property and regional level is in obtaining the basic data needed to model herd structure, reproduction and growth rates and turn-off numbers. This is over and above the difficulties highlighted earlier in the paper with regard to predicting methane output from the consumption of tropical pastures and shrubs.

However, models will be essential to the implementation of abatement projects under the CFI – both to set a baseline for GHG emissions and to demonstrate subsequent abatement brought about by activities undertaken in the CFI project. While there are a number of models built to estimate GHG emissions from livestock (University of Melbourne GHG models for beef, FarmGAS, livestock module of NCAT) and there are production models such as Breedcow, the integration of the two types of models is yet to be achieved in a manner that will enable CFI livestock abatement projects.

Modelling is also used to assess the "carbon footprint" of beef products through a life cycle assessment approach that takes into account the whole of life GHG emissions associated with a product. There is an increasing requirement for environmental impact measures to be provided for products and services, as evidenced by the commitment of large global retailers, such as Tesco and

Walmart, to the introduction of environmental impacts to the suite of criteria used to make purchasing decisions.

Conclusions

Global warming and the link to greenhouse gases are contentious issues for producers, particularly when GHG emissions may have an economic impact on the industry. It is important that the industry has good understanding of factors that affect methane emissions from livestock and that it has the tools to abate emissions. Recent research in the development of measurement and modelling techniques has demonstrated the potential of management to reduce methane emissions intensity for the northern industry. Ongoing advancement in the development of mitigation technologies will also assist the industry in reducing its methane "footprint". These developments coupled with government policies offering incentives to reduce emissions should ensure the industry is well placed to meet the challenge of GHGs in the future.

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Strategies for adapting to climate change

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Abstract. Grazing lands occupy some the harshest environments where existing climates and variability already impose substantial challenges for land management. Climate change could add to these challenges by impacting the amount and quality of produce, reliability of production and the natural resource base on which pastoralism depends. The pastoral industry will be best placed to deal with these challenges if proactive steps are taken to prepare for the range of new challenges and opportunities that can be anticipated. In the short-term, many of the of the initiatives aimed at promoting best management practices will help graziers immediately, but also place them in a better position to deal with future climate changes. These would include management practices that improve land condition and flexible approaches that are responsive to year-to-year fluctuations in weather. While such incremental changes to management have served the industry well in the past, it is also important to recognise that a business-as-usual approach may not be sufficient in locations where impacts are severe particularly, as seems increasingly likely, if global temperatures rise above 2°C. Dealing with challenges that overwhelm the capacity on individual enterprises to adapt will require higher levels of assistance and intervention such as policy change, structural adjustment and development of new breeds and technologies. Such responses will take time to develop and require long-term planning if they are to be available, evaluated and effective when needed. These actions will have the greatest chance of success if they begin now with active input from pastoralists, policy-makers, researchers and information/extension providers.

Introduction

Livestock production is the dominant land use, both nationally and globally, much of it in harsh and variable environments that are unsuitable for other uses. The risks of climate change are now adding to existing climate challenges. Climate change could impact the amount and quality of produce, reliability of production and the natural resource base on which agriculture depends (Howden *et al.* 2008; McKeon *et al.* 2009; Stokes and Howden 2010). In order to continue to thrive in the future, livestock industries need to anticipate these changes, be prepared for uncertainty, and develop adaptation strategies now. There will be new challenges and new opportunities, both of which will require proactive planning to modify existing management guidelines and to develop and implement appropriate new responses.

While climate change will have some direct effects on livestock, the dominant influences will be through changes in plant growth and the timing, quantity and quality of forage availability. Climate change will involve a complex mix of responses to (1) rising atmospheric carbon dioxide (CO_2) levels, (2) rising temperatures, (3) changes in rainfall and other climate factors, and (4) wider issues related to how pastoralists and people more broadly respond to these changes. We briefly discuss each of these influences of climate change and adaptation in this paper.

Impacts, challenges and opportunities

Rising atmospheric carbon dioxide

The most certain aspect of the changing environment for future livestock production is the rising level of CO_2 in the atmosphere (Nowak *et al.* 2004). Already, CO_2 levels are almost 40% higher than in pre-industrial times, and are still rising exponentially.

Plants are therefore already growing in CO_2-enriched environments and rising levels of CO_2 will further benefit plants by allowing them to use water, nutrient and light resources more efficiently

(Nowak *et al.* 2004; Stokes and Howden 2010). In the northern rangelands, the biggest benefit of CO_2 is likely to be improvements in plant water use, which allows pastures to grow more using the same amount of water. However, the trade-off is that increases in pasture production come at the expense of reduced forage quality, since grasses grown at high CO_2 have lower protein content and lower digestibility. There could also be changes in vegetation because higher CO_2 levels favour trees and legumes.

While CO_2 will largely have a positive effect on pasture growth, these benefits will taper off at higher CO_2 levels and much of the maximum potential benefit is already being experienced from increases in CO_2 that have already occurred. In contrast, many of the negative aspects of climate change and its impacts on agricultural systems lag at least several decades behind the rises in greenhouse gases (GHG) that cause them, and those impacts continue to become more negative as GHG levels rise.

Temperature change

The next most certain aspect of climate change is rising global temperatures, which is the primary effect of increasing GHG levels on the climate (CSIRO and BOM 2007). Because of past GHG emissions, some future warming is unavoidable and global average temperatures could well increase by 4ºC or more this century. Warming will be greater towards the interiors of continents (away from the moderating effects of oceans) (Fig. 1a). Each 1ºC increase in temperature will cause a warming in climate that would be roughly similar to moving about 145 km (or about 2º in latitude) closer to the equator.

a) temperature

b) rainfall

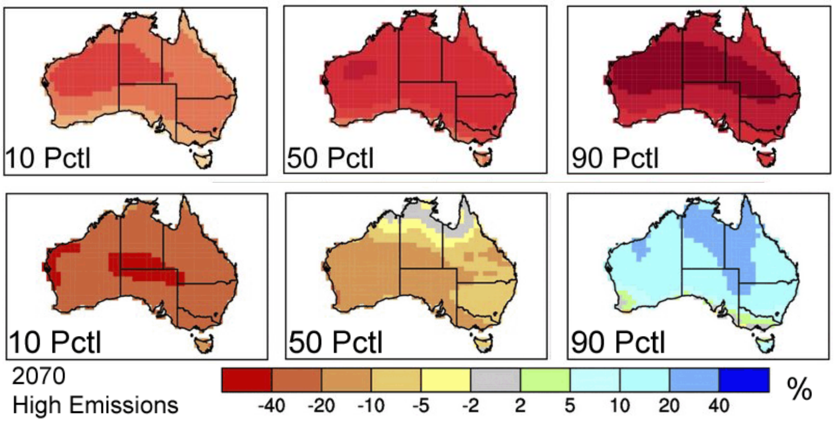

Fig. 1. Projected changes in a) temperature and b) rainfall for a high emissions scenario in 2070, including percentile ranges of uncertainty (CSIRO & BOM 2007).

In climates where low temperatures limit pasture growth during winter, rising temperatures could extend the length of the growing season and reduce frost damage (McKeon *et al.* 2009). However, increased plant growth in the cooler months could reduce water availability and pasture growth through the remainder of the growing season. In the tropics, warmer conditions also tend to reduce forage quality and increase the risks of plant heat stress. Furthermore, greater vapour pressure deficits (the 'dryness' of the air) will adversely affect plant growth by increasing evaporation and lowering water use efficiency, offsetting some benefits of higher CO_2.

Livestock will be exposed to greater risks of heat stress, particularly in locations where they are concentrated such as feedlots, and water demand would increase (by about 13% for a 2.7ºC increase in temperature) (Howden *et al.* 2008). This will also mean that livestock will be unable to travel as far from watering points in rangelands, concentrating grazing pressure and risks of soil degradation near watering points while areas further from water become less-utilized.

Under warmer conditions, tropical grasses, weeds, pests and diseases are likely to expand into cooler, southern regions (Stokes and Howden 2010). This could increase the costs of control and damage from pests (e.g., cattle ticks) and alter the species composition of pastures (e.g. increases in less nutritious tropical grasses) (Howden *et al.* 2008).

Rainfall and other climate changes

Changes in rainfall could have the greatest affect on livestock production systems in some locations, but this is likely to be one of the most geographically variable aspects of climate change (Fig. 1b) (CSIRO and BOM 2007). At a global scale, higher temperatures are expected to intensify the hydrological cycle (more evaporation and more intense rain). As a general global pattern, regions near the equator are expected to get wetter and mid-latitudes (such as most of Australia) are more likely to become drier. But, at the enterprise scale, local factors such as topography and changes in wind patterns and storm tracks can redistribute rainfall between regions. Climate change projections at local/enterprise scales will therefore always involve large uncertainties. An essential element in adapting to climate change will be to accept the inherent uncertainty and develop approaches that can cope with these risks.

Changes in pasture production tend to magnify changes in rainfall, particularly in more arid regions. For example, pasture growth would decline by more than 10% for a 10% decline in rainfall (McKeon *et al.* 2009). River flows are even more sensitive to changes in rainfall (e.g. a 10% change in rainfall can alter runoff by 30-40%) (Chiew *et al.* 1995) which could affect beneficial flooding (e.g., in the Channel Country).

Seasonal patterns of forage quality and availability are also likely to be affected by climate change. For example, declines in spring and autumn rainfall would tend to shorten growing seasons. In contrast, warmer temperatures could allow spring growth to start earlier in cool climates, and CO_2 could delay water use, prolonging growth at the end of the wet season. Fire regimes and the fire management will be affected not only by changes in seasonal fuel loads and curing, but also changes in temperature and humidity (which could shorten the period when conditions are suitable for prescribed burning).

Increases in rainfall intensity are likely to increase soil erosion by increasing runoff, particularly where drying climates reduce protective vegetation cover (McKeon *et al.* 2004). Erosion and management risks will likely be further increased by greater year-to-year variability in rainfall. Maintaining perennial grass cover will become even more important.

Adapting to climate change

The ultimate impacts of climate change will be strongly modified (for both better and worse) by the way in which producers, governments and supporting organisations respond to these challenges (Howden *et al.* 2007; Stokes and Howden 2010). How well one region fares under climate change will also be influenced by how strongly other beef-producing regions (nationally and globally) are affected and how well they respond in dealing with their own challenges and opportunities. For example, markets for livestock products will be affected by global competitors (and their impacts and responses), changing demand for livestock products (e.g., concerns over ruminant methane emissions), and the emerging biofuel industry (which competes with the livestock industry for grain) (Howden *et al.* 2008). Climate change will also influence patterns of land use and competition between different land uses.

It is just as crucial to understand what helps and hinders people in adapting effectively, as it is to understand the biophysical aspects of climate change (Fig. 2). Successful adaptation will require (1) the availability of effective adaptation options, (2) capability of enterprise managers to implement these options and (3) a policy and institutional environment that promotes the development, evaluation and adoption of practicable adaptation strategies. Vulnerability to climate change can be reduced by preparing, evaluating and implementing adaptation strategies that limit the risks of negative impacts while taking advantage of new opportunities.

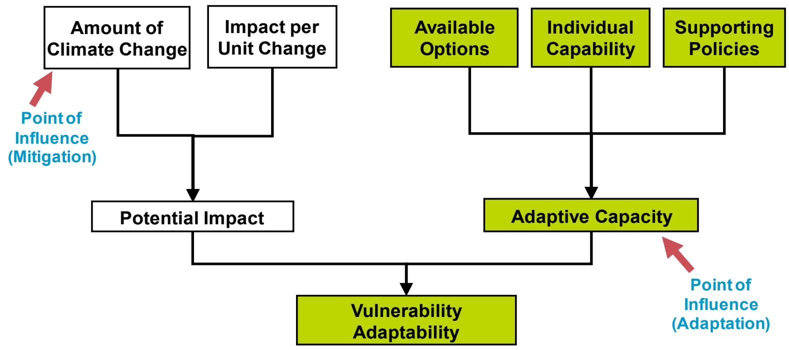

Fig. 2. Both biophysical factors and human actions will determine the ultimate outcomes of climate change for pastoral enterprises.

In the short term, many adaptation options are likely to correspond strongly with efforts to promote existing 'best management practices' that are both economically and environmentally sustainable (Table 1). This would include practices such as managing diet quality (using diet supplements, legumes and choice of introduced pasture species), matching stocking rates to pasture production, adjusting herd management to altered seasonal patterns of forage production, using fire to control woody thickening, arranging water points to even out grazing pressure, and monitoring the spread of pests, weeds and diseases (Stokes and Howden 2010). In most grazing lands, where coping with climate variability is already a management priority, building capacity to cope with climate variability can serve as a strong starting foundation in preparing for climate change. Enhancing such practices is a sensible initial priority because it provides an immediate and ongoing benefit, irrespective of whether a region is impacted by climate change. Over the longer term, it will also be necessary to develop new management options that are better suited to emerging novel climate conditions.

There are two important constraints on adaptation that could lead to inaction, or delayed action, and leave the pastoral industry poorly prepared for climate change. The first is the notion that projections of climate change and its impacts are too uncertain, so we should wait until those uncertainties are resolved (Sarewitz and Pielke 2007). However, much of this uncertainty will never be resolved until after the impacts have already occurred, so risk-based strategies will be required that are robust enough to deal with a range of plausible outcomes (Dessai *et al.* 2009; Stokes and Howden 2010), rather than 'betting' on just the most likely scenario. Furthermore, we can anticipate with reasonable confidence what the nature of the emerging challenges and opportunities will be (as outlined above). A broad array of adaptation options can be prepared to deal with geographic differences in grazing resources, culture, institutions, economies and impacts and opportunities of climate change. We may not know yet exactly where and when some of these options will apply, but development needs to start now if they are to be available when situations requiring their use arise.

The second constraint that could prevent proactive adaptation is the notion that existing approaches of making incremental enterprise-level management changes and improving approaches to cope with climate variability will, by themselves, be sufficient for coping with climate change. While such incremental changes to management have served the industry well in the past, it is also important to recognise that they may not be sufficient in locations where impacts are severe particularly, as seems increasingly likely, if global temperatures rise above 2oC (Ash *et al.* 2011). As regional climate conditions progressively deviate from historic 'norms', past management experience will become less and less relevant, requiring novel new approaches (often involving supporting changes beyond the property boundary) suited to the emerging novel new climate. Dealing with challenges that overwhelm the capacity of individual enterprises to adapt autonomously will require higher levels of assistance and intervention such as policy change (Nelson et al. 2008), structural adjustment and development of new breeds and technologies. Such responses will take time to develop and require long-term planning if they are to be available, evaluated and effective when needed. These actions will have the greatest chance of success if they begin now with active input from pastoralists, policy-makers, researchers and information/extension providers.

Table 1. Climate change impacts and adaption options (modified from Ash *et al*. 2011).

Change variable	Nature of impact	Gradual or threshold change	Can current strategies manage the impact and limits to adaptation
Increasing CO_2	Increased plant productivity, altered species composition, decreased forage quality	Largely gradual change but there are likely to be some threshold changes in species composition (woody-grassy balance, weeds, sufficient fuel loads for fire)	Enhanced fire and weed management strategies may help manage vegetation change for some time but it is likely unavoidable transitions will occur Declining forage quality could be managed through nutritional supplements
2^{o}C temp increase (increasingly unavoidable)	Longer growing seasons in cold climates, some reduction in plant growth in hot climates, some heat stress in animals, contraction of grazing zones around water sources, shifts in plant species (e.g. C3/C4), southward expansion of pests, weeds & diseases	Gradual change	Animal breeding for heat tolerance, altered herd and grazing management, additional shade, altered fire regimes, more efficient use of water resources, enhanced opportunities in temperate climates Improved monitoring & control of pests
4^{o}C temp increase (likelihood increasing)	Likely to be beyond the coping range of animals (and possibly humans) in some environments, significantly reduced plant production in hot climates	Thresholds likely to be crossed where production systems in hot climates fail	Limit to adaptation reached in some hot environments – change to seasonal use of resources Light yards for evening/night time animal handling
Decreasing rainfall (more likely in the south)	Increased exposure to drought, water resources less reliable especially where year-round stream flows become seasonal	Gradual change in many environments but thresholds might be crossed where water resources reach critical levels particularly systems that are dependent on seasonally available key resources	Improved use of seasonal climate forecasts, increased use of water storages, recalculation of safe stocking rates, increased mobility or availability of other forage resources, cropping land becomes marginal with conversion to pasture
Increasing rainfall (more likely in northern tropics)	Increased water availability for other uses, potentially more flooding in some areas	Gradual change	Opportunities for diversified agricultural use, pressure on pastoral land conversion to agriculture
Increase in extremes/variability	Direct impacts on vegetation and herd viability; on the vectors, extent and severity of livestock disease outbreaks;	Likely to be threshold changes	Support from policy to help deal with extreme events (e.g. drought relief, flexibility in land tenure arrangements), Limits to adaptation will be tested by extreme events recurring frequently

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Soil carbon - challenges of measurement, monitoring, modelling and management: a review

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Abstract. Market-based systems for soil carbon sequestration and soil health assessment have renewed opportunities to explore soil carbon stock measurement and methodology to assess change in soil carbon with time. The large distribution of Australian rangelands across soil, vegetation, fire and climate gradients (temperature and rainfall) and diverse range of management practices undertaken presents a challenge: how to determine broad-scale management effects, yet be detailed enough to inform at the paddock scale? In addition to the inherent variability in soil carbon across the landscape, relatively few soil carbon studies have been undertaken in Australian rangelands due to high costs associated with remote site access and analysis of soil carbon (in particular soil organic carbon) and soil carbon fractions (used to assist carbon cycling models and estimation of carbon change)

Several avenues of research and development (R&D) have recently been established to gain a better understanding of soil carbon dynamics in the northern rangelands. These programs consider a range of land management options common across the north including land clearing, grazing management, fire management and combinations of these. Increased R&D efforts are also being focused to improve analytical capabilities for the measurement and prediction of soil organic carbon and soil organic carbon fractions. Opportunity exists to link this information with other industry initiatives, to assist northern Australian Beef cattle businesses to improve their production efficiency and business resilience by considering productivity, profitability, land condition, greenhouse gas emissions and climate change risk.

Greater research attention is still required within Australian rangelands to reduce uncertainty in soil carbon estimation associated with (i) large spatial scale, (ii) relatively few datasets available for representation and modelling purposes, and (iii) analytical challenges associated with range of soil types, including carbonate soils within Australian rangelands. Such information would aid the understanding of rangeland soil health and productivity, grazing management effects on SOC and SOC pools, and evidence-based carbon sequestration accounting. In addition, this information could be used to improve the validation of soil carbon models used within Australia's National Carbon Accounting System.

Introduction

Soil carbon in rangelands is gaining increasing interest worldwide as new opportunities arise for market-based systems, including carbon sequestration and soil condition/soil health assessment; for comprehensive reviews on grazing lands and greenhouse gas fluxes, see publications from Australian (Cook *et al.* 2010) and global (Laca *et al.* 2010; Powlson *et al*. 2011) perspectives. The Carbon Farming Initiative (CFI) Bill, introduced to the House of Representatives in 2011, provides a framework and guidelines for the potential inclusion of soil carbon in domestic voluntary and international markets. Under the proposed Bill, sequestration projects and abatement activities (such as carbon offset projects) which 'involve management practices designed to reduce expected losses of soil carbon as well as increasing soil carbon sequestration' are considered (for details, see http://www.climatechange.gov.au/cfi). In addition to carbon offset markets, soil carbon provides an important indication of land condition and soil health in Australian rangelands since one of the major threats to the sustainability of Australian grazing lands is the depletion of soil organic carbon (SOC), particularly where inputs such as fertilizer are not economically feasible (Allen *et al.* 2010). The heightened level of attention and debate on soil carbon measurement and monitoring provides a challenge for science, policy, industry and public interests: for example, is information being obtained and communicated at the rate and clarity required to inform and assist management decisions? The following paper provides a brief overview of soil carbon in Australian rangelands, including considerations facing producers and industry, as well as research and development within this field. Finally, we discuss outcomes and gaps with regards to the potential for carbon offsets as well as to deliver productivity, efficiency or sustainability gains to producers and industry.

Issues and challenges facing producers and industry

Discussion regarding sampling methodology to assess soil carbon stocks and changes in carbon stock over time remains ongoing, making direct comparison of land use, soil type or management effects for reporting at regional or national levels challenging. Main considerations for Australian rangelands include:

Inherent variability in soil carbon across the landscape. Little information is available on the variability in soil organic carbon stocks in Australian grazing lands compared with other land uses, although greater heterogeneity is generally found in grazing areas than in cropped locations. The extent of variability is complicated by variation in soil type, landscape, topographic position, vegetation type and distribution and other factors such as seasonality, temperature and rainfall amount and distribution (Allen *et al.* 2010).

Sampling design approaches to soil carbon measurement. The role of grazing land management on soil carbon contents in Australian rangelands has been considered from tussock (Northup *et al.*, 2005) to plot scales (Harms *et al.* 2003; Bray *et al.* 2006; Witt *et al.* 2011), including plot-studies to assess soil carbon at the catchment level (Cowie *et al.* 2007). Complex interactions and processes affecting soil carbon concentrations and stocks are reflected across this range (see Allen *et al.* 2010). For example attempts to replicate tussock scale patterns at the paddock scale by measuring the distance from the soil core location to the closest perennial grass tussock have been problematic (Fig. 1). Thus, reporting of soil carbon stock at paddock, regional and national scales poses numerous questions – do the different scales of sampling require different sampling approaches? Will the sampling design for spatial representation of soil carbon stocks be suitable for the monitoring and assessment of temporal changes in soil carbon stocks over long periods? (Fig. 2).

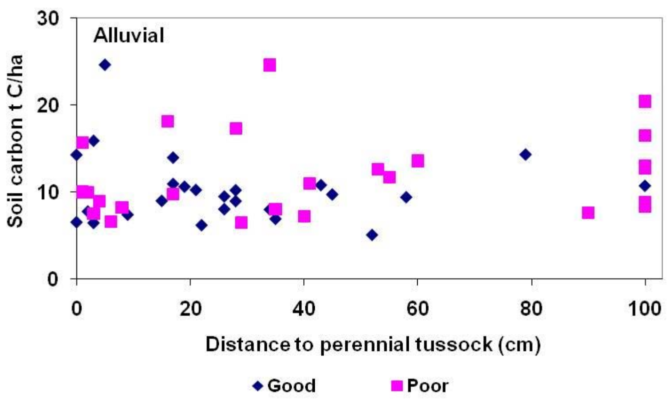
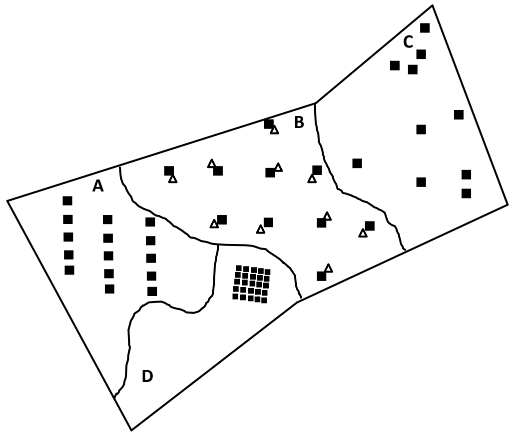


Fig. 1. Relationship between soil carbon content (0-10cm) and distance from the soil core to the closest perennial grass tussock (>3cm diameter) on an Alluvial soil in north Queensland. Good and Poor land condition sites were sampled (Bray *et al.* 2010).

Sampling options at paddock-scale



A = transect-style sampling
B = geostatistical-style sampling
C = random sampling
D = sub-sampling within paddock of interest

Sampling approaches may be undertaken as simple (ie entire paddock of interest) or stratified according to particular land use or management, e.g. soil type (denoted by curved lines).

Sampling options at national-scale

Australian National Soil Carbon Research Program:

- Site selection in major regions based on soil type and rainfall within agricultural regions
- Major land uses of regional interest identified using Australian Land Use and Management Classifications:
  Production from Relatively natural environments
  - Grazing natural vegetation
  Production from dryland agriculture and plantations
  - Grazing modified pastures
  Native/exotic pasture mosaic
  Woody fodder plants
  Pasture legumes
  Pasture legume/grass mixtures
  Sown grasses
  Production from irrigated agriculture and plantations
  Irrigated modified pastures
- Random selection of paddocks within region of interest

Other national sampling options

- Grid based sampling
- Stratification based on biophysical classes (see Cook *et al.* 2010 fig. 1).

Fig. 2. General sampling design options for Australian rangelands at (a) paddock scale and (b) national scale

Diversity of management practices across northern rangelands. Cook *et al*. (2010) note that rangelands comprise a large and diverse proportion of the Australian continent - this diversity challenges the interpretation of a national framework beyond a one-size-fits-all approach, in particular, how to document the wide range of management practices to assist Australian Land Use and Management classifications (noted in Fig. 2) for interpretation and integration of soil carbon stocks under different grazing management at a national level.

Measurement costs. Given the wide extent of Australian rangelands, relatively few soil samples have been collected due to (i) the high cost associated with field sampling in remote regions, (ii) large number of samples, and (ii) high analytical costs ($AUD 20-50 per sample) of soil carbon measurement.

Soil carbon fractions and management. A range of carbon fractions can be measured, including (i) less than 2mm fine-earth (generally reported as total soil carbon), (ii) 53µm-2mm fraction (particulate organic carbon) and (iii) less than 53µm fraction (charcoal and non-charcoal components including humus) (Skjemstad *et al.* 2004). Furthermore, soil carbon may be reported as total carbon (inorganic + organic) or as total organic carbon (removal of carbonate-carbon), although it usually is the soil organic carbon (SOC) which is considered for carbon sequestration and soil health purposes (Lal *et al.* 2007). Carbon isotope signatures relate to vegetation changes from C_3 (trees, shrubs) to C_4 vegetation (tropical perennial grasses), and may be used to assess the contribution of different vegetation types (trees, grasses) to total SOC stocks and turnover periods of different SOC fractions (Skjemstad *et al.* 2004; Krull *et al.* 2005).

Different methods for reporting soil carbon. Literature currently reports soil carbon as carbon concentration, or stock, the latter takes into account soil bulk density. Furthermore, soil carbon stock may be reported by spatial sampling depth (e.g. 10cm increments) or as a function of cumulative soil mass, to enable comparison on an equivalent mass basis (Gifford and Roderick 2003) to account for changes in bulk density due to management and/ or soil type.

Uncertainty regarding policy framework. The Carbon Farming Initiative is an emerging legislation, therefore, the development of a whole-of-system accounting framework to address additionality, permanence, leakage and other market-based considerations (including management of carbon credit rights, business off-sets, climate variability/climate change risk; for example, reporting times for soil carbon stock changes following management need to be long enough (50 – 100 years) to remove variability caused by extended dry years and permanence remains an iterative process. A large amount of information is currently in circulation in science and public arenas, some of which is conflicting – where to access the 'clear picture'?

Issues and challenges facing R&D in northern rangelands - how to deliver real productivity, efficiency or sustainability gains to producers and industry

Several avenues of R&D have recently been established to gain a better understanding of soil carbon dynamics in the northern rangelands. These programs consider a range of land management options common across the north including land clearing, grazing management, fire management and combinations of these. Further, effort to improve analytical measurement and prediction of SOC is being considered within the national soil carbon research project. These R&D activities include:

Grazing management and soil carbon studies. Recent work in Australian rangelands suggests contrasting responses of soil carbon stocks to management may be observed at the paddock-scale. For example, a detailed spatial study undertaken on two paddocks at Wambiana long-term grazing management trial, north Qld (Fig. 3) found a strong interaction of stocking rate and soil type on SOC stocks in the top 30cm of the soil profile, although the stocking rate response within each paddock varied according to the soil type (Table 1).

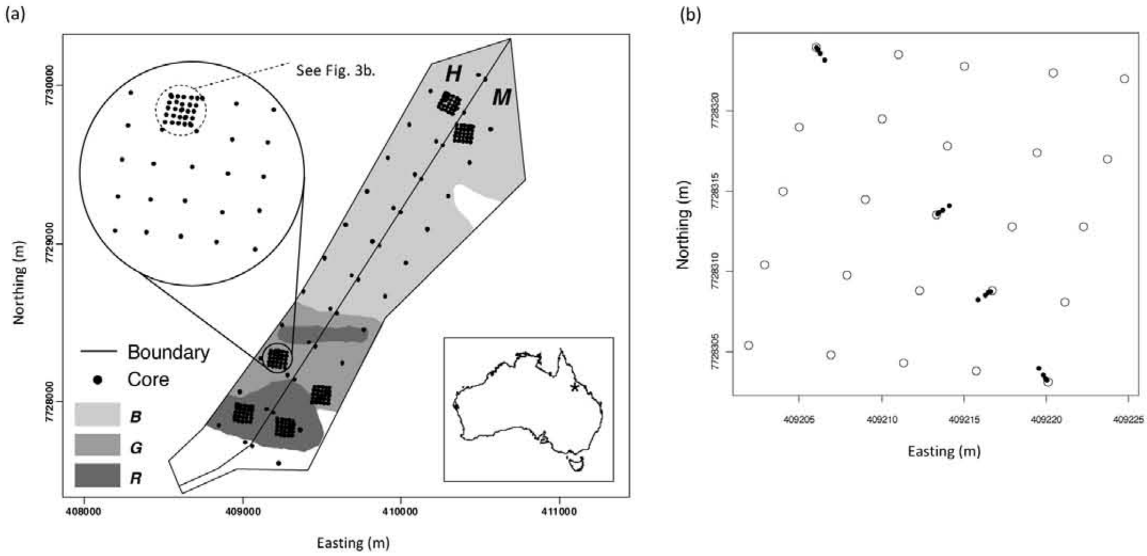


Fig. 3. Sampling method for soil organic carbon measurement at Wambiana long-term research site, Qld: (a) paddock (denoted *M*) represents historically moderate cattle-stocking rates, while paddock (denoted *H*) represents historically heavy cattle-stocking rates. Closed circles indicate where the paddock was soil sampled. Background shading indicates the classes of the soil map (*B* = black sodosol-yellow kandosol complex; *G* = grey vertosol; *R* = red kandsol); (b) Enlargement of the detail in Fig. 2a. Open circles indicate where soil was sampled in a grid pattern; closed circles indicate where soil was sampled on exponentially spaced transects (Pringle *et al.* 2011).

Fire and soil carbon in northern rangelands. Fire is common across most of northern Australia and is particularly prevalent in the wetter rangelands (termed 'savannas') of the Northern Territory, western Cape York, Queensland and the Kimberley, Western Australia (Russell-Smith *et al.* 2009). Australia's national greenhouse gas inventory currently accounts for non-CO_2 (methane and nitrous oxide) emissions from savanna burning which make up, on average, 3% of Australia's annual greenhouse gas emissions (Cook and Meyer 2009). This accounting underpins fire management programs for greenhouse gas abatement which aim to implement strategic early dry season burning to limit the extent and frequency of late season fires (Whitehead *et al.* 2008) of high intensity. Current fire abatement projects are being undertaken on Aboriginal-owned lands located in ungrazed savanna in the Northern Territory, but there is interest and ongoing research to extend these programs across the north (e.g. www.nailsma.org.au), including areas that are also grazed by cattle (see www.australianwildlife.org)

Table 1. Values of the final linear mixed model fitted to carbon stock (Mg ha^{-1})[A] at 0-30 cm depth, at selected moderate and heavy grazing paddocks, Wambiana, Qld[B].

	Soil Type[C]		
Grazing management	*B*	*G*	*R*
Moderate	16.21[b]	16.08[b]	11.40[c]
Heavy	17.13[d]	14.61[e]	10.56[f]

[A]Carbon stock values shown are the back-transformed mean, $\bar{z}$, of a log.-transformed variable is (Zhou and Gao, 1997): $\bar{z} = \exp\left(\bar{z}_t + \sigma_t^2/2\right)$, where $\bar{z}_t$ and σ_t^2 are the log.-transformed mean and variance, respectively. Within variables, values with a common letter are not significantly different at *P* = 0.05.
[B]Sampling design, including paddocks sampled, is shown in Fig. 2.
[C]Classes of soil type (*B* = black sodosol-yellow kandosol complex; *G* = grey vertosol; *R* = red kandsol).

However, fire affects not only non-CO_2 greenhouse gas emissions but also sequestration of C in above- and belowground C pools. Current work in northern Australia has been examining the impact of changing fire frequency and intensity on soil carbon stocks (Richards *et al*. 2011). Recent modelling results for mesic rangelands in the Northern Territory suggest that greatest soil carbon is stored under a fire regime of low intensity (early dry season) fires every 4 to 6 years (Richards *et al.* 2011) (Fig. 4). These estimates were made for Kandosol soils and when extrapolated across the Northern Territory, in areas receiving greater than 1000 mm rainfall per year, suggest that 0.2 t CO_2-e ha^{-1} y^{-1} could be stored in soil if fire regimes were reduced to one low intensity fire every 5 years (Richards et al. 2011). This figure is up to 5 times higher than the equivalent non-CO_2 emissions abatement generated by the reduced fire frequencies although the effect of the changed early season fire regimes every 5 years on grass and animal productivity was not modelled.

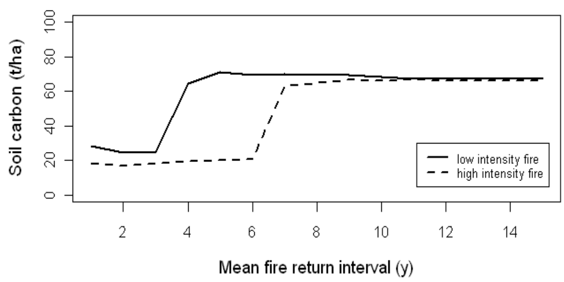


Fig.4. CENTURY model outputs of total soil organic carbon stocks to 30 cm depth under low intensity and high intensity fire regimes for a typical mesic (> 1000 mm annual rainfall) savanna open-forest growing on Kandosol soils. Outputs were generated by setting fixed fire return intervals and running the CENTURY model for 500 years so that soil pools were at equilibrium.

Additional research to quantify grazing and fire impacts on soil carbon stocks is being undertaken by CSIRO Researchers in Darwin. For example, Leigh Hunt has been undertaking a CSIRO funded scoping study to determine above- and below-ground carbon stocks and livestock methane emissions across the northern IBRA bioregions where grazing occurs. This study aims to prioritise those regions where there is greatest scope for increasing total carbon stocks under alternative grazing and fire management practices.

National soil carbon research project (SCRP). In brief, this joint national project involving federal and state agencies, CSIRO and Universities, aims to provide a nationally consistent assessment of soil carbon across major land-use and soil type combinations used for agricultural production across Australia, as well as data for further development of FullCAM, Australia's national carbon accounting tool (see http://www.csiro.au/science/Soil-Carbon-Research-Program.html).

Integration of greenhouse gas emissions and sequestration considerations into individual agricultural business decisions will be a key component of achieving on-ground change. The Climate Clever Beef project is an example of a DAFF and MLA supported demonstration project which aims to help northern Australian Beef cattle businesses to improve their production efficiency and business resilience by considering productivity, profitability, land condition, greenhouse gas emissions and climate change risk (see http://www.dpi.qld.gov.au/27_20060.htm). By integrating these components when analyzing past and possible future management options the individual business and the community will have a clearer understanding of the magnitude of change required and costs to meet a range of objectives (e.g. amount of sequestration required through improved land condition to offset livestock methane emissions).

Investigating Cell Grazing and other grazing management systems in northern Austalia (MLA, DEEDI, see Hall *et al*. 2011). This project includes case studies and costs for changing grazing management practices (e.g. increasing intensification of grazing).

Douglas Daly Research Farm, Research Project 'Cell Grazing for Better Productivity and carbon sequestration'. The project, established in 2009, aims to assess whether time-controlled or cell grazing management systems improve animal and pasture production and increase soil carbon sequestration, when compared with set stocked continuous grazing systems; the project will also assess whether there is potential for extra income for producers under a carbon trading scheme (see http://www.nt.gov.au).

Conclusions and recommendations

Decision uncertainty remains while a national policy framework and legislation relating to sampling protocol for soil carbon is maturing. Greater research attention is still required within Australian rangelands to reduce uncertainty by taking into account (i) large spatial scale, (ii) relatively few datasets available for representation and modelling purposes, and (iii) analytical challenges associated with range of soil types, including carbonate soils within Australian rangelands. Greater frequency of soil carbon measurements, including carbon fractions, will add to the understanding of rangeland soil health and productivity, and grazing management effects on SOC and SOC pools. In addition, these measurements will assist evidence-based carbon sequestration accounting as well as to improve validation of soil carbon models e.g. models used within Australia's National Carbon Accounting System, such as RothC and 3PG, and CENTURY models. Linking this information with possible management options at an individual-business level will provide clearer understanding of the magnitude of change and cost required to meet accounting and sustainability objectives (e.g. amount of soil carbon change required through land management to offset emissions or change in management practice).

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Recent advances in nutrition for improving liveweight gain

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Abstract. The beef industry faces on-going economic challenges with returns from cattle often not keeping pace with the increasing costs of production. Increases in the growth rate of cattle can lead to both improved gross margins, especially when associated with shifting the time of sale to one of price premium, and higher product quality, e.g., better compliance with Meat Standards Australia (MSA). In terms of nutritional strategies for increasing growth rates, all rely on improving the feed base with options around pasture improvement and supplementation being most practical. Recent research in this field includes defining the growth response relationships to major supplement types for young (weaners; <12 months) and older, finishing cattle on low quality tropical forages and defining the most appropriate phase of the growth path, from a cost-efficiency viewpoint, in which to undertake such nutritional interventions. Responses by both young and older steers were higher with protein meals compared with energy sources (e.g., grains and molasses mixes) at lower intakes (up to 1%W/day) but were similar at higher intakes, and were higher for older compared with younger steers overall. Identifying novel, low cost protein sources remains a priority for the north Australia beef industry and will probably require the source being grown on-property. The growth path can be manipulated either pre- or post-weaning. Studies from NSW indicate that restricted pre-natal and pre-weaning nutrition reduces calf weight at weaning but does not affect post-weaning growth rate on pasture, though age to finishing is extended. In a current grazing study in north Queensland the cost of supplementation of steers to a similar weight at the end of the second dry season post-weaning (24 months of age) was $60 more when a high-input molasses-based supplement was fed in 2 dry seasons compared to just the second one. The alternative of finishing steers on improved leucaena/grass pasture reduced the age of slaughter by 3 months. The need is for these studies to be more widely tested across seasons and to include a genotype overlay to exploit genotype x nutrition interactions. There is potential to improve growth rate in the future by applying new techniques now available, for instance molecular-based methods to understand and potentially manipulate the rumen microbial ecosystem and produce more microbial protein, or to examine and target by nutritional manipulation the expression of genes likely to enhance ruminant production.

Issues and challenges facing producers

Producing beef profitably in north Australia is becoming increasingly difficult in an environment where prices for beef are not keeping pace with the increasing costs of production. In a recent situation analysis of the north Australian beef industry, McCosker, McLean and Holmes (2009) indicated that as a result of escalating direct and overhead costs and of increasing indebtedness, the return on assets for beef properties had declined to very low levels of between 0.3 to 2% on average. Their analysis documented increases in overhead and direct costs per unit large stock unit (LSU) over the last decade of 54% and 150%, respectively. Of relevance to this paper, they also concluded that improvements in nutrition would have by far the greatest response when directed to improving the very poor reproductive rates of extensive beef herds, as for example detailed by Schatz and Hearnden (2008), when compared with feeding for increased growth. Nevertheless, their analysis showed that increased growth rates and higher turnover rates contributed to increased gross margins especially when associated with shifting the times of sale and purchase of stock to those of price premiums. These findings align with the earlier economic analysis carried out by MLA in developing the northern beef program strategic plan 2006-11 (Anon. 2006). The three main contributors to increased on-property productivity were increased branding rate, reduced age of sale and increased sale weight, where the latter two resulted from increased rate of liveweight (LW) gain (LWG). Whilst the main emphasis in this paper is increasing LWG of growing cattle the authors acknowledge that for real improvements in on-property profitability this would have to be achieved hand- in-hand with improved breeder herd performance.

Quite apart from economic effects, any improvement in weight for age at slaughter will have important impacts on meat quality. The significance of this is underlined by the development over the last decade of the Meat Standards Australia (MSA) grading system (Polkinghorne *et al.* 2008) which provides a yardstick for assessing improvements in eating quality of domestically-consumed beef. Compliance with such market targets will require considerable increases in LWG of cattle under grazing conditions in north Australia. For instance, English *et al.* (2009) estimated that compliance with MSA grading required an annual LWG of cattle of about 180 kg which was unachievable from grazing alone in most regions with the possible exception of the endowed areas, e.g., Brigalow and Darling Downs, and then only with pasture improvement and in good rainfall years. It is likely that similar demands for certified product quality will be imposed on export beef in the future.

As encapsulated in all of the major nutritional feeding standards, e.g., CSIRO (2007), an increase in LWG requires an associated increase in energy intake by the animal (see Poppi and McLennan 1995). In practical terms this generally means improving the feed base, for instance using improved pastures such as buffel or leucaena, or adding a supplement into the system. The challenge is to do this in a cost-effective way. For much of northern Australia the low fertility of the soils and the vagaries of the climate including low rainfall makes changing the forage feed base difficult or cost prohibitive with the result that less than 5% of northern Australia has been improved with introduced species and fertiliser. Supplements provide another option, their advantage being that they can be initiated or discontinued at short notice, for instance with changing climate or market conditions. In this paper the emphasis is on the use of both pasture and supplement options to increase LWG and thereby achieve higher final LW at younger age for various markets.

Recent R&D developments

Whilst the focus here is on nutritional strategies, we acknowledge that major and sustained improvements in production will occur through other means, particularly the application of genetic technologies. The use of breeds of cattle of higher growth potential, crossbreeding and heterosis, and selection within breeds for higher growth rate, for example by comparing estimated breeding values (EBV) of sires generated by BREEDPLAN (Grasser *et al.* 2005), will all contribute to improvements in overall growth rate and an integrated approach including improved genetics and nutrition is warranted (Graham *et al*. 2009; McKiernan *et al.* 2009; Wilkins *et al.* 2009). This paper will summarise recent findings in key broad areas, viz., growth response relationships to nutrients and the timing of nutritional intervention in the growth path of cattle.

Supplement response relationships

Supplementation research carried out in the past has progressed the general understanding of the growth and intake responses to various supplement types, in particular supplements which provide mainly a source of energy (carbohydrates), rumen degradable protein (RDP) and undegraded dietary protein (UDP), or combinations of all of these. A compilation of our own studies carried out in pens with young growing steers (about 200 kg; 6-12 months of age) has shown quite different responses to the protein meals compared with energy sources such as molasses and grains fortified with rumen degradable nitrogen (RDN) and limiting minerals (see Fig. 1; McLennan 1997, 2002). In general the response curve to energy sources tended to be linear across the full range of intakes, whilst that to the protein meals was curvilinear such that the highest incremental response was to small intakes of protein meal in keeping with a stimulus in microbial protein production in the rumen. At higher intakes responses were similar for both supplement types.

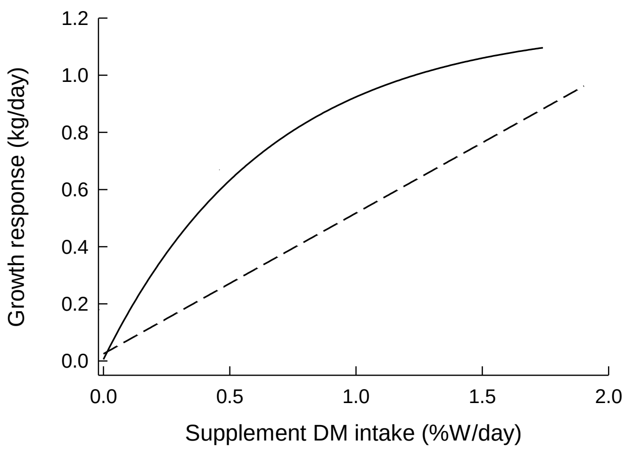

Fig. 1. Growth responses by young steers to protein meals (solid line) and 'energy' sources (dashed line).

Whilst this work has well defined the responses by young cattle to different supplement types, the same dose response information was not readily available for the older animal entering the finishing phase. Conventional wisdom would suggest that younger steers would show greater responses to supplement, in particular to protein, than their older counterparts given their higher deposition of protein relative to fat in gain (see CSIRO 2007). If so, the most cost-effective supplement would change according to the animal's stage of maturity. Pen feeding experiments have recently been carried out at Brian Pastures Research Station (S.R. McLennan and D.P. Poppi, unpublished) in which Brahman crossbred steers of the same origin, either 6-9 months or 30-33 months of age, were fed low quality (4.2% CP) pangola grass (*Digitaria eriantha*) hay with increasing intakes of either cottonseed meal (CSM; 0-1%W/day) or barley fortified with urea and minerals (Bar; 0-2%W/day). The growth response curves (Fig. 2A) indicated, as previously described, greater responses to CSM than to Bar for both age groups when intakes were expressed as a percentage of live weight although the difference between supplements was smaller for the older steers. In addition, the responses were greater for the older than younger steers within supplement type. Two subsequent experiments just recently completed (S.R. McLennan, C.H. Pham and D.P. Poppi, unpublished) with other diets have confirmed this higher response by the older steers. Despite these response curve differences, the plot between estimated metabolisable energy (ME) intake and energy retention, calculated using the feeding standards (CSIRO 2007), showed a single linear relationship for both age groups and supplements (Fig. 2B) indicating that the differences were not due to differences in efficiency of energy use (k_g; *ca*. 0.45) but to differences in ME intake modified by substitution effects.

Combining the results of these pen experiments several general conclusions can be drawn:

1. At low to medium intakes (0-1%W/day), responses to protein meals are greater than to energy sources for young and older cattle. However, at higher intakes the differences between supplements are less and energy sources will usually be more cost-effective due to their lower cost per tonne.
2. Responses to supplement are greater for older compared with younger steers when intake is expressed on a %W/day basis, but appear similar across age groups on a kg/day basis (results not shown). Thus within supplement type, there appears a similar requirement for supplement (kg/day) to achieve the same growth response by younger and older steers.
3. There tends to be a single linear relationship between ME intake and energy retention across age groups and supplement types, i.e., the efficiency of use of energy for growth is similar.

Protein sources

Despite the demonstrated high responses to protein meals their high cost limits their use under practical feeding conditions. This situation is unlikely to improve in the future with increased competition for protein sources from the monogastric industries, and the solution may be to grow a source of protein on-property. Leucaena is being used successfully in this role (see later) in areas of suitable soil type and climate and its use is expanding. Algae provide another possible option for this, being high in protein content and often containing high concentrations of lipids. Work by our own group has demonstrated growth responses by cattle to *Spirulina* spp algae inclusion in the diet which were similar to, but slightly lower in magnitude than CSM (D.F.A. Costa, S.R. McLennan and D.P. Poppi, unpublished). There is, however, considerable variability in composition between algal sources and growth responses are likely to vary widely accordingly. Costa *et al.* (2011) showed that inclusion of both *Spirulina* and *Chlorella*, but not *Dunaliella*, in the diet with low quality hay increased total DM intake by steers similarly to CSM. The major challenge in the future will be to find practical ways of growing the algae on-property in sufficient quantities to significantly increase protein intake.

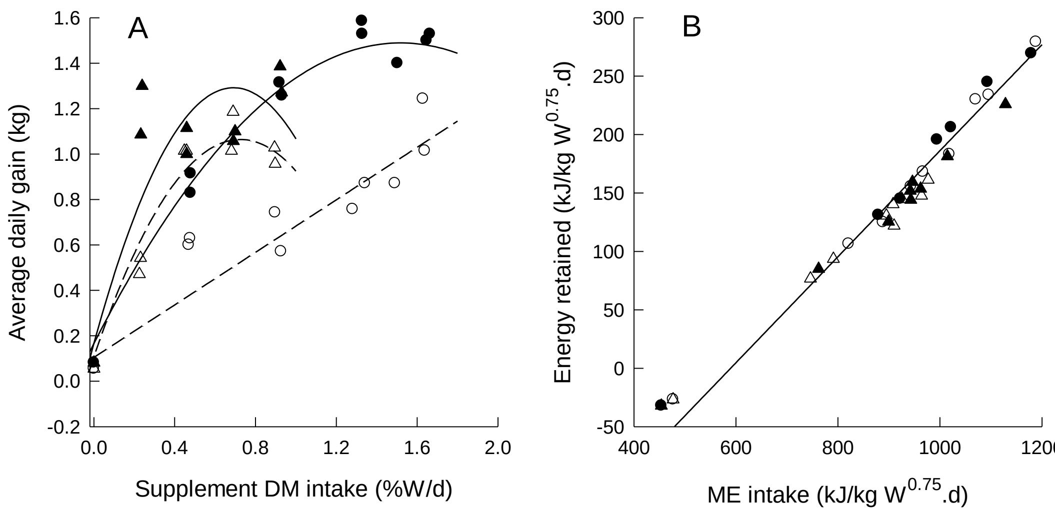

Fig. 2. Relationships between (A) intake of barley mix (circles) or cottonseed meal (triangles) and growth rate for young (open symbols, dashed lines) or older (closed symbols, solid lines) steers receiving hay *ad libitum*, and between (B) estimated metabolisable energy (ME) intake and energy retained by the steers in growth (same symbols as (A)). The regression line in (B) is: Y = -267.5 + 0.454 X; R^2 = 0.98, RSD = 13.69).

Growth path studies

Another major deficiency identified in the knowledge relating to cattle production in north Australia is how to incorporate nutritional treatments into the whole-of-life growth path when this often traverses several dry and wet seasons. Growth responses to such treatments in the dry season are often eroded by compensatory growth in the following wet season (Winks 1984; Ryan 1990) thereby reducing the economic returns from that earlier treatment. Winks (1984) suggested that compensatory growth could be from 0 to 100% and stressed its unpredictability.

Exploiting natural variability. Notwithstanding the effects of imposed treatments on growth rate, it is well known that there is considerable natural variability in the growth of cattle in north Australia which could be a product of their genetic background or of the variable management associated with pre-weaning performance, reproductive history and age of the cow and the stresses associated with weaning on the calf. A recent study in the Northern Territory (Streeter *et al*. 2011) investigated the relationship between dry season LW change of steers post-weaning and their LWG in the following wet season and found no correlation between the two. In further studies Farmer *et al.* (2011) selected steers on early post-weaning growth rate and measured their subsequent growth in pens on diets of low (Mekong grass (*Brachiaria brizantha*; 3% CP) plus urea-S and copra meal) or higher (Cavalcade (*Centrosema pascuroum*; 10.5% CP)) quality. They recorded no differences in growth rate by steers previously selected for low or high post-weaning LWG, nor were there differences between groups in the composition of their rumen microbial populations prior to feeding (Martinez *et al*. 2011). It appears that selecting cattle on early post-weaning growth rate is not a reliable way of ensuring whole-of-life growth performance and infers that weaning management has the overriding effect on early post-weaning performance.

Pre-weaning nutrition. In northern NSW the recent research emphasis has been on the impact of under-nutrition of the cow during pregnancy and lactation on the whole-of-life growth of the progeny (Cafe *et al*. 2006, 2009; Greenwood and Cafe 2007). Restricted pre-natal and pre-weaning nutrition and growth resulted in lighter calves at birth and weaning but did not generally affect subsequent (post-weaning) growth and efficiency when cattle were grown out on pasture-based systems, although this could depend on the quality of the feed post-weaning. Nevertheless, in the apparent absence of any appreciable compensatory growth, those calves growth-restricted early in life were lighter than their well-grown counterparts at any age which led to an increase in age of slaughter, with obvious economic implications. It is likely that the impacts of low growth of calves prior to weaning will be greater in the north Australian tropics where the quality of post-weaning nutrition is usually lower than that encountered in temperate and sub-tropical regions. This warrants investigation. However, under extensive grazing conditions modifying pre-weaning nutrition and growth other than by judicious breeder management is difficult as it usually coincides with the wet season when supplementation is difficult, so most treatments are applied post-weaning.

Post-weaning nutrition. Wilkins *et al.* (2009), Graham *et al.* (2009) and McIntyre *et al.* (2009) carried out studies in southern and Western Australia to determine the effect of post-weaning (backgrounding) growth rate on final carcass characteristics of cattle. Over all experiments, there was a direct relationship between growth rate post-weaning and level of fatness in the animal either just prior to feedlot entry or after feedlot finishing. However, in these studies using *Bos taurus* cattle the rate of 'slow' growth was at least 0.5 kg/day. Thus the relevance of these results to extensive grazing system of north Australia based on *Bos indicus* crossbreds with growth paths often incorporating significant periods of weight loss is still to be determined.

Currently a grazing experiment is underway in the sub-coastal speargrass region of north Queensland at Swans Lagoon Research Station to investigate whether, when targeting higher finishing weights at young age, it is more efficient to supplement steers at a young (immediately post-weaning) or older (pre-finishing phase) age in terms of the costs of feeding. One-hundred and fifty Brahman crossbred steers grazing native pasture were allocated at weaning to various supplement and pasture treatments incorporating low (L), medium (M) or high (H) growth rates in the first (DS1) and second (DS2) dry seasons post-weaning. Low (L) groups received a commercial urea/S/salt dry lick (*ca*. 30 g/d urea) in DS1 whilst the M and H groups in DS1 and DS2 received a molasses-urea-copra meal-salt-dicalcium phosphate-Rumensin (100:3:10:1:1:0.05 w/w, as fed; MUC) mix at varying intakes. One group received no supplement in DS2 (nil) whilst another group was transferred to leucaena/grass pasture at Brian Pastures, Gayndah (leuc). The treatments can be summarised according to their DS1 and DS2 treatments as: L-nil, L-H, L-leuc, M-M and H-H. The aim was for the L-H, M-M and H-H groups to reach the same LW, but via different growth paths, at the end of DS2 by varying intakes of MUC supplement for these groups in the second year. Superimposed across these supplement treatments, half the steers in each group were implanted with hormonal growth promotants (HGP) from weaning to slaughter.

The growth paths for the different treatment groups of draft 1 are illustrated in Fig. 3A. Comparing the H-H and L-H groups, the LW advantage to the former receiving MUC (3.9 kg/day) was 48 kg, at an estimated additional cost of $90 ($98 vs. $8) compared with the latter receiving dry lick, by the end of DS1 but this was reduced by compensatory growth to 25 kg by the end the following wet season. By feeding the MUC supplement to both groups in DS2, albeit at different rates averaging 5.3 and 6.0 kg/day, respectively, these groups achieved similar LW by January 2010 which was 107 kg heavier than that of the L-nil group, unsupplemented in DS2. This latter group has had to be carried over for an extra 12 months to achieve the same slaughter weight as other groups (Fig. 3A). The estimated total costs of feeding from weaning for the L-H and H-H groups to similar LW at the end of DS2 was $60 less for the L-H treatment. Shifting the steers to a high quality feed base in leucaena/grass pasture at the beginning of DS2 (L-leuc) markedly accelerated growth and resulted in reducing the time to slaughter by over 3 months. The cost of this option is yet to be assessed. The growth response to HGPs from weaning to the end of the second wet season averaged 8% (23 kg) for the steers grazing native pastures at Swans Lagoon but was 15% (45 kg) for the steers growing faster on leucaena pastures. This is a low-input treatment which bears consideration but the potential impacts on meat quality, for instance lowered MSA scores, need to be considered.

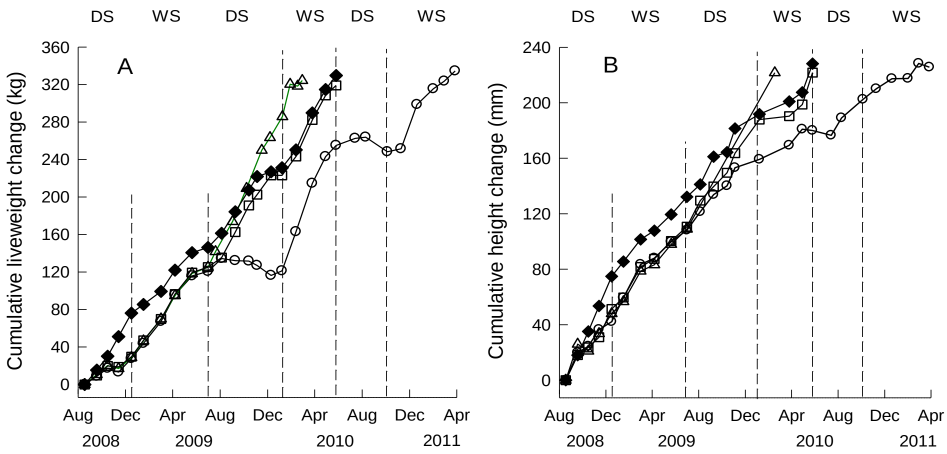

Fig. 3. Cumulative changes in (A) liveweight and (B) height post-weaning for steers on different growth paths derived using different combinations of supplement over two dry seasons: L-nil (circle), L-H (square), L-leuc (triangle) and H-L (diamond; see text for descriptions). Dry (DS) and wet (WS) seasons are separated by vertical dashed lines.

The relationship between LW and height, which is a function of skeletal growth, is important as it has been previously established that muscle deposition follows skeletal elongation (Holly *et al*. 1980). It was significant here that even during periods of weight loss (e.g., L-nil in DS2) height continued to increase for some time (Fig. 3B). It was, however, at a slower rate than the 0.35 mm/day achieved overall by the H-H group where no major disruption to growth occurred. The challenge thus is to devise ways of maintaining skeletal growth at higher levels during periods of nutritional deprivation in order to later exploit compensatory growth through accelerated muscle deposition.

The results from these studies illustrate the opportunities to manipulate the growth path, either pre- or post-weaning, in order to more cost-effectively achieve target market outcomes. Some innovative approaches will be required in the future in this area to maintain profitability and make most efficient and sustainable use of grazing lands.

Future R&D areas to deliver real productivity and efficiency gains to the beef industry

Liveweight gains from native or improved pastures have been quantified during the 1960s and 1970s (Winter *et al*. 1991) and there is no evidence of major increases since then as the pasture base has not changed substantially and supplementation strategies have been considered too expensive to implement. The biological answer to increasing LWG off the pasture base is simple and the most effective solutions are to either add a protein source or replace the feed base. Novel alternative sources of protein are urgently needed and because of the international requirement for protein for many industries the only long-term cost-effective way is for producers to grow their own. Algae are one such option but more are needed. Alternative replacement feed bases are also urgently needed and these would be best targeted towards filling feed gaps or extending growing seasons in order to manipulate growth paths. Such a strategy means that only small areas need be developed and could be achieved within the rangeland setting.

More speculative strategies target the basic physiology of the animal. Compensatory growth, rumen function and gene expression are three aspects which provide challenges to our capacity to understand how we might manipulate growth. New approaches to exploiting compensatory growth are linked to increasing skeletal elongation to provide the mechanics for associated muscle growth. The two are intimately linked but the challenge during dry season under-nutrition is to keep the skeleton elongating at a rate commensurate with that achieved during the wet season so that the animal is primed for much greater compensatory growth. Future studies in this area are warranted but should also include a genetic overlay in order to better understand the interactions between breed attributes and growth under variable conditions.

Enhancing the capacity of the rumen to provide more microbial protein and increase the rate of fibre digestion would increase growth rate. There are clear experimental models which demonstrate that liveweight gain would increase with or without an increase in intake by the animal if more microbial protein flowed to the intestines (see Poppi *et al.* 1999). Molecular-based methods now provide a means for us to understand the interaction of the host, the rumen conditions created through diet and the ecology of the microbial species in the rumen. The question is whether this will lead to novel strategies to enhance rumen function and the supply of microbial protein.

Recent developments in molecular-based methods have facilitated the characterisation of the bovine genome and a better understanding of the role of certain genes in different aspects of ruminant production. The value of characterising genes or developing markers that enable better genetic selection is obvious but their application with multi-gene traits such as LWG is not quite as simple as first conceived. Examining the expression of genes in tissues of animals under different nutritional regimes provides a means to understand the metabolic control of the animal response but, by itself, does not provide the means to increase production. The hope is that a better understanding of gene pathways within various animal models may lead to different nutritional manipulations than are currently used to target key genes or groups of genes to enhance ruminant production. One aspect not yet well understood is the effect of the *in utero* environment on gene expression, and tissue and organ development of the embryo and foetus and the potential long term impacts on lifetime productivity of ruminants.

Animal growth is constrained by the digestibility of the feed base. A blue sky approach is to increase the digestibility of that feed base by some exogenous treatment. This was attempted in the past with alkali and ammoniation treatment of straws with little practical success. Nevertheless the cellulosic biofuel industries face the same problem in that they have to release monosaccharides of various chain lengths from the inhibiting matrix of lignin complexes for fermentation. The ability to design and produce enzymes of a particular structure and function is expanding rapidly and the biofuel industry is investing heavily in this area. These enzymes could also be used in pre-treatment of low quality forage so there may be real opportunities in the future for the ruminant industries to capitalise on outputs from the biofuel cellulosic industries.

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Phosphorus nutrition and management – overcoming constraints to wider adoption

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Abstract. The importance of phosphorus nutrition for cattle grazing northern Australian rangelands has been well documented and demonstrated. Phosphorus is clearly one of the most important nutritional deficiencies, within the limitations of potential metabolizable energy intakes, of grazing cattle in the seasonally dry tropics. Nevertheless it appears that only a small proportion of cattle grazing phosphorus deficient pastures are supplemented or otherwise managed to alleviate phosphorus deficiency. Estimated requirements for dietary phosphorus by various classes of cattle grazing tropical pastures have recently been revised (CSIRO 2007). The development of faecal near infrared spectroscopy (F.NIRS) allows the routine estimation of metabolizable energy and nitrogen concentrations in the diet, and thus the potential productivity, of cattle grazing northern rangelands. The concentration of phosphorus in the diet of grazing cattle can be estimated from the concentration of phosphorus in the faeces, at least in cattle not fed phosphorus supplements. Combining estimates of diet metabolizable energy, nitrogen and phosphorus allows estimation whether current needs of the animal are supplied by the diet. Phosphorus-replete cattle have substantial body reserves of phosphorus which can be mobilized, especially in late pregnancy and lactation, to alleviate a dietary deficiency. However, these body reserves need to be replenished in late lactation or post-lactation if mobilization occurs each year. Diagnosis of subclinical phosphorus deficiency in grazing cattle, and prediction of animal responses to phosphorus supplements is difficult. In growing cattle the concentration of inorganic phosphorus in blood (Pi), in the late wet or early dry season, combined with information on diet metabolizable energy and nitrogen concentrations obtained by F.NIRS, provides the most reliable test. In pregnant or lactating cows measurements of faecal phosphorus concentration and F.NIRS provide the best estimate of whether phosphorus intake meets the current needs of the animal. However, estimates of adequacy of phosphorus supply need to also consider possible mobilization of body phosphorus reserves. Indicative responses to provision of phosphorus supplements by cattle grazing pastures ranging from marginal to acute deficiency are summarized. Economic evaluation of benchmark enterprises where cattle are expected to be phosphorus deficient indicate that phosphorus supplementation is highly cost-effective. Major obstacles to more widespread adoption of phosphorus supplementation appear to be lack of knowledge and appreciation by managers of the phosphorus status of their cattle, lack of appreciation of the cost-effectiveness of a phosphorus supplementation particularly for some classes of cattle, and the practical difficulties in implementing phosphorus supplementation during the wet season.

Introduction

The importance of phosphorus as a limiting nutrient for cattle grazing the rangelands of northern Australia has been recognized for many decades. Against the background of the generally low metabolizable energy concentration and intake of tropical forages in the seasonally dry tropics, intake of phosphorus is arguably the single most important nutritional constraint for increased productivity in a large proportion of the northern beef herd. Phosphorus is seldom a major nutritional constraint for cattle production in temperate or intensive systems since extensive use of phosphorus fertilizers and availability of high phosphorus feedstuffs usually ensure adequacy. Indeed the focus of phosphorus nutrition in such systems has changed to reduction of phosphorus usage to address environmental concerns. Knowledge of phosphorus as a nutrient limiting for grazing cattle is primarily from research and experience in northern Australia and South Africa.

Proceedings of a phosphorus workshop (Tropical Grasslands 1990) and McCosker and Winks (1994) provide excellent overviews of knowledge, and practical perspectives, of phosphorus in the nutrition of cattle in northern Australia at that time. Major studies in northern Australia since then are those of Ternouth *et al.* (1996), Ternouth and Coates (1997) and Miller *et al.* (1998). The principal pathways of digestion, absorption and excretion of phosphorus are known. Usually about 75% phosphorus in forages is digested and absorbed from the gastrointestinal tract, while the availability of phosphorus in supplements may vary depending on the source. Absorbed phosphorus passes to the blood inorganic phosphate pool. A large amount of inorganic phosphorus in the blood is transferred (recycled) to the rumen in saliva, and in grazing ruminants this recycling is usually much greater than the phosphorus intake. At low to moderate phosphorus intakes almost all excretion of phosphorus is via faeces.

Deficiency of dietary phosphorus can have large effects on animal health and productivity. Clinical symptoms of phosphorus deficiency such as abnormalities associated with skeletal structure and abnormal ingestive behaviour (pica, bone chewing) are well known (McCosker and Winks 1994). In acutely phosphorus-deficient land systems the productivity of cattle is usually reduced severely and the problems obvious. Often the more difficult situation to evaluate is that of subclinical phosphorus deficiency where cattle growth and reproduction are lower than expected, but symptoms of deficiency are not obvious. Phosphorus deficiency in cattle is typically associated with reduced voluntary intake of forage (e.g. by up to 50%) and poor productivity. Reduced fertility is due primarily to consequent poor body condition. Botulism as a consequence of bone-chewing may cause high mortality in cattle which have not been vaccinated. The effects of phosphorus deficiency on the animal seem to be mediated primarily at the metabolic level rather than through direct effects on rumen digestion. There are interactions between the metabolism of phosphorus and calcium. Phosphorus in bones can provide a reserve for animals through intervals of dietary phosphorus shortage comparable to the role of fat reserves for the energy requirements of the animal.

Adoption of management to alleviate phosphorus deficiencies across northern Australia

The most obvious approach to addressing phosphorus deficiency is to provide phosphorus supplements, although other management such as earlier weaning and lower stocking rate are also important. It appears that phosphorus as a nutritional constraint is not effectively addressed in many northern cattle herds.

The reasons for the generally low adoption of management options to effectively alleviate phosphorus deficiency across northern Australia have not been documented. Based on the opinion of experienced extension officers, technical staff in the stockfeed industry and property managers, and a small survey in the Kimberley region (P. Smith, unpublished results) the most important reasons appear to be:

(i) a lack of knowledge by property managers of the phosphorus status of their land systems and their cattle, and often a perception that phosphorus is not a serious constraint in their circumstances and during the wet season when cattle are already growing. This results from the lack of a simple and effective diagnostic tool to measure the severity of phosphorus deficiency,

(ii) a lack of knowledge of the economics of phosphorus supplementation, and confidence that the animal responses to phosphorus supplementation would be economically worthwhile. Key concerns include the amounts of phosphorus required, animal growth and reproduction responses in specific situations, the input costs and the delays before the production benefits can be captured. This is often exacerbated by lack of adequate herd records,

(iii) the practical difficulties in implementing phosphorus supplementation during the wet season (e.g. access, achieving satisfactory supplement intakes, labour).

Economic benefit of phosphorus supplementation

A major difficulty with costs and benefits analysis for commercial properties is that introduction of a phosphorus supplementation program is usually accompanied by other management changes (e.g. improved vaccination, culling, weaning). It is usually difficult to identify the contribution of phosphorus supplementation versus other management changes to improved productivity and economic performance of the enterprise. Thus estimation of the effects of phosphorus supplementation on performance of commercial cattle herds has to depend primarily on subjective 'best estimates' of experienced people.

Table 1. The cost-benefit of wet season phosphorus (P) supplementation for a benchmark cattle property (Croydon, north Qld) in a phosphorus deficient region.

Variable	With dry season P supplementation	With wet season + dry season P supplementation
Animal Equivalents (AE)	4000	3600
Total cattle	6,032	4,828
Breeders mated	2,944	2,411
Female/total turnoff (%)	37	46
Gross margin per AE ($)	57	103
Herd gross margin ($)	228,000	372,000
Herd advantage to WS P supplement ($)		144,000

The economic benefit of phosphorus supplementation on a commercial cattle property has recently been evaluated for a 'typical' benchmark cattle property in the Croydon area of north Queensland where very low soil phosphorus leads to extensive and acute phosphorus deficiency of cattle given no phosphorus supplements. 'Best estimates' by experienced extension officers with knowledge of the region were used to estimate the required inputs and the changes in the herd structure and herd outputs from introduction of wet season phosphorus supplementation. The evaluation was done using the using the Breedcow / Dynama Herd Budgeting software program.

Assumptions for an established 'dry season phosphorus supplement' situation included: (i) a herd of 4,000 adult equivalents (AE) or 6,032 head including weaners, (ii) 2,944 breeders mated and a 43% weaning rate, (iii) annual breeder mortality of 7.9%, (iv) dry season supplements fed providing N and also 3 g P/breeder/day ($19 per breeder and $16 per heifer or steer), (v) steers sold at 42 months at 350 kg liveweight, and (vi) cull cows sold at 400 kg liveweight. Assumptions for a 'wet season plus dry season phosphorus supplement' situation included: (i) 10% less AE (3,600) to allow for the increased pasture intake of phosphorus supplemented cattle. Also a higher AE rating was used to account for the greater liveweight of cattle; the new herd comprised 4,828 head including weaners, (ii) 2,411 females mated and 53% weaning rate (i.e. a 10 percentage units or a 23% increase), (ii) annual breeder mortality of 4.2% (i.e. a 3.7 percentage units or 47% reduction in mortality rate), (iv) no change in the dry season supplement fed, (v) steers sold at 30 months at 360 kg liveweight, (v) cull cows sold at 420 kg liveweight. Additional input costs for wet season phosphorus supplementation included: (i) lick sheds and shipping containers for storage (capital cost $22,000), (ii) ongoing labour and vehicle costs ($3,970 per annum), and (iii) ongoing costs for the wet season phosphorus supplement at $13 per breeder and $9 per heifer or steer.

The economic analyses (Table 1) indicated that the wet season phosphorus supplementation in this situation was highly cost effective with an advantage (net of the new fixed costs) of $144,000 per annum for the property or $36 per AE of the herd before the management change. Other advantages would accrue if the wet season phosphorus supplementation allowed reduced dry season supplementation and easier handling of quieter cattle.

Another analysis of the economic benefits of phosphorus supplementation in the context of Central Queensland (Donaghy *et al.* 2010) also found very favorable economic benefits to phosphorus supplementation, comparable with those described above. Evaluation of the benefits from phosphorus supplementation in regions of marginal phosphorus status is more difficult. The increases in herd performance are likely to be lower, but so also the input costs since lesser amounts of phosphorus supplement will be required. Overall, these evaluations suggest that phosphorus supplementation is highly cost-effective where cattle are deficient in phosphorus.

A new approach to the estimation of requirements for phosphorus supplement

The calculated requirements of dietary phosphorus by various classes of cattle grazing tropical pastures have recently been revised (CSIRO 2007) based on studies of Ternouth *et al.* (1996) and Ternouth and Coates (1997). The estimated requirements are generally lower than those previously adopted. However, a difficulty with this approach is that the DM intake must be estimated for each specific situation. We have used F.NIRS data sets to estimate the diet DM digestibility corresponding to various rates of liveweight change of young growing cattle in the northern rangelands, and then based on CSIRO (2007) and QuikIntake estimated pasture intakes for both growing and breeder cattle. The phosphorus required for cattle in various rates of liveweight gain or loss, and for the pregnant and lactating cow, was calculated (Table 2).

Table 2. The estimated phosphorus (P) requirements of 400 kg steers and lactating cows calculated following CSIRO (2007) and likely threshold values for adequacy of dietary P requirements. Any net mobilization of P from body reserves will reduce these required amounts.

Liveweight gain (kg/day)	Estimated DM intake (kg/day)	Diet P required (g/day)	Diet P required (g/kg DM)	Faecal P required (g/kg DM)[A]	Faecal P/DietME required [B]	Faecal P/diet DMD required [C]
Steers						
-0.3	6.1	4	0.6	1.5	220	30
0	6.8	7	1.0	2.1	290	40
0.3	8.6	10	1.2	2.5	330	46
0.6	10.3	14	1.4	2.7	340	49
0.9	11.6	18	1.5	3.0	360	51
1.2	12.8	21	1.6	3.2	370	53
Lactating breeders[D]						
-0.3	8.2	13	1.6	3.1	430	60
0	9.5	17	1.7	3.3	420	60
0.3	10.7	20	1.9	3.5	410	59
0.6	12.0	23	1.9	3.6	400	57
0.9	13.3	27	2.0	3.7	380	55

Notes: [A], the concentration of P in faeces at which dietary P requirements are expected to be met. [B], the ratio of the concentration of P in faeces (mg P per kg faecal DM) to ME content of the diet (MJ ME per kg diet DM) at which dietary P requirements are expected to be met. [C], the concentration of P in faeces (mg P/kg DM) to the DM digestibility (%) of the diet at which dietary P requirements are expected to be met. [D], calculations assume 5 kg milk per day and 2 months pregnancy.

A second aspect to the new approach is to use the concentration of phosphorus in faeces to estimate the concentration of phosphorus in the diet. In cattle grazing tropical pastures there is a close relationship between diet and faecal phosphorus concentrations in cattle not fed phosphorus supplements, with faecal concentration about twice that in the diet. Estimation of DM intake and diet phosphorus concentration allows estimation of the phosphorus intake by grazing cattle (Table 2). Furthermore, the concentration of phosphorus in faeces, or the ratios of faecal phosphorus concentration to diet DM digestibility or diet metabolizable energy content provide 'threshold' values specific to classes of cattle below which phosphorus intake is likely to be lower than animal requirements. The amount of phosphorus supplement needed by the animal to meet current requirements can then be calculated by difference.

The role of bone phosphorus reserves

In cattle in replete phosphorus status there are about 7–8 g phosphorus/kg liveweight. Thus a 400 kg cow has about 3000 g phosphorus, and most is in bone. Experimentation from sheep, goats and dairy cows indicates that up to 40% of bone phosphorus in the replete animal may be mobilized to alleviate severe and prolonged phosphorus deficiency during late pregnancy and lactation, and the rate of mobilization can exceed 25 mg P/kg liveweight/day. Observations that growing cattle may not reduce voluntary intake until 2-4 months after a change to a phosphorus-deficient diet indicates that body reserves of phosphorus can also be used to alleviate dietary deficiencies in this class of animal. However, there is little information to estimate the rate and the interval over which mobilization of body reserves of phosphorus occurs in the northern Australian cattle, and most importantly in the breeder cow. Nevertheless, a conservative estimate that 20% of phosphorus reserves are mobilized would equate to 600 g phosphorus. This amount would be sufficient to provide 10 g P/day for a month at peak lactation plus 5 g P/day for a further 2 months, and thus make a major contribution to the phosphorus status of the breeder cow through the high requirements of late pregnancy and early lactation.

A South African study (Read *et al.* 1986a; 1986b; 1986c) where breeders grazed phosphorus deficient pasture for 5 years clearly demonstrated the role of body phosphorus reserves to alleviate the effects of dietary phosphorus deficiency. In initially phosphorus-replete heifers the provision of phosphorus supplements had only modest effects on metabolizable energy intake and liveweight during the first annual cycle. Effects of phosphorus supplementation on cow liveweight and calving rate were not observed until the second annual cycle, and effects on Pi and rib bone phosphorus composition not until the third annual cycle. The cows were apparently able to mobilize sufficient phosphorus reserves during the first annual cycle to avoid most of the effects of the diet deficiency.

Clearly if a cow mobilizes body phosphorus reserves to alleviate diet deficiency during late pregnancy and lactation, these body reserves must be replenished in late lactation and/or post-lactation before the next interval of high phosphorus demand. In the northern Australian context the cow which is calving in the early wet season each year will have limited opportunity to replenish reserves since late dry season pastures are generally low in phosphorus, although early weaning should allow increased replenishment. Cows which calve each second year should have ample opportunity for replenishment.

Metabolic control of phosphorus and mobilization of body phosphorus reserves depends primarily on the calcium status of the animal. A cow in dietary calcium deficiency can be expected to mobilize calcium from skeletal reserves to provide for this deficiency, and phosphorus will be mobilized even if dietary phosphorus intake exceeds the current requirements of the animal. Conversely, if intake of dietary calcium is in the excess of current animal requirements, the animal may not mobilize phosphorus, or will mobilize lesser amounts of phosphorus, even if the intake of phosphorous is less than the current requirements. Thus high calcium intakes, such as are likely to occur for stylo pastures with high Ca:P ratios (up to 20:1), may reduce mobilization of body phosphorus reserves. Also, because the concentration of phosphorus declines much more that that of calcium as tropical grass pastures mature, dry season pastures will often have elevated Ca:P ratios. A further implication is that inclusion of calcium as limestone in dry season supplements is not likely to be beneficial, and may even have adverse effects on the performance of grazing cattle if mobilization of phosphorus body reserves is reduced.

Diagnosis of phosphorus deficiency

Diagnosis of acute phosphorus deficiency is likely to be straight-forward when symptoms such as peg-leg, pica and bone chewing are observed or when soil is known to be uniformly phosphorus deficient. Diagnosis of sub-clinical deficiency associated with reduced cattle production is generally both more difficult and more important. Miller *et al.* (1990) outlined a useful decision tree approach to this problem.

In the growing animal not fed phosphorus supplements the concentration of inorganic phosphorus in blood (Pi) during the late wet or early dry seasons following the main interval of liveweight gain appears the most reliable diagnostic test. However defined sampling protocols (e.g. TCA precipitation of blood, adjustment for jugular or caudal vein sampling site) must be followed (Wadsworth *et al.* 1990; Coates 1995), and there are often serious obstacles to obtaining appropriate blood samples in commercial property situations. Pi primarily reflects intake of absorbed dietary phosphorus. Pi < 25 or 25-35 mg P/L indicates acute deficiency or deficiency respectively and a large response to phosphorus supplements. For Pi > 50 mg P/L only a low response, or no response, can be expected to phosphorus supplements. Associated F.NIRS evaluation of the diet quality indicates potential liveweight gain as constrained by diet metabolizable energy and nitrogen concentrations.

In lactating cows satisfactory reproductive performance can be maintained when Pi is as low as 30 mg P/L, and possibly at even lower Pi concentrations. The lactating cow can apparently often mobilize sufficient phosphorus from body reserves to maintain performance even when Pi is very low. In cows in late pregnancy and lactation the most appropriate diagnosis is likely to be by measurement of the concentration of phosphorus in faeces of animals not fed phosphorus supplements to estimate the concentration of phosphorus in the diet pasture selected. Estimation of the phosphorus status will require consideration of the expected phosphorus requirement of the animal (from estimates of the metabolizable energy intake derived from F.NIRS) and the potential for mobilization of phosphorus from body reserves to provide for dietary deficiency of phosphorus at least over restricted intervals. In addition the Pi of growing steers or non-pregnant heifers in the same herd should provide a diagnosis. Where herds are being fed phosphorus supplements, the removal of supplements for 1-2 weeks before blood or faecal sampling should allow the Pi or faecal P concentrations to decrease and to be similar to cattle not fed phosphorus supplements, and thus allow satisfactory diagnosis.

Likely responses to phosphorus supplements

Whether cattle in a specific situation respond to phosphorus supplements, and the magnitude of this response, depends on numerous factors, but the principal issue is whether phosphorus is the first-limiting nutrient. The majority, or all, of the annual response in growing cattle occurs during the wet and wet-dry transition seasons. Dry season pastures are usually primarily deficient in nitrogen or available energy, not phosphorus. In addition, because animal responses generally depend on an increase in voluntary intake of pasture, responses will only occur when there is sufficient pasture available for cattle to be able to increase their pasture intake when phosphorus supplements are given.

Indicative estimates of the cattle responses to phosphorus supplements (Table 3) are based on reported trials (Winks 1990; Miller *et al.* 1998), observation and experience. Clearly responses have varied widely between trials and between years within a trial, and sometimes were less than or occasionally much greater than indicated (e.g. up to 130 kg liveweight per annum).

Established recommendations (McCosker and Winks 1994) are that phosphorus supplements should be fed to growing cattle only during the wet and the wet-dry transition seasons when pasture quality is sufficient for liveweight gain. In addition they should be fed during the dry season to lactating breeders with their high demand for phosphorus for milk production. However, recent knowledge suggests that benefits can also be expected from dry season phosphorus supplementation of breeders post-lactation. First, the evidence from other ruminants indicates that there is normally extensive deposition of phosphorus into bone reserves in late lactation and post-lactation, and extensive mobilization of phosphorus from bone reserves in late pregnancy and early to mid lactation. Although there is little experimental evidence for the northern breeder cow, it is likely that in late pregnancy such breeders grazing dry season pastures can deposit additional supplementary phosphorus into bone reserves which can be subsequently mobilized during the wet season. Regardless of the extent of deposition of phosphorus, provision of supplementary phosphorus to the late pregnant cow grazing dry season pasture should allow the high phosphorus demands of the foetus to be met without the need to mobilize bone reserves, and thus improve the overall phosphorus status of the reproducing cow for lactation. Second, de Brouwer *et al.* (2000) have demonstrated substantial production benefit to dry season supplementation of breeder cows grazing phosphorus deficient pastures. Clearly more experimental information is needed.

Table 3. Indicative estimates of increases in production due to feeding phosphorus (P) supplements to cattle grazing wet season pastures of good quality and adequate availability.

Indicative measurement or variable	Acutely deficient or very deficient	Deficient	Marginal
Soil, plant and animal estimators			
Soil P ($P_{B\ ppm}$) [A]	< 4	4 - 6	7 - 8
Plant P (mg P/g DM)	< 0.5	0.5 - 1.0	1.0 - 1.5
Diet g P/MJ ME in the diet	180 - 240	240 - 300	300 - 360
Faecal mg P/g diet DM digestibility	2.5 - 3.0	3 - 4	4 - 5
Blood Pi of growing cattle (mg/L) [B]	< 25	25 - 35	35 - 45
Likely liveweight change response of growing cattle (kg/annum)			
Native pasture	40 - 60	20 - 40	0 - 20
Stylo pasture	------	40 - 80	0 - 40
Stylo pasture + moderate P fertilizer	------	0 - 20	nil
Likely response of breeder cattle grazing native pastures			
Weaning rate (%)	10 - 30	10 - 30	nil - 10
Calf weaning weight (kg)	10 - 30	5 - 15	0 - 10

[A], $P_{B\ ppm}$, bicarbonate extractable phosphorus. [B], Pi, concentration of inorganic phosphorus in blood.

R D & E areas with greatest potential to deliver productivity and efficiency gains

There is extensive evidence that more effective management of phosphorus nutrition can provide large herd productivity gains through improved reproductive performance and growth in many regions of the rangelands of northern Australia.

Major obstacles to more widespread and effective use of phosphorus supplementation appear to be lack of recognition of the importance of phosphorus and the economic returns to supplementation, knowledge of the phosphorus status of cattle in specific situations, and the cost of supplementation. These are associated with the difficulty to definitively diagnose sub-clinical phosphorus deficiency. Advances in understanding the role of phosphorus concentration in faeces and in blood to estimate diet phosphorus intake, and F.NIRS to estimate metabolizable energy and nitrogen in the diet, provide opportunity to improve diagnosis. However more robust information is needed for reliable predictions of phosphorus intake across northern Australian rangeland systems.

Research is needed to improve understanding of the extent to which short-term dietary deficiencies of phosphorus are alleviated by mobilization of body phosphorus reserves, particularly in the breeder cow. Improved understanding is needed of the efficacy of phosphorus supplementation during the dry season to preserve body phosphorus reserves in the late pregnant cow, when body reserves of phosphorus are repleted from phosphorus ingested in supplements and/or in forage, and whether repletion occurs during the dry season and particularly in the breeder cow. The benefits of phosphorus supplementation in relation to timing and to amounts (including dose-response curves) need to be more clearly defined for the variety of circumstances which occur in the industry.

From an on-property perspective, innovative approaches are needed to improve supplement delivery systems during the wet season when the nutritional demands of cattle for phosphorus are greatest. It is suggested that D & E should focus on encouraging adoption with emphasis on better targeting of the classes of animals with most favourable cost/benefit, the need for herd records, the assembly of case studies where managers have successively addressed nutritional phosphorus deficiency, and on on-property demonstrations to demonstrate the implementation and benefits of phosphorus supplementation.

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Carcass characteristics and profitability of young grain-fed *Bos indicus* entire male cattle

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Abstract. Beef cattle enterprises can benefit from the highly efficient, fast growing characteristics of entire male cattle. We tested the hypothesis that young bulls would produce a greater carcass value than steers of the same chronological age in a north Australian production system. The experiment analysed carcass and meat quality parameters and the subsequent grading and gross values between *Bos indicus* bulls and steers that were either –homozygous, heterozygous or +homozygous for the calpastatin gene. Overall bulls produced a heavier carcass (P=0.005) that had less marbling (P=0.001) and had greater ossification scores (P=0.007) when compared to steers. Bulls also produced *M. Longissimus dorsi* that were less tender after aging for 14 days (P=0.001) and 28 days (P=0.005) compared to steers. Bulls that were either heterozygous (P<0.05) or +homozygous (P<0.05) for the calpastatin gene were heavier than steers of similar genotypes. Steers and bulls that were –homozygous produced the lightest carcass weights. Bulls produced a carcass that had a superior gross value when compared to steers (P=0.009). We concluded that bulls that are either heterozygous or +homozygous for the calpastatin gene can be produced profitably from a northern beef enterprise in accordance with domestic market grain fed yearling specifications.

The full paper is being submitted for a scientific journal publication.
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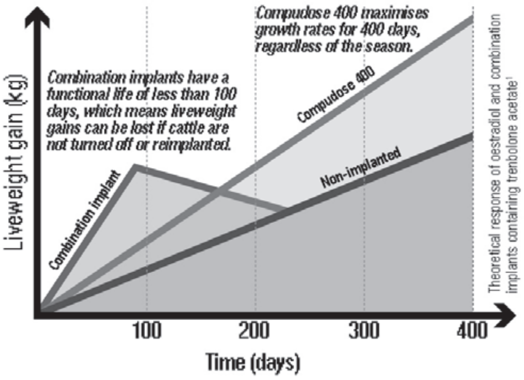

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Reproductive performance of Ongole cows in Indonesian villages

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Introduction

Increasing beef cattle production by smallholder farmers in Indonesia requires an increase in the reproductive performance of cows and more efficient utilisation of existing feed resources such as rice straw and other agricultural by-products. The aim of the Straw Cow Project is to establish a cow-calf system based on rice straw, with strategic supplementation to the cow during periods of high energy demand. The Straw Cow Project will run for 4 years in Indonesia. This paper presents some preliminary results from the first year of the project.

Methods

Two village sites (Probolinggo and Malang) were established in East Java, Indonesia, in January 2010. Across the two sites, 250 Peranakan Ongole cows (*Bos indicus*) were identified and enrolled in the project. Farmers were encouraged to feed the cows a basal diet of rice straw *ad libitum* plus an energy and protein supplement in the form of tree legumes or agricultural by-products (e.g. rice bran). Dates of mating, calving and weaning were recorded. Data was analysed using ANOVA in SPSS.

Results

Length of lactation, post partum anoestrus and estimated calving interval were shorter in Probolinggo compared to Malang (Table 1). Average body condition score (BCS) of cows at calving was lowest in Probolinggo, with 63% of cows in BCS less than 3 at calving. Only 21% of cows in Malang were in BCS less than 3 at calving. Average weight of cows after calving was 306 and 325 kg in Probolinggo and Malang respectively.

Table 1. Reproductive performance of Ongole cows (average, range).

Parameters	Probolinggo		Malang		P value
BCS at calving (1-5 scale)	2.7	(2 - 3.5)	3.1	(2 – 5)	< 0.05
Length of lactation (days)	110	(23 – 165)	166	(21 – 217)	< 0.05
Post partum anoestrus (days)	81	(41 – 198)	132	(41 – 264)	< 0.05
Estimated calving interval (days)	380	(314 – 447)	464	(351 – 558)	< 0.05

Conclusions

Although reproduction was higher at Probolinggo than Malang, there is room for improvement at both sites. Minimum post partum anoestrus was 41 days at both sites, indicating opportunities to achieve higher reproduction rates. Low BCS of cows at calving, particularly in Probolinggo, is likely to delay return to oestrus. Oestrus detection, access to bulls and AI, and timing of mating are issues at both sites which impact on reproduction rates and will be targeted by Indonesian extension workers during the second year of the project.

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Use of fixed-time AI for genetic improvement in northern Australia

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Introduction

The use of artificial insemination (AI) in northern Australia is estimated to be 1% of breeding females inseminated annually. Limited access to skilled labour, inaccurate oestrus detection and the access to AI technicians are some of the common factors limiting adoption of AI in northern Australia. The use of hormonal treatments to synchronise ovulation to enable AI at a fixed time (FTAI) can facilitate use of this technology. The aim of this project was to define the pregnancy rate (PR) to FTAI in Droughtmaster heifers treated to synchronise ovulation.

Methods

Droughtmaster heifers were enrolled in a FTAI program on four Queensland cattle stations. Heifers on stations A (n=36) and C (n=41) were 2 yr old and had an average liveweight (LW) of 336±4 kg and 430±7 kg, respectively. Heifers on stations B (n=90) and D (n=173) were yearlings and weighed an average of 332±3 kg and 314±2 kg, respectively. Only cycling heifers were enrolled; determined by ultrasonographic detection of a corpus luteum (CL) on one of two occasions 10 days apart. All heifers were treated to synchronise ovulation; at Day -10: 1 mg oestradiol benzoate (ODB; Cidirol) intramuscularly (im) + intravaginal progesterone releasing device (IPRD; Cue-Mate®; 0.78 g progesterone) was inserted intravaginally for 8 days; Day -2: IPRD removed + 500 µg cloprostenol (Estromil) im + 300 IU equine chorionic gonadotrophin (Pregnecol®) im. Day -1: 1 mg ODB (im). Day 0: FTAI (54 to 56 h after IPRD removal). All females were exposed to bulls (3:100) 10 days after FTAI. Pregnancy diagnosis was performed 65 days after FTAI and recorded as pregnant to FTAI, natural mating or not detectably pregnant (NDP).

Results and Conclusions

Herd did not significantly affect PR to FTAI, but Herd D did have a significantly lower PR to natural mating (proportion pregnant to number not pregnant to FTAI) than herds B and C. Therefore, overall pregnant was significantly lower for herd D than A, B and C (Table 1). The PR to FTAI and natural mating was not affected by BCS (P = 0.981 and P = 0.894) or LW (P = 0.629 and P = 0.618) at Day -10. This study has shown that in well managed FTAI programs involving cycling Droughtmaster heifers the mean PR to FTAI was 40.7 % with overall 66.5 % pregnant within 37 days.

Table 1. Pregnancy rate (%) to FTAI, natural mating and overall (Superscripts differ at P<0.05)

Pregnancy rate	Herd				
	A (n=36)	B (n=90)	C (n=41)	D (n=173)	P value
FTAI	52.1	38.0	35.3	37.4	0.590
Natural	$39.0^{a,c}$	$47.0^{a,d}$	$69.3^{b,d}$	24.3^{c}	0.044
Overall	69.4^{a}	66.7^{a}	78.0^{a}	52.0^{b}	0.004

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Breeder fertility improved through selection in a NT Brahman herd

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Introduction

Brahman cattle are popular in northern Australia due to their high resistance to environmental stresses; however they have low inherent fertility. Improving Brahman fertility has the potential to increase production efficiency of northern Australian beef breeding enterprises.

Materials and methods

The NT Department of Resources has been selecting for fertility in a Brahman herd (SEL) since 1994, using objective selection on fertility traits and the BREEDPLAN genetic evaluation system. The method of selection and management of this herd has been detailed in Schatz *et al.* (2010).

The fertility of the SEL herd was assessed by comparing the pregnancy rates of lactating cows (at the May weaning muster ie. WR1) in the SEL herd and in an unselected Brahman control (CON) herd. Although the herds were in different paddocks at the Victoria River Research Station, they were stocked at the same utilisation rate and managed in the same way except that the CON herd was continuously mated while the SEL herd was control mated. Therefore only CON cows that were due to calve at the same time as SEL cows (assessed by pregnancy testing) were compared.

Results and Discussion

Table 1 shows the proportion of breeders lactating and reconceiving in the SEL and CON herds. Reconception rates were on average 31% units higher in SEL cows than CON cows, and the differences were significant in all years except 2009 (P<0.05).

A higher proportion of cows returned to pregnancy while lactating in the SEL herd. Schatz et al. (2010) also showed that pregnancy rates in yearling mated heifers from the SEL herd were on average 35% higher than heifers from commercial herds, and that BREEDPLAN estimated breeding values for fertility traits (Days to Calving and Scrotal Size) had improved markedly in the SEL herd compared to the Brahman Breed Society average since selection began in 1994. These results indicate that fertility of the SEL herd has been improved by selection.

Table 1. Proportion of breeders lactating and pregnant at first round weaning muster (May) in the SEL and CON herds.

Year	2004	2005	2006	2007	2008	2009
SEL	73%[a]	61%[a]	85%[a]	84%[a]	94%[a]	72%[a]
	n=105	*n=95*	*n=85*	*n=88*	*n=68*	*n=81*
CON	40%[b]	32%[b]	42%[b]	11%[b]	60%[b]	63%[a]
	n=30	*n=56*	*n=55*	*n=70*	*n=30*	*n=19*

*Pregnancy rates in the same column with different letter superscripts are significantly different.

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Strategies for improving young breeder re-conception rates in extensive cattle enterprises

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Introduction

A recent study conducted by the Department of Agriculture and Food WA focussed on management strategies to improve young breeder performance in the Pilbara and Kimberley. The findings of this study concluded that the first requirement to improve the productivity of heifers and young breeders was to keep them segregated from the breeder herd at least until they weaned their first calf (Smith *et al*. 2010). The recent pastoral industry survey conducted in the Kimberley and Pilbara indicated that while the majority of pastoralists segregate heifers from the breeder herd until first mating, less than 20% segregate them until weaning their first calf (Dray *et al.* 2010).

Segregation provides the opportunity to more intensively manage this high risk group; e.g. provide supplementation, muster twice a year to wean, provide better country or better grazing management. While these management practises may not be practically or economically feasible for the whole herd they will help young females to become productive breeders for life. Optimising the time of first calving is critical to allow females the opportunity to successfully produce and wean a calf and improve the opportunity to re-conceive during their first lactation.

Results and Conclusions

The heifer project demonstrated that controlling bulls to control the time of first calving is seldom successful or practical in extensively managed herds in northern WA. The WA study indicated that time of first conceptions of heifers was most likely determined by the onset of puberty rather than planned mating. This view is supported by survey results which show that 80% of producers in the Kimberley and Pilbara continuously mate heifers. The main reason cited for not implementing control mating was problems with controlling bulls.

One strategy to reduce the effects of ineffective bull control is to pregnancy test and use foetal aging to segregate young females into 'calving groups'. Each group can then be managed according to their requirements (DF Lynch, pers. comm.). For example, young females due to calve too early may need to be kept in paddocks close to infrastructure in order to allow the weaners to be pulled off late in the year and probably at a lighter weight than might normally occur. Establishing the timing of the calving pattern provides the opportunity to allocate resources in advance, thereby ensuring potential problems are adequately addressed.

Strategies for dealing with late calving young females will depend on a number of factors including cash flow considerations, the amount of pasture on hand, the requirement for keeping calves and market options. Getting the management of the first calving of young breeders right will improve opportunities for conception during first lactation, reduce mortality rates, improve the cost/benefit of supplementation and improve breeder herd productivity.

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Brahman teat and udder score changes during lactation

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Introduction and Methods

Enlarged teats and udders have previously been associated with neo-natal calf mortality in *Bos indicus* cattle (Holroyd 1987). From 2004 to 2011, 975 Brahman cows were monitored over 4 sites in NE, NW, SE and central Queensland. The cows were in four year groups and aged between 3 and 8 years. Each lactated between 1 and 6 times. Between 5% and 10% of cows were culled annually. The percentage of cows calving at 3 years was 67%, 61% at 4 years and 83-85% thereafter. Teat and udders were scored using a 5-point scale (1-small; 3-moderate; 5-large) at calving and three times during lactation: start of mating, end of mating and at weaning.

Results and Discussion

Scores were similar for front and back teats in over 90% of cows at 3 and 4 years of age with equal proportions of the balance having either larger front or back teats. In cows aged 5 to 8 years, there was a trend for front teat scores to be higher than back teat scores and the difference increased from starting levels by approximately 5% annually. All scores followed a similar pattern of reducing by an average of 0.5 for teats and 0.8 for udders, after calving and remained relatively constant for the duration of the lactation (Fig 1). Average teat and udder scores during lactation increased by approximately 0.3 score units over 6 breeding seasons; teat scores at calving increased by twice this level.

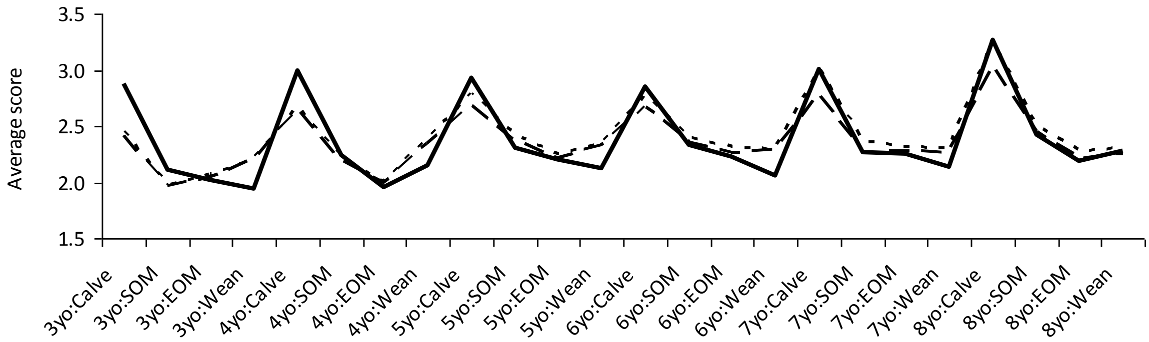

Fig. 1. Average front teat (dots), back teat (dashes) and udder (line) scores (1-5 scale) for Brahman cows over six lactations. SOM and EOM = start and end of mating, respectively; 3yo = 3 years old, etc

This basic teat and udder description provides the basis for analyses which will investigate the impacts on calf survival and performance, and describe the genetics of teat and udder scores.

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Targeting better breeder performance – a group approach

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Introduction

Reproductive performance remains a critical issue for beef cattle herds throughout Queensland. Reduced conception rates, foetal and calf losses, delayed conceptions and lighter weaners significantly impact on herd profitability. For this reason, 7 producers from the Billaboo CQ BEEF group in the Emerald – Springsure region established a Producer Demonstration Site (PDS) to measure their herds' reproductive performance and to implement management strategies to improve the productivity of their breeder herds.

Method

On each of the 7 properties, the owners have undertaken steps to learn more about their herd's fertility. These steps include:

- Pregnancy testing and foetal ageing for all joined females
- Identifying foetal and calf losses from pregnancy test to weaning
- Monitoring and managing breeder body condition
- Monitoring weaner weights
- Structured testing for Bovine Viral Diarrhoea Virus (Pestivirus) to determine the risk herds face.

The group meets regularly to review results and discuss management strategies.

Results

Following pregnancy testing and foetal ageing the 7 enterprises have detailed information on conception rates and patterns. The data has identified where breeder condition and heifer joining weights have affected conception rates. Branding and weaning records are being used to determine foetal and calf losses from pregnancy test to weaning.

Serological tests showed that all herds had been exposed to BVDV. Of 442 animals tested, 65% were positive for BVDV antibodies. Across the 7 herds the percentage testing postive ranged from 50% to 95%. Of the 2009 born cattle, 75% were positive with property results ranging from 60% to 92%. In the older age groups (born 2007 and prior), 65% had exposure overall with a range across the properties of 33% to 100%.

Discussion

As a result of the coordinated pregnancy testing and foetal ageing the producers have a better understanding of their herd's performance and are using the records in decision making. The importance of better monitoring and management of breeder body condition has been highlighted. There are also opportunities to increase heifer performance by improving growth rates and selection strategies.

Testing for BVDV has given producers an understanding of the status of their herds and will help with development of management strategies. An economic analysis will be undertaken to determine whether vaccinating against Pestivirus is a cost effective option.

The PDS has been an excellent activity for the group with the results providing a focus for reviewing herd performance and identifying improved management practices.

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Predicting pregnancy rates from pre-calving body condition score of first-lactation Brahmans

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Introduction

Schatz (2010) reported a relationship that gives the predicted pregnancy rates from pre-calving liveweights for first lactation Brahman females in the Northern Territory. However measuring liveweight is time consuming and expensive, and so is not often done in commercial situations. An alternative is the use of a body condition score (BCS) system, as it is a simple method of visually assessing the body reserves of cattle. This study reports the pregnancy rates (PRs) that are predicted for each pre-calving BCS (in a 1-5 system) in first lactation females.

Materials and methods

Using Beef CRC data, the relationship between liveweight and BCS in female beef cattle has been established (G Fordyce, unpublished data). This was used to determine the average liveweight of each BCS for first lactation Brahman females. Then BCS was substituted for liveweight allowing the data of Schatz (2010) to be adapted to show the predicted PR for each BCS. The accuracy of these predictions was evaluated by comparing them to the raw means of PR (at the time of weaning) for each BCS in first lactation females from preliminary analysis of data (n=5276) from the Cash Cow project (K McCosker, unpublished).

Results and Discussion

Fig. 1 shows that the PRs predicted for each half BCS were very similar to the actual average PRs from the Cash Cow data, suggesting that this is a valid relationship. Table 1 shows the PR predicted for each pre-calving BCS and the equivalent average liveweight of each BCS. This information will be useful for managers of first lactation females in northern Australia.

Pre-calving BCS	Pre-calving Wt (kg)	Predicted PR (%)
1 (poor)	334	12
2 (backward)	393	29
3 (moderate)	452	55
4 (forward)	511	79
5 (fat)	569	91

Table 1. The equivalent liveweight and predicted pregnancy rate for each pre-calving BCS in first lactation Brahmans.

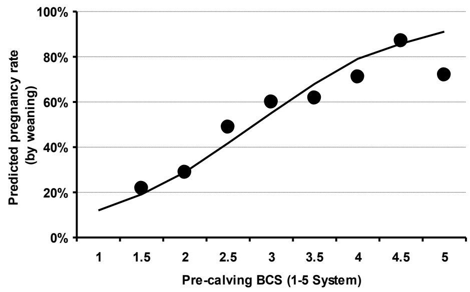

Fig. 1. Predicted pregnancy rate (solid line) and Cash Cow data mean pregnancy rate (filled circles) for each (half) BCS.

Reference

Schatz TJ (2010) Understanding and improving heifer fertility in the Northern Territory. Final report Project NBP.339. Meat and Livestock Australia, North Sydney, NSW 2059.

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Selection improves fertility in a Brahman herd

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Introduction and Methods

Brahmans are considered to have low inherent fertility; however they are still popular in northern Australia due to their resistance to environmental stresses. If Brahman fertility can be improved it has potential to greatly increase production efficiency in northern Australia.

The Northern Territory (NT) Department of Resources has been selecting for fertility in a Brahman herd (SEL) since 1994, using objective selection on fertility traits and the BREEDPLAN genetic evaluation system. The method of selection and management of this herd has been detailed in Schatz *et al.* (2010). The improvement in fertility in the SEL herd was assessed by comparing the change in fertility trait estimated breeding values (EBV) in the SEL herd relative to the breed average using the BREEDPLAN annual report (Brahman Group BREEDPLAN 2009). Also an experiment has been conducted which compared pregnancy rates from yearling mating of heifers from the SEL herd and heifers sourced from commercial (COM) NT Brahman herds (Schatz *et al.* 2010).

Results and Discussion

Figs 1 and 2 show that two BREEDPLAN measures of fertility (EBV for days to calving and scrotal size) for the SEL herd have improved markedly over time relative to the average of the Brahman Breed Society. The yearling mating study found that over 3 years, pregnancy rates were an average of 35% higher (P = 0.009) in SEL heifers than in COM heifers (Schatz *et al.* 2010).

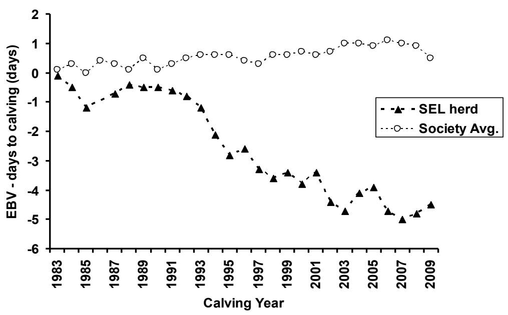

Fig. 1. Change in the days to calving EBV in the SEL herd and the Brahman Society average.

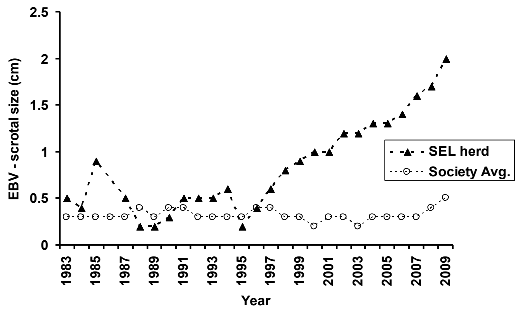

Fig. 2. Change in the scrotal-size EBV in SEL herd and the Brahman Society average.

These results indicate that substantial improvements in fertility have been made in the SEL herd through selection. This has large implications for the northern beef industry where cattle require a high *Bos indicus* content to perform under the stressful conditions. Increasing Brahman fertility has the potential to improve the profitability of cattle properties in northern Australia.

Reference

Schatz TJ, Jayawardhana GA, Golding R, and Hearnden MN (2010) Selection for fertility traits in Brahmans increases heifer pregnancy rates from yearling mating. *Animal Production Science* **50**, 345-348.

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Productivity consequences of incorporating 25% later maturing genes into a Brahman herd in the Victoria River District

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Introduction

Incorporating later maturing genes into Brahman herds could increase the value adding potential of cattle supplied to SE Asia. However, the most productive animals in harsh tropical environments are those with the right balance of genes for growth potential (*Bos taurus*) and stress resistance (*Bos indicus*) (Frisch and Vercoe 1984) and animals which contain too high a proportion of later maturing genes have not performed well in northern Australia in the past. This study investigated the performance of breeders with approximately 25% Charolais content.

Methods

Mature cows that were approximately 75% Brahman and 25% Charolais (1/4 Cha cows) were randomly divided into two management groups. One group was continuously mated to purebred Brahman and F1 Charolais x Brahman bulls. These management groups were compared to a high-grade Brahman herd. All animals were managed under the best practice management system and performance was compared using, pregnancy rate, reconception within 3 months of predicted month of calving, calf loss from confirmed pregnancy to weaning and breeding herd efficiency. Frequencies were compared using a Peasons chi squared test and breeding herd efficiency and weaner weights were compared using ANOVA.

Results and Conclusions

The management group of ¼ Ca cows mated to Brahman bulls had significantly lower pregnancy rates and losses from confirmed pregnancy to weaning than the other 2 groups. The ¼ Cha cows mated to F1 Charbray bulls were not significantly different to Brahman.

There were no significant differences between the 3 management groups in percent of cows pregnant within 3 months of expected calving, average weaner weight of progeny or breeding herd efficiency. Therefore, the performance of ¼ Cha cows was found to be similar to high grade Brahman.

Table 1. Performance of ¼ Charolais x ¾ Brahman cows (1/4 Cha cows) mated to Brahman (Bra) and F1 Charbray (F1) bulls at Victoria River Research Station during 2003-2006 relative to Brahman.

	Brahman		¼ Cha cows x Bra bulls			¼ Cha cows x F1 bulls		
	Mean	S.E.	Mean	S.E.	Sig	Mean	S.E.	Sig
No. of cattle	127		117			129		
Pregnancy rate (%)	85.4	1.6	80.3	1.8	P<0.05	85.1	1.6	ns
Percent pregnant within 3 mths of predicted calving (%)	26.5	3.0	32.2	2.9	ns	28.2	3.0	ns
Calf loss between confirmed pregnancy to weaning (%)	9.9	1.7	3.9	1.1	P<0.05	11.2	1.8	ns
Average weaner weight (kg)	171.3	2.9	174.1	3.4	ns	182.5	3.0	ns
Breeding herd efficiency (kg/AE)	148.8	10.0	153.5	14.1	ns	135.1	14.4	ns

References

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Survey of selected north Australian beef breeding herds. 1. Management

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Introduction and Methods

North Australian herds are characterised by: low bull control; a high level of supplementation; husbandry concentrated into the April-August period and weaning a calf in an average of 2 of every 3 years. In 2008 and 2009, owners or managers of 75 beef businesses (SEQ: Queensland east of ~148^{O}E; WQ and NQ: west and north of ~148^{O}E and ~20^{O}S in Queensland; NT&WA: north of ~19^{O}S in the Northern Territory and Western Australia) were surveyed on their management of their beef breeding herd as part of the North Australian Beef Fertility Project (Cash Cow).

Results and Discussion

Property size, cow herd size, and the proportion of properties using continuous mating were lowest in SEQ and highest in NT&WA (Table 1). Average weaner age was highest in SEQ. Peak calving for all ages was Sep-Nov in SEQ, and a month later in other regions. The peak periods for weaning and pregnancy diagnoses were Apr-May and Aug-Sep in all regions. An estimated median weaning rate of 64% was derived for 14 NQ and 1 NT businesses. These 15 businesses had medians of 1,434 cows and 27% replacement heifers, and used a 3.5% bull:cow ratio. Dry season supplementation was practised for most age classes in 85%, 100%, 60% and 20% of NT&WA, NQ, WA and SEQ herds, respectively. Almost all herds provided wet season supplementation to first lactation females, though 63-71%, 50-62%, 0% and 0-30% of herds supplemented other age groups in NT&WA, NQ, WA and SEQ herds, respectively. These results show that prevailing basic beef breeding herd management and performance in north Australia are not dissimilar to that reported by Bortolussi *et al*. (2005) for 1996-97.

Table 1. Descriptions and basic husbandry by participating properties and herds

	SEQ Av/Med*	WQ Av/Med*	NQ Av/Med*	NT&WA Av/Med*
Median area (ha)	8,181 (20)	28,687 (8)	32,592 (18)	403,037 (10)
Median rainfall (mm)	650 (10)	450 (3)	750 (7)	690 (8)
Cows (median number)	600 (20)	890 (8)	2,250 (18)	9,070 (12)
Use continuous mating (median)	0% (20)	13% (8)	28% (18)	73% (11)
Cow culling age (years)	10.2 (19)	10.3 (4)	9.9 (10)	9.4 (11)
Avg. weaner age (months)	6.9 (18)	6.4 (5)	5.2 (15)	6.3 (9)

*The number of properties in each observation is shown in brackets in Table 1.

Reference

Bortolussi G, McIvor JG, Hodgkinson JJ, Coffey SG, Holmes CR (2005) The northern Australian beef industry, a snapshot. 2. Breeding herd performance and management. *Australian Journal of Experimental Agriculture* **45**, 1075-1091.

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Survey of selected north Australian beef breeding herds. 2. Diet quality

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Introduction and Method

Under-nutrition, thus poor body condition, is a major constraint to reproduction in re-breeding cows in north Australia. Near infrared reflectance spectroscopy of faeces (F.NIRS Dixon *et al*. 2007) can be used to monitor diet quality and benchmark.

During Jan, Mar, May Aug, Nov of 2009 and 2010, 1240 faecal samples were collected from 165 mobs on 78 properties in northern Australia. Thresholds for adequacy (able to maintain body condition) were set for lactating cows at 7.0% CP and 55% DMD.

Results and Discussion

Nutritional adequacy in lactating cows decreased rapidly from the early wet season, to the late dry season in all regions. There was a trend for the lowest diet quality to occur in north Queensland during a severe and extended 2009 dry season. The data reflects the improved seasonal conditions in 2010 dry season.

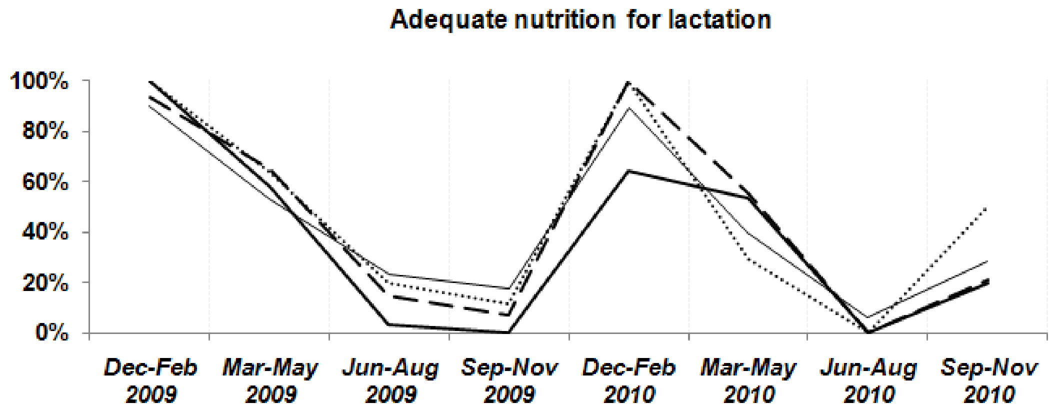

Fig. 1. Percentage of mobs where diet quality was adequate to maintain body condition in lactating cows (SE and central Qld ___, Western Qld ·····, NT & WA — —, Northern Qld ——).

The results emphasise the importance of minimising dry season lactation to maintain breeder body condition and reduce dry season management costs. Failure to arrest condition loss increases survival risk and reduces the ability of lactating cows to cycle and conceive before weaning in the following year (Fordyce *et al*. 1990).

References

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Fordyce G, Tyler R, Anderson VJ (1990) The effect of reproductive status, body condition and age of *Bos indicus* cross cows early in a drought on survival and subsequent reproductive performance. *Australian Journal of Experimental Agriculture* **30**, 315-322.

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Survey of selected north Australian beef breeding herds. 3. Bull selection and management

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Introduction and Methods

One approach to investigating the impact of bulls on herd reproductive performance is to categorise the likely fertility of the bull group according to bull selection and management policies. 63 properties enrolled in the MLA funded Cash Cow project returned email surveys detailing their current bull selection and management practices.

Results and Discussion

Table 1. Percentage of properties by region utilising specific bull selection and management practices.

Bull Selection & Management Practice		Region				
		SE & Central QLD (n=26)	Western QLD (n=10)	Nth QLD (n=15)	NT/WA (n=12)	**TOTAL (n=63)**
Bull to Female mating ratio						
≤ 2 :100		12%	20%	13%	-	11%
>2 to 4 : 100		73%	70%	80%	75%	75%
> 4 : 100		15%	10%	7%	25%	14%
Selection of replacement bulls						
EBV data used		54%	40%	40%	25%	41%
Physical exam only by vet		38%	50%	40%	0%	33%
Physical exam & microscopic exam of semen by vet		31%	40%	27%	0%	25%
Management of replacement bulls						
Season of introduction	Spring/Summer	92%	78%	57%	60%	76%
to property	Autumn/Winter	8%	22%	43%	40%	24%
Duration of acclimatisation	< 2 months	40%	33%	60%	50%	46%
prior to 1st joining	2 to 4 months	56%	33%	27%	40%	42%
	≥ 4 months	4%	33%	13%	10%	12%
Annual bull management						
Breeding soundness examination conducted annually		38%	50%	27%	25%	35%
Age bulls routinely culled	< 6yrs	12%	0%	0%	9%	7%
	6 to 9yrs	67%	86%	86%	82%	78%
	>9yrs	21%	14%	14%	9%	16%
Bulls maintained in satisfactory body condition		85%	80%	47%	33%	65%
Bulls treated for external & internal parasites		50%	50%	67%	8%	46%

Only about a third of properties routinely use breeding soundness evaluations to select replacement bulls, and the period of acclimatisation for replacement bulls is often short. Further, only about a third of properties annually conduct breeding soundness evaluations on their herd bulls.

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Survey of selected north Australian beef breeding herds. 4. Vaccination to control reproductive loss

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Introduction and Methods

The common causes of infectious reproductive loss recognised in tropical regions of the world have all been shown to be prevalent in north Australian beef herds. Property owners/managers enrolled in the MLA-funded Cash Cow project were emailed a survey to complete detailing their current vaccination practices for maiden heifers, cows and bulls.

Results

Table 1. Percentage of properties by region vaccinating against each infectious disease.

Disease	Group	% Vaccinating	Region		
			*North & West (n=44)	SE & Central QLD (n=27)	Overall (n=71)
BVDV (pestivirus)	*Maiden heifers*	Prior to joining	1 (2%)	5 (18%)	6 (8%)
	Cows	Annually	1 (2%)	3 (11%)	4 (6%)
	Bulls	Annually	1 (2%)	1 (4%)	2 (3%)
Vibriosis	*Maiden heifers*	Prior to joining	6 (14%)	1 (4%)	7 (10%)
	Cows	Annually	1 (2%)	1 (4%)	2 (3%)
	Bulls	Annually	33 (75%)	15 (56%)	48 (68%)
Leptospirosis	*Maiden heifers*	Prior to joining	7 (16%)	16 (59%)	23 (32%)
	Cows	Annually	4 (9%)	12 (44%)	16 (22%)
	Bulls	Annually	4 (9%)	8 (30%)	11 (15%)
BEF (3-day sickness)	*Maiden heifers*	Prior to joining	0	1 (4%)	1 (1%)
	Cows	Annually	0	0	0
	Bulls	Annually	5 (11%)	12 (44%)	17 (24%)

* North & West = north and west Queensland, Northern Territory and Kimberley region Western Australia

Discussion

Across both regions there were a relatively high proportion of properties vaccinating bulls to control vibriosis, and in SE & central Queensland nearly half the properties vaccinated females for leptospirosis and bulls for BEF. However, apart from these cases the proportion of properties vaccinating breeding cattle to control infectious causes of reproductive loss was low.

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Survey of selected north Australian beef breeding herds. 5. Prevalence of *Campylobacter fetus* subsp. *venerealis* infection

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Introduction and Methods

Vibriosis is a venereal disease caused by infection with *Campylobacter fetus* subsp. *venerealis.* It can cause transient infertility, early embryonic death and sporadic abortion in cattle (Hum *et al.* 1994). As part of the MLA funded project Cash Cow, vaginal mucus samples (n=20-30) were collected from females enrolled in each breeding mob at the time of the annual pregnancy testing muster using a systematic random sampling approach. The samples were tested for antibodies to *C. fetus* subsp. *venerealis* using an IgA enzyme-linked immunosorbent assay (Hum *et al.* 1994). Breeding mobs in which >20% of females tested had antibodies to *C. fetus* subsp. *venerealis* were classified positive for vibriosis i.e. the disease was present and may impact on the reproductive performance of the mob.

Results and Discussion

Table 1. Prevalence (%) by region of breeding mobs where vibriosis was present.

Region	Maiden heifers				Cows			
	No. mobs	% positive mobs	No. samples	% Test positive	No. mobs	% positive mobs	No. samples	% Test positive
Southern and Central QLD	26	27	529	11	32	22	707	11
Northern Queensland	5	40	100	9	16	12	415	6
Western Queensland	10	10	248	13	10	20	240	12
NT and WA	9	0	188	1	13	0	323	4

Overall, 17% of breeding mobs surveyed were classified positive for vibriosis, and the prevalence of positive maiden heifer mobs was similar to that for cow mobs. The prevalence of positive mobs was higher in southern and central Queensland than in the other regions combined (24% vs. 11%). The apparent very low prevalence of infection in the Northern Territory and Western Australia (Kimberley) region needs to be investigated further.

References

Hum S, Quinn C, Kennedy D (1994) Diagnosis of Bovine Venereal Campylobacteriosis by ELISA. *Australian Veterinary Journal* **71**, 140-143.

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Survey of selected north Australian beef breeding herds. 6. Prevalence of bovine pestivirus infection

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Introduction and Methods

Bovine pestivirus infection of naïve cattle around the time of mating and during the first 4 to 5 months of pregnancy can result in a wide range of losses including lower than expected pregnancy rates and/or weaning rates and reduced turn-off of young cattle (McGowan and Kirkland 1995). As part of the MLA funded Cash Cow project a cross sectional sample (n=15 to 20) of females in each enrolled breeding mob were bled either at the time of pregnancy testing (maiden heifers) or at the first annual weaning/branding muster (cows), and the sera tested for antibodies to bovine pestivirus using the Agar Gel Immunodiffusion (AGID) test. The prevalence of tested cattle in each mob with an AGID test result of ≥3 (indicative of infection in the past 1 to 9 months) was used to categorise mobs as having a low (0-14%), moderate (20-39%) or high (≥40%) level of evidence of recent infection with bovine pestivirus.

Results and Discussion

Table 1. Proportion of breeding mobs by region with evidence of low, moderate and high levels of recent infection with bovine pestivirus.

Breeding Mob	Level of recent infection in the SE & Central Qld Region			Level of recent infection in the North and West Region*		
	Low	Moderate	High	Low	Moderate	High
Maiden heifers	57% n=14	14% n=14	29% n=14	44% n=18	28% n=18	28% n=18
Cows	76% n=38	13% n=38	11% n=38	57% n=51	33% n=51	10% n=51

*North & West = north and west Queensland, Northern Territory and Kimberley region Western Australia

Overall, the prevalence of breeding mobs across northern Australia with evidence of a moderate to high level of recent infection with bovine pestivirus was 39%, with a higher prevalence observed in the maiden heifer mobs in both regions. It is likely that in those mobs with evidence of a moderate to high level of recent infection that some females would have become infected during the critical stage of gestation, and this could result in reduced weaning rates and turn-off of young cattle from these mobs.

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McGowan MR, Kirkland PD (1995) Early reproductive loss due to bovine pestivirus infection. *British Veterinary Journal* **151,** 263-270.

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Effects of increased scrotal temperature on semen quality in Brahman bulls

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Introduction

Spermatogenesis is a temperature dependent process. However studies have shown that *Bos indicus* bulls are more heat tolerant when exposed to high ambient temperatures, and may have slower and less pronounced decrease in semen quality, and a faster recovery (Brito *et al*. 2004). The objective of the present study was to assess the change in sperm parameters occurring after an acute temperature increase obtained through scrotal insulation (SI), in *Bos indicus* bulls.

Materials and Methods

A total of six 2-years old Brahman bulls were used in the study. SI was applied to three bulls for a period of 48 hours and the remaining bulls were used as controls. Thermochron® iButton® (Dallas Semiconductor) were attached on the scrotal skin on all bulls, to monitor scrotal skin temperature (SST). The bulls were electro ejaculated every third day from -19 days to SI (0-2), and up to +74 days. Samples were collected to determine sperm morphology (%) and progressive motility (%) using microscopy, seminal plasma protein composition and sperm DNA integrity.

Results

The SST measured during the SI period was 22.3-37.8°C (min-max) in the control bulls and between 32.0-39.2°C (min-max) in the SI bulls. During the initial two hours of SI, a stabilization of the SST was seen; 34.5±0.3°C in the control and 37.6±0.5°C in the SI bulls. The percentage of sperm with normal morphology in the SI bulls decreased from >60% to 35.7% 8 days after initiation of SI with increase in both sperm head defects (HD) and proximal cytoplasmic droplets (PD). The percentage of cells with normal morphology returned to >60% at 38 days with HD decreasing from 31 days and PD decreasing from 38 days. A decrease in sperm motility was detected 2 days after initiation of SI returning to >60% after 38 days. The sperm DNA integrity analysis and the protein composition are still to be analysed.

Discussion

This study showed that small increases in scrotal skin temperature (3°C) in *Bos indicus* bull using a scrotal insulation model over a short period of time (48 hours) have detrimental effects on ejaculated sperm. An increase in the percentage of sperm with morphological defects, including HD and PD, and a decrease in motility were seen as early as 8 days and up to 37 days after the insult, hence disturbing spermatogenesis at the level of the spermatozoa, spermatocytes and spermatids. Further analysis of the DNA integrity and the seminal plasma protein composition will reveal the extent of the damage to the DNA and changes to the sperm microenvironment. The regulatory mechanisms for testicular temperature are restricted during scrotal insulation as compared to whole animal exposure, and further studies should therefore be conducted to determine how environmental temperature effects semen quality in *Bos indicus* bulls.

Reference

Brito LFC, Silva AEDF, Barbosa RT, Kastelic JP (2004) Testicular thermoregulation in *Bos indicus*, crossbred and *Bos taurus* bulls: relationship with scrotal, testicular vascular cone and testicular morphology, and effects on semen quality and sperm production. *Theriogenology* **61**, 511-528.

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Shooting blanks or failure to compete? Low calf output in multi-sire extensive NT herds

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Introduction

Bulls are the main drivers of fertility in every herd, but in extensive herds poor performing bulls can be common. Causes of low calf output suggested in previous literature include poor semen morphology and failure to compete with dominant bulls. The objective of this paper is to assess calf output across eight extensive Northern Territory (NT) herds.

Methods

As part of a larger project, 450 bull DNA samples were taken the year previous to weaner data collection from eight trial sites located in the Barkly, Victoria River, Sturt Plateau, Floodplain and Arnhem Land regions. The following year at weaning, 1962 (range of 206 to 286 per site) weaner steers on each property were randomly selected from one paddock's entire steer progeny to enter the trial and DNA samples were collected. Bull percentages ranged from 2.8% to 5.2% and the number of breeders in the paddocks where trial weaners originated ranged from 1000 to 2500.

Results

Of the bulls and calves sampled, 32% of bulls had no male progeny in the selected group. Average number of male calves per sire was 4.4.

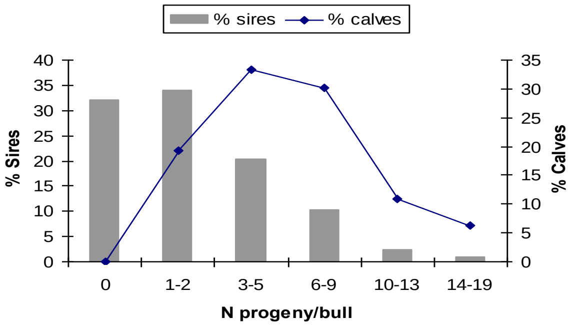

Fig 1. Male calves sired per bull

Discussion/Conclusions

It is difficult to compare number of progeny per bull with other literature as other studies have included steers and heifers. However, similar to previous studies, a small number of bulls sired the majority of calves and there was large calf output variability by individual bulls (0-19) (Holroyd *et al.*, 2002). High bull percentages, breeding soundness and social behaviour are all factors which may be affecting calf output in extensive NT herds.

Reference

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Molecular detection and identification of *Campylobacter fetus* subspecies *venerealis* in bulls at slaughter

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Introduction

Campylobacter fetus subspecies *venerealis* (Cfv) is a venereal disease that is characterised by infertility, early embryonic death and abortion resulting in considerable economic losses. To date, the "gold standard" for Cfv identification is culture isolation. These methods are not sensitive due to the rapid overgrowth of contaminants during transport to diagnostic laboratories. Molecular identification tools offer 1000 times increase in sensitivity over culture (McMillen *et al*. 2006).

Materials and Methods

Smegma samples were collected from the prepuce of 945 bulls post exsanguination using the Tricamper™ sampling device into PBS and processed using McMillen's real-time PCR protocol.

Results

Table 1. Prevalence of *Campylobacter fetus* subspecies *venerealis* in bulls by region of origin

	CQ	NQ	NWQ	SQ	SEQ	WQ	NT	NSW	Total
Positive (n)	6	0	2	20	6	12	3	20	69
(%)	3.5	0	8.3	9.0	4.3	16.7	15.8	7.3	7.3
Total (n)	174	21	24	223	139	72	19	273	945

Discussion

The molecular screening results detect similar levels of positive samples as described previously (McMillen *et al.* 2006). The ELISA results by Ardila *et al.* (this conference) estimate 17% prevalence. The gene target used in the McMillen assay has demonstrated a proportion of false negative and positive results (Willoughby *et al.* 2005; Spence *et al.* 2011). Our laboratory has been researching alternative molecular assays while using the McMillen assay simultaneously. Results to date demonstrate that approximately 10-20% of results do not correlate between different molecular targets but results do correlate for at least 80% of samples. Correlation of our culture and real time PCR data is under on-going investigation.

References

McMillen L, Fordyce G, Doogan VJ, Lew AE (2006) Comparison of culture and a novel 5' *Taq* nuclease assay for direct detection of *Campylobacter fetus* subsp. *venerealis* in clinical specimens from cattle. *Journal of Clinical Microbiology* **44**, 938-945.

Spence RP, Bruce IR, McFadden AMJ *et al*. (2011) Cross-reaction of a *Campylobacter fetus* subspecies *venerealis* real time PCR. *Veterinary Record* **168**,131-2.

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Monensin increases weight gain of steers fed low quality forage

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Introduction

Inclusion of monensin has become widespread in dry season protein supplements fed to breeding and growing cattle. Monensin is known to increase daily liveweight gain of grazing cattle when growing at moderate to high rates (Tedeschi *et al.* 2003). However, dry season pastures usually only support low growth rates in cattle. This experiment examined the response to monensin at low and moderate planes of nutrition.

Methods

Thirty Brahman crossbred steers with an initial liveweight 191.4 ± 7.1 (±SD) kg were used in an individual pen feeding experiment at Brian Pastures, Gayndah. All steers were fed, *ad libitum*, low quality (57 g CP/kg DM) pangola grass (*Digitaria eriantha* subspecies *Pentzii)* hay. The steers were allocated evenly across five groups receiving supplements of: nil (Control), urea-molasses block (20% urea, w/w of block, as fed; RMB), RMB plus monensin (RMB+M), weaner pellets (16% CP; WP) and WP plus monensin (WP+M). Blocks were fed at 0.1 kg/day and pellets at 0.75% liveweight (LW)/day. Monensin was included at 1100 and 34 mg/kg DM for blocks and pellets, respectively.

Results and Conclusions

There were main effects of supplement type and monensin, but no interaction, on liveweight gain (see Table 1). Monensin increased liveweight gain by about 0.1 kg/day (P<0.05) overall. Steers receiving weaner pellets gained more weight (0.58 kg/day; P<0.05) than their block supplement counterparts (0.35 kg/day), consistent with the much higher energy inputs. Hay intake was lower, but total intake higher, for steers receiving pellets compared with blocks illustrating a substitution effect. Monensin had no effect on supplement, hay or total intakes. A daily dose of 50–100 mg monensin can increase growth rates of weaner steers consuming low quality forage when included in supplements promoting liveweight gain above maintenance.

Table 1. Effect of feeding urea-molasses blocks or weaner pellets to steers with or without monensin on liveweight (LW) gain, and hay and total (hay + supplement) DM intake over 70 days.

Treatment	Liveweight gain (kg/day)	Hay DM intake (%LW/day)	Total DM intake (%LW/day)
Control	0.17^{A}	1.86^{A}	1.86^{A}
RMB	0.29^{B}	1.98^{A}	2.02^{B}
RMB + M	0.40^{C}	1.94^{A}	1.98^{AB}
WP	0.52^{D}	1.65^{B}	2.34^{C}
WP + M	0.64^{E}	1.70^{B}	2.36^{C}

Within columns, means with different superscript letters are significantly different (P=0.05).

Reference

Tedeschi LO, Fox DG, Tylutki TP (2003) Potential environmental benefits of ionophores in ruminant diets. *Journal of Environmental Quality* **32**, 1591-1602.

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"Hormone free": Variable HGP retention rates in Northern Territory cattle

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Introduction

Hormone growth promotants (HGPs) are used by a large proportion of cattle enterprises in the Northern Territory (NT). They are regarded as an effective means of improving liveweight gain by 10-15% in northern Australia, provided that they are used correctly (Hunter 2010). Obviously a HGP will not give a benefit when it does not stay in place in the ear. A lost HGP is an opportunity cost of around $70 or 11% of the total sale value of a 350kg animal (at $1.80/kg). In extensive cattle herds, animals are not inspected after implantation and it is assumed that the implant remains in place although this may not be the case. In the past HGP loss has been identified as an issue in US feedlots with Hoechest-Rousel Agri-vet (1988) reporting a 1.7% loss in an annual survey. This study reports HGP retention rates in extensive cattle herds in the NT for the first time.

Methods

HGP retention rates were recorded in herds of steers on 5 NT cattle properties between 2008 and 2010. The properties represented a range of geographical locations and management systems. Steers were either implanted as calves or as weaners. The presence of HGPs (present vs. missing) was then recorded at weaning (for those implanted as calves) and at approximately 4 months after weaning (for those implanted as weaners).

Results

Table 1. HGP retention rates in herds of steers on 5 NT cattle properties.

Property	Region	Breed	Implant timing	N	Missing HGP (%)
A	Barkly	Brahman	Weaning	185	5.0
B	Barkly	Composite	Weaning	224	52.0
C	Victoria River District	Brahman	Calf	239	12.0
D	Sturt Plateau	Brahman	Weaning or calf	242	1.5
E	Darwin	Brahman	Calf	186	2.0

Discussion/Conclusions

Retention rates varied considerably between properties and suggest that some properties have significant implant retention issues (HGP loss of >10%). This data has important practical implications for HGP use in the NT, as it highlights a management problem that many people may not be aware of. To avoid the opportunity costs of HGP loss, training in implantation techniques is strongly recommended and should include correct hygiene, positioning and insertion techniques.

References

Hoechst-Roussel Agri-Vet (1988) Freedom of information summary for Finaplixâ-H. Cited in; Lehman FD and Rains JR (1996) *Comp. Cont. Edu. (Food Animal)* **18**, S174-S177.

Hunter RA (2010) Hormonal growth promotant use in the Australian beef industry. *Animal Production Science* **50**, 637-659.

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Liveweight gain of weaner steers selected on growth rate after weaning and fed Cavalcade (*Centrosema pascuroum*) or Mekong grass (*Brachiaria brizantha*) hay

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Introduction

A large variation in live weight gain exists in weaned cattle grazing crude protein (CP) deficient pastures across northern Australia. Differences in growth rate may be inherent (genotype x environment) or may be a consequence of the weaning and post-weaning management process. This experiment measured the average daily gain (ADG) of steers selected on the basis of highest and lowest post-weaning ADG when offered either Cavalcade hay (high CP) or Mekong grass hay (low CP) under controlled feeding conditions in pens.

Methods

Two hundred and three male calves from Lakefield Station, Mataranka, NT, were weighed, marked and weaned in April 2010 and then grazed native pastures as a single mob and were offered a loose lick supplement (10% urea, 26% salt, 15% kynofos, 10% gran-am, 15% copra meal, 20% limestone and 4% trace mineral mix) at approximately 120 g/head/day. Ninety days after weaning the steers were weighed and post-weaning ADG was determined. Thirty six pairs of steers divergent in post-weaning ADG were selected for the pen study by pairing steers with the same weaning weight and with the highest (H-ADG) and lowest (L-ADG) post-weaning ADG. The steers were then allocated to one of 24 pens with n=3 steers/pen with diets randomly allocated to pens. The two treatment diets were Cavalcade hay (105 g CP/kg DM) and Mekong grass hay (30.4 g CP/kg DM) hay *ad libitum*. Urea and ammonium sulphate (US; 20 g/head/day) and copra meal (200 g/head/day) were added to the Mekong grass treatment to provide approximately 70 g CP/kg DM. Steers were fed daily and weighed weekly for 10 consecutive weeks.

Results

The average live weight of the entire mob of steers at weaning and 90 days post-weaning was 138.7 ± 1.8 kg (range 78 - 206 kg) and 152.4 ± 1.7 kg (range 88 - 222 kg), respectively. The average live weight of H-ADG and L-ADG selected steers 90 days post-weaning was 163.0 ± 3.8 and 147.8 ± 3.7 kg, respectively or 0.208 and 0.028 kg/day respectively. There was no difference in ADG between H-ADG (0.387 ± 0.018 kg/day) and L-ADG (0.369 ± 0.018 kg/day) steers during the pen study nor any dietary CP x selected ADG interaction. Steers fed Cavalcade hay had greater ADG than steers fed Mekong grass (0.473 and 0.282 ± 0.018 kg/day, respectively).

Discussion

These results demonstrate that no inherent differences in ADG exist when steers divergent in post-weaning growth rate are offered high or low CP diets under controlled conditions. It may be concluded that causes of variation in ADG of steers post-weaning are related to a range of management issues around weaning rather than any genotype x nutrition interaction.

We acknowledge the assistance of farm staff from the Katherine Research Station and Meat and Livestock Australia for funding this study.

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No growth response was found from PEG supplementation of cattle on a mulga diet

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Introduction

Mulga (*Acacia aneura*) is frequently grazed by cattle in central Australia, especially during severe dry periods (droughts). Previous research has found that polyethylene glycol (PEG) binds with the condensed tannins, found in mulga and similar plants, allowing more protein to be digested by ruminants (Jones and Mangan 1977). The objective of this research was to determine the effectiveness of PEG supplementation of cattle in central Australia.

Methods

An 8 week pen trial was designed with Droughtmaster heifers (n=10, average liveweight 289kg ±6kg) individually penned; half supplemented with PEG (PEG) and half as a control (CON) without PEG. During the first 6 weeks the PEG heifers were supplemented with PEG-4000 in their drinking water at a low, but variable rate (due to variation in water intake) with a median intake of 60g/head/day (range 14 - 105 g/head/day). During the final 2 weeks, the PEG heifers were drenched daily at a higher level of PEG supplementation (200g/head/day). To replicate the diet of cattle during severe dry periods, the diet was comprised of on average; 79% mulga (7.6 ME MJ/kgDM, 18.2% Crude Protein [CP]) and 21% poor quality hay (8.4 ME MJ/kgDM, 4.9% CP). Animals were weighed weekly and during the final 2 weeks daily Dry Matter (DM) intake and weekly DM digestibility and nitrogen excretion were recorded.

Results

Over the duration of the trial there were no significant differences between the treatments (PEG vs CON) in liveweight gain (mean 0.188 vs 0.314 kg/day), DM intake (mean 4.2 vs 4.7 kg/day) and DM digestibility (mean 48% vs 50%). There was significantly ($p<0.001$) less nitrogen excreted in the faeces of the PEG heifers during the period of high PEG supplementation (1.04% faecal DM for PEG vs 1.36% for CON). Also the mean "N absorbed : N intake" ratio was significantly ($p=0.0007$) higher in PEG heifers (802.8g DM/Kg DM) than CON heifers (762.8 g DM/Kg DM).

Discussion

As PEG is quite expensive (currently around $7.20/kg) and PEG supplementation was not found to have any positive effect on cattle performance in this trial, it is not recommended to Central Australian pastoralists as a viable supplementation strategy during dry conditions. It is hypothesised that other nutrients may be required in addition to PEG to give a benefit, as was found by Strachan (*et al.* 1988). However this would further increase the cost of the supplementation.

References

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Relationship between rumen bacterial populations and post-weaning live weight gain in steers selected on different growth rates in the Northern Territory

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Introduction

Large variation in live weight gain (LWG) occurs in weaners. One aspect that may differ is the association of the microbial population with the LWG. The aim of this experiment was to evaluate the relationship between the ruminal bacterial population and post-weaning LWG by examining (using denaturing gradient gel electrophoresis (DGGE)) rumen bacterial profiles of steers grazing low crude protein (CP) pasture.

Methods

Two hundred and three male calves from Lakefield Station, Mataranka, NT, were weighed, marked and weaned in April 2010 and then grazed native pastures as a single mob and were offered a loose lick supplement (10% urea, 26% salt, 15% kynofos, 10% gran-am, 15% copra meal, 20% limestone and 4% trace mineral mix) at approximately 120 g/head/day. Ninety days after weaning the steers were weighed and post-weaning ADG was determined. Thirty six pairs of steers divergent in post-weaning ADG were selected for the pen study by pairing steers with the same weaning weight and with the highest (H-ADG, 0.208 kg/day) and lowest (L-ADG, 0.028 kg/day) post-weaning ADG. They were transferred to Katherine Research Station and grazed a Sabi grass (*Urochloa mosambicensis*) dominant pasture for three weeks. From these two groups, 24 steers (n=12 steers per treatment) were rumen sampled after morning grazing before allocation to the pen experiment (Farmer *et al.* 2011). The V2V3 region of the 16S rRNA gene was amplified from extracted DNA and amplicons were separated by DGGE. Pearson similarities between sample profiles were visualized by principal component analysis (PCA) performed using MINITAB software.

Results and Discussion

The first two components of PCA explained 71% and 86% of the variation in the data of DGGE profiles. These components revealed that no animals clustered together based on the selected post-weaning LWG. The rumen microbial population appeared stable and similar across all treatments of selected LWG and thus do not explain the differences in LWG. Other issues associated with management at weaning are more likely to explain the difference in LWG post-weaning. This work suggests that there are no inherent differences in the microbial population of high and low growth rate weaners.

Reference

Farmer T, Cowley T, Streeter SJ, Perkins N, Quigley SP and Poppi DP (2011) Liveweight gain of weaner steers selected on growth rate after weaning and fed Cavalcade (*Centrosema pascuroum*) or Mekong grass (*Brachiaria brizantha*) hay. *Proceedings of the Northern Beef Research Update Conference, Darwin 2-5 August 2011*.

We acknowledge the assistance of T. Farmer and farm staff from the Katherine Research Station and Meat and Livestock Australia, University of Queensland, NT DoR and DEEDI for funding this study.

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The effects of weaning weight on postweaning growth in the VRD

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Introduction

There is little published information on the post-weaning growth of cattle on commercial properties in the Victoria River District (VRD) to assist managers as they target live export markets. This study was conducted to provide information on post weaning growth and to determine if it is affected by weaning weight as some managers are reluctant to wean smaller calves.

Materials and methods

The growth of calves weaned between 1999 and 2003 at Mt Sanford Station (17° 12' S, 130° 38' E) in the VRD was studied for a year after weaning. Each year the liveweight of calves at weaning (Wn Wt) was recorded. Following the weaning process they grazed in paddocks at a stocking rate of 20 head per km^2 and were weighed again in October and in the following May to allow calculation of dry season (DS = Weaning to Oct.), wet season (WS= Oct.-May) and total year (TY) growth. The number of animals (with complete data sets) studied each year was; 107 (1999/00), 111 (2000/1), 401 (2001/2) and 388 (2002/3). Only males were used in 1999/00 and 2000/1 while both males and females (evenly distributed between weight ranges) were used in 2001/2 and 2002/3.

Results and Discussion

Average TY growth ranged from 72 kg (2002/03) to 127 kg (2001/2). Wn Wt range had a significant effect on post weaning growth in two of the four years (Table 1), when animals in lighter weaning weight ranges grew more. Generally smaller weaners performed better over the dry season and despite gaining slightly less weight over the wet season their TY growth was greater. These results concur with the findings of Sullivan *et al.* (1992) in the northern VRD. The years in which Wn Wt range did not have a significant effect on growth were those with good seasonal conditions where TY growth of all Wn Wt ranges was high (>120 kg) and animals did not lose weight over the dry season. Therefore, in general, smaller weaners performed better than larger ones under adverse conditions.

Table 1. The effect of weaning weight range on postweaning growth in the VRD.

	1999/00 growth (kg)			2000/1 growth (kg)			2001/2 growth (kg)			2002/3 growth (kg)		
Wn Wt (kg)	DS	WS	TY	DS	WS	TY	DS	WS	TY	DS	WS	TY
100-140	8^{a}	111^{a}	119^{a}	9^{a}	116^{a}	125^{a}	10^{a}	118^{a}	128^{a}	-7^{a}	88^{a}	81^{a}
141-180	0^{b}	124^{b}	124^{a}	10^{a}	116^{a}	126^{a}	7^{b}	120^{a}	127^{a}	-12^{a}	88^{a}	77^{ab}
181-220	-7^{c}	117^{ab}	110^{ab}	7^{a}	115^{a}	122^{a}	5^{b}	122^{a}	127^{a}	-21^{b}	91^{a}	70^{bc}
221-260	-9^{c}	114^{ab}	105^{b}	6^{a}	111^{a}	117^{a}	5^{b}	122^{a}	126^{a}	-26^{c}	94^{a}	69^{c}
All	-2	116	114	8	114	122	7	120	127	-20	92	72

Averages in the same column with different letter superscripts are significantly different.

Reference

Sullivan RM, O'Rourke PK, Neale JA (1997) A comparison of once- and twice-yearly weaning of an extensive herd in northern Australia 2. Progeny growth and heifer productivity. *Australian Journal of Experimental Agriculture* **37,** 287-293.

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Processing calves prior to weaning on a Sturt Plateau (NT) cattle property

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Introduction

There is a perception among some Northern Territory (NT) cattle producers that processing calves (branding, dehorning, castrating etc.) before weaning helps with recovery and gives better performance after weaning. An experiment was conducted to compare the performance of calves processed before or at the time of weaning.

Materials and methods

A Brahman cross herd at Avago Station (Sturt Plateau region, NT) was mustered on 20 May 2009 and all calves were individually identified with ear tags but only every second calf was processed at this time ("Pre Wean" treatment). All the calves were then weighed and returned to the herd. The herd was mustered again on 7 August 2009 and all un-processed calves were processed ("At Wean" treatment). All the calves were then weighed and weaned. The weaning process involved keeping them in cattle yards for 2 weeks for training. They were then put in a large paddock with other weaners to graze pasture until 10 June 2010. Average weight gain and loss rates (percentage of missing animals) were compared between treatments over the following periods: P1 (20 May 2009 – 7 August 2009), P2 (7 August 2009 – 17 November 2009), P3 (17 November 2009 – 10 June 2010), and Post Wean (7 August 2009 - 10 June 2010).

Results and Discussion

The small difference in growth (1.5 kg) between the treatments over the Post Wean period (Table 1) was not significant and the higher loss rate (+5.6%) in the At Wean treatment was also not significant with this sample size (a difference of 7% is required for significance with this sample size). In a study in north Queensland, Petherick *et al.* (1998) also found that processing calves before weaning gave no long term benefits in liveweight, but did not comment on loss rates.

If early processing did reduce loss rates by 5% then this would result in an extra 13 kg of liveweight per calf processed, by the end of the post weaning period (assuming the average weaning weight is 160 kg and average growth over the post weaning period is 100 kg).

Table 1. The effect of time of calf processing on growth (average weight change) and loss rates.

Sex/Treatment	n (at P1)	Loss P1	Loss P2	Loss P1-P3	Growth P1	Growth P2	Growth P3	Growth Post Wean
Male - Pre Wean	72	0%	2.8%	2.8%	16.7	1.7	98.3	100.3
Male - At Wean	66	3.0%	6.1%	9.1%	20.0	-0.3	101.5	100.9
Female - Pre Wean	60	5.0%	0%	5.0%	13.0	-0.5	84.6	84.0
Female - At Wean	61	3.3%	6.6%	9.8%	12.8	-4.1	85.7	81.6
Pre Wean - Total	132	2.3%	1.5%	3.8%	15.1	0.7	92.2	93.1
At Wean - Total	127	3.1%	6.3%	9.4%	16.6	-2.1	93.8	91.6

Reference

Petherick JC, Holroyd RG, Doogan VJ, Cooper NJ (1989) Timing of weaning and processing: Effects on liveweight changes of weaner cattle. *Animal Production Australia* **22**, 320.

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Effect of early-processing on the growth and survival of NT weaner cattle

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Introduction

The process of weaning has been shown to be a significant stressor of animals without the additional procedures such as castration, dehorning, and branding that can also occur at this time. The following study investigated the logic that production gains may exist if calves spend time with their dams following branding, dehorning and castration prior to imposing the stress of weaning.

Materials and methods

The performance of 891 progeny from a mob of mature breeders that calved between January-February 2009 was monitored for approximately 11 months on the Barkly Tableland, NT. At the initial muster in May (Day 0), on presentation at the branding cradle, alternately the progeny were either processed (Early Processed) (dehorned, branded, ear tagged, ear-marked, and if male, castrated and given a HGP implant), or not-processed (Late Processed) (ear-tagged). Late processed calves were processed 10 days after weaning (Day 127). At allocation, EID, sex and liveweight were recorded. The mean weight at allocation was 105.6 kg and 103.8 kg for early and late processed females respectively and 110.6 kg and 111.0 kg for early and late processed males respectively. At subsequent musters EID and liveweight were recorded. Animals failing to re-muster were also recorded.

Results and Discussion

Changes in liveweight were subjected to ANOVA. Differences in weight since allocation between early and late processed female progeny were not significant at the weaning (63.3 *vs.* 64.3 kg), pre-wet (78.4 *vs.*76.8 kg) and post-wet (144.6 *vs.* 142.4 kg) musters at $P<0.05$. Differences in cumulative weight changes since allocation for male progeny were not significant at the weaning muster (69.2 *vs.* 67.8 kg), pre-wet (83.6 *vs.* 80.8 kg) and post-wet (158.2 *vs.* 157.5 kg) musters.

Table 1. Re-muster rates of male and female progeny processed either early or late.

	Female			Male		
	Early processed	Late processed		Early processed	Late processed	
No. of Animals	226	219		233	213	
Weaning re-muster	0.0%	0.0%	ns	2.1%	0.0%	ns
Pre-wet re-muster	0.4%	0.9%	ns	3.4%	0.5%	*
Post-wet re-muster	4.0%	3.2%	ns	5.2%	0.9%	*

*Significant difference at $P<0.05$ and ns, not statistically significant using Fishers exact test.

Differences in weight changes were not significant between early processed and late processed calves at either the weaning, pre- or post-wet season musters. The percentage of animals failing to re-muster was not significant between early processed and late processed female calves. However, a higher percentage of early processed male calves failed to re-muster at pre- and post-wet musters.

References

Petherick JC, Holroyd RG, Doogan VJ, Cooper NJ (1998) Observations on the influence of repeated sampling procedures on temperatment changes of weaner cattle. *Animal Production in Australia* **22**, 294.

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Repeatability of liveweight measurement for two common weighing systems

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Introduction

Many conclusions of cattle research rely on the measurement of liveweight to accurately reflect an animal's true body weight. When research is undertaken on commercial properties using their equipment, it is important is understand the level of weighing error that may be involved when drawing inferences from data. This study assessed the agreement between two repeated weights of cattle to determine the extent of weighing error in systems commonly used for measuring liveweight: the weigh box (WB) and portable platform (PP) infrastructures.

Methods

Two repeated liveweight (kg) measurements (W1 and W2) were collected on 6 groups of steers on commercial properties in the Northern Territory. Three groups were weighed using a weigh box system (WB_1, WB_2, WB_3) and 3 groups using a portable platform (PP_1, PP_2, PP_3). All animals were curfewed from feed and water for at least 12 hours prior to weighing. W2 was recorded within 1 hour of W1. The repeatability of the each system was assessed by calculating the coefficient of repeatability, or CR as 1.96SD of mean difference of W1-W2 (Bland and Altman 1999).

Results and Discussion

WB_1, WB_2 and WB_3 had a CR of 4.6 kg, 3.8 kg and 3.6 kg respectively. PP_1, PP_2 and PP_3 had CR of 14.4 kg, 6.7 kg and 12.0 kg respectively. The CR for the WB and PP groups combined was 4.0 kg and 11.3 kg respectively. This indicates that a repeated measure on a WB should be within ± 4.0 kg, and could be up to ±11.3 kg on a PP (Fig. 1). Weight difference was independent of Average Weight for both WB (P=0.086) and PP (P=0.172), as determined by regression.

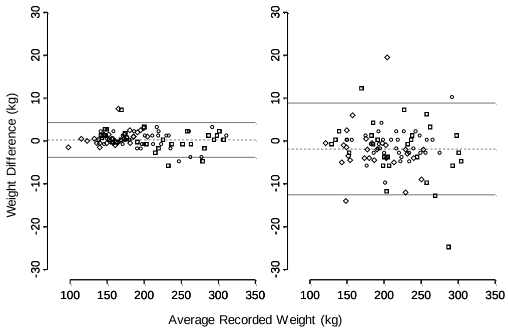

Fig. 1. Weight difference versus average recorded weight (kg) with mean difference and 95% limits of agreement. Left: Weigh box (□ WB_1 ○ WB_2 ◇ WB_3); Right: Portable platform (□ PP_1 ○ PP_2 ◇ PP_3)

The results of this study suggest that WB systems are almost 3 times more accurate in terms of repeat measurements than PP systems. The potential level of error associated with platform weighing systems should be considered when drawing inferences from liveweight data collected using these weighing systems.

Reference

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Steers ranked on dry season weight gain re-rank on wet season growth

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Introduction

High within-herd variation in growth rates represents a potentially a significant opportunity for improvement in productivity of northern Australian cattle herds. Wet and dry season growth rates are not expected to be independent of each other. Compensatory growth (Ryan 1990) and genetic antagonisms (McKinnon *et al.* 1990) are possible reasons for why dry season weight performance may not reflect wet season gain potential. This study investigated steers previously ranked on dry season ADG (DS_ADG) and their re-ranking on wet season ADG (WS_ADG).

Methods

Brahman steers (n=254) grazing predominately *Astrebla* spp. pastures in the western Barkly region of the Northern Territory were weighed at weaning, end of dry season (128d) and end of wet season (214d). Steers were ranked on dry season ADG where the highest ranking animals on ADG (n=40) were allocated DS_0, the lowest ranking animals (n=39) were allocated DS_2 and all other animals allocated DS_1 (n=140). The same ranking procedure was followed with WS_ADG to allocated animals to groups WS_0 (n=40), WS_1 (n=139) and WS_2 (n=40).

Results

Eighty-seven percent of animals ranked DS_0 re-ranked higher on WS_ADG, and 80% of animals ranked DS_2 re-ranked lower on WS_ADG (Table 1).

Table 1. ADG and ranking count (n) of steers on dry season ADG (DS_ADG), with re-ranking on wet season ADG (WS_ADG) and percentage change of rank.

	DS_ADG (kg/day)	WS_0	WS_1	WS_2	change up (%)	change down (%)	no change (%)
WS_ADG (kg/day)		0.18 + 0.04	0.28 + 0.03	0.38 + 0.05			
DS_0	-0.12 + 0.06	5	21	13	87	-	13
DS_1	0.05 + -0.06	22	99	19	14	16	71
DS_2	0.23 + 0.05	13	19	8	-	80	20

Discussion

These results demonstrate that a considerable proportion of steers with the highest dry season ADG within herd can rank lower on wet season gain, and those with lower dry season ADG can rank higher on wet season ADG. Hence, ranking on annual ADG is not an accurate reflection of growth potential. It may be concluded that these changes are a reflection of compensatory growth resulting from previous restrictions or be related to the genetics of adaptability and maintenance.

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Intake and digestibility of spear grass hay by steers supplemented with algae

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Introduction

Inclusion of Spirulina algae in the diet has increased microbial production, feed intake (Panjaitan, 2010) and weight gain (Costa *et al*., unpublished) of cattle fed low crude protein (CP) basal diets. It is unknown if other algae species have similar effects and how these compare to traditionally used supplements. The objective of this work was to compare the effect of Spirulina, Chlorella, Dunaliella and cottonseed meal (CSM) on feed intake and digestibility of cattle fed a low CP hay.

Methods

Five Brahman-cross steers (187 ± 22 kg weight (W); mean ± SEM) were randomly allocated to pens and treatments in a 5x5 Latin square with 12 days preliminary feeding followed by 9 collection days. The 5 treatments were spear grass (*Heteropogon contortus*) hay *ad lib* (control), and Spirulina (4 g DM/kg W.day), Chlorella (4.8 g DM/kg W.day), Dunaliella (4 g DM/kg W.day) and CSM (6.1 g DM/kg W.day) with speargrass fed *ad lib,* all with 300 g/day molasses. Chlorella and CSM were fed at an equivalent amount of N and Dunaliella at an equivalent amount of DM as that supplied by Spirulina. Data was analysed using the general linear model in SAS v8.2.

Results

Hay and total DM intake was highest for steers fed Spirulina and lowest for control and steers fed Dunaliella (Table 1). Steers fed Spirulina, Chlorella and CSM consumed all supplement allocation. Intake of Dunaliella was lowest and less than that offered. Digestibility was highest for CSM, Chlorella, followed by Spirulina and lowest for control and Dunaliella.

Table 1. Hay, supplement and total intake and digestibility of steers fed speargrass hay alone (control) or supplemented with Spirulina, Chlorella, Dunaliella and cottonseed meal (CSM).

Parameter	Control	Spirulina	Chlorella	Dunaliella	CSM	SEM
Hay intake (g DM/kg W.day)	11.4^{a}	16.0^{b}	12.1^{ab}	11.6^{a}	14.3^{ab}	1.3
Supplement intake (g DM/kg W.day)	0.0^{a}	4.0^{c}	4.7^{d}	0.7^{b}	6.0^{e}	0.3
Total intake (g DM/kg W.day)	12.6^{a}	21.2^{b}	18.1^{b}	13.4^{a}	21.5^{b}	1.4
Dry matter digestibility (%)	41.8^{ab}	45.5^{ab}	47.9^{b}	41.2^{a}	47.6^{b}	2.0

Values are means with standard error of the mean (SEM). Different alphabetical superscripts across the rows indicate significant difference between treatments (P<0.05).

Discussion

Dunaliella did not increase intake or digestibility. Spirulina, Chlorella and CSM were similar as supplements in increasing intake and digestibility. Spirulina and Chlorella are potential alternative protein supplements for cattle grazing low CP pasture.

This work was funded by Meat and Livestock Australia.

Reference

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Using ultrasound to measure carcass fat depth in live animals

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Introduction and Method

Real-time (B-Mode) ultrasound is increasingly being used for live-animal assessment of beef cattle carcass and reproductive traits. Its measurement efficacy of subcutaneous fat at the 12^{th}-13^{th} rib and P8 (rump) sites was assessed using 154 steers (2 weeks pre-slaughter) and 192 cows. Assessments were with a small (2.3 kg) portable unit (H101: Honda-HS 101V, 5MHz linear array probe), larger (~11 kg) desk-top units (H2100: Honda-HS 2100V, 10MHz linear array probe; Pie: Pie Medical Aquila Vet, 3.5MHz linear array probe) and a digital-read-out unit (UltraMac: AMAC Armidale, A-mode system, point probe for P8 only). Machine was confounded with operator. Breedplan-accredited Pie measurements in live animals were the reference. H101 and H2100 readings were without callipers.

Results

Cow P8 (0.5-28 mm) and rib fat (0.5-17 mm) depths were similar to those of the steers (2-25 mm and 1-17 mm, respectively). H101 readings of P8 and rib fat measures were highly repeatable in 37 random cows with representative fat depth distribution (mean difference [MD] = 0.16-0.24 mm, P>0.05, mean absolute difference of readings [MADR] = 0.61-0.89 mm, r = 0.96-0.97). When P8 fat depth was <4mm, the UltraMac was unable to give a reading or obviously gave a reading for muscle depth (>30 mm; reading discarded) in 49% of 78 cases. When P8 fat depth was >3mm, it gave one reading for muscle depth. Fat depth measures were made in live animals with the H2100 (MD *v* Pie = 0.28 mm, P<0.001, MADR = 0.68 mm, r = 0.96), the H101 (MD *v* Pie = -0.16 to 0.18 mm, P>0.05, MADR = 0.63-0.95 mm, r = 0.92-0.98), and the UltraMac (where a reading was given: MD *v* Pie = 0.03 to 0.36 mm, P>0.05, MADR = 1.27-1.31 mm, r = 0.73-0.95). Pie and H101 measures were compared to carcass measures of steer P8 and rib fat depths two weeks after scanning (MD *v* abattoir = 0.11 to 0.31 mm, P>0.05, P8: MADR = 1.76-1.77 mm, r = 0.815; Rib fat: MD *v* abattoir = -1.86 to -1.89 mm, P<0.001, MADR = 2.39-2.40 mm, r = 0.45-0.48). The same comparison was made for P8 fat depth using the UltraMac (MD *v* abattoir = 0.47 mm, P>0.05, MADR = 2.28 mm, r = 0.64).

Discussion and Conclusions

Live-animal fat depth measures vary with deviation due to marked fat thickness differences over short distances, probe pressure, and non-calliper reading (H101 and H2100; small consistent error by the H2100 operator). In this observation both the H101 and H2100 had high accuracy (low mean difference) and precision (low mean absolute difference between readings and high correlation) for measurement of a wide range of subcutaneous fat depths. When fat depth exceeds 3 mm and if readings obviously giving muscle rather than fat depth are discarded, the UltraMac has high accuracy but slightly lower precision than the other machines tested. The relationships between carcass and ultrasound measures of fat depth were poorer than that between ultrasound measures.

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Innate susceptibility of various cattle breeds to tick fever disease caused by *Babesia bovis* and *Anaplasma marginale*

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Introduction

Bos indicus cattle have been shown to be naturally much more resistant to *Babesia bovis*, the most important cause of tick fever in Australia, than British *Bos taurus* breeds, which are quite susceptible. *Bos indicus/Bos taurus* crosses have levels of resistance somewhere in between. All breeds showed susceptibility to anaplasmosis, although *Bos indicus* breeds are slightly more resistant (Bock *et al.* 1997). Since that trial in the mid 1990s, there has been increasing infusion of other exotic breeds into the northern Australian beef herd. Many northern Australian pastoralists and the larger pastoral companies have also standardised their base breeding herds as composites, which contain infusions of these exotic genotypes in combination with *Bos indicus* and British and European *Bos taurus* breeds. However, little information is available on the susceptibility to tick fever of breeds such as Wagyu, Senepol, and Tuli (all regarded as *Bos taurus*). In the trial described here (funded by MLA in 2010) these breeds were compared to a European *Bos taurus* and pure *Bos indicus* breed. In addition, two crossbred (or composite) groups were included. Composite A comprised 75% *Bos taurus* genotypes, including 25% Senepol; Composite B contained 50% *Bos taurus* genotypes.

Method

Naive cattle representative of these breeds were artificially inoculated with virulent tick fever organisms. Susceptibility to *B. bovis* was assessed first followed by that to *Anaplasma marginale*. Each animal was monitored after inoculation to assess the level of tick fever organisms in the blood, the development of anaemia and, in the case of *B. bovis* infection, also fever.

Results

The results were consistent with those of the previous trial. Pure *Bos indicus* cattle were quite resistant to *Babesia bovis* infection in both trials while pure *Bos taurus* breeds were, as expected, quite susceptible. Interestingly, the Tulis, Senepols and Wagyus were as susceptible to *B. bovis* infection as the European cattle with development of marked anaemia and fever. Similar percentages in each of these breed groups required specific treatment. The composite or crossbred groups had intermediate susceptibility to *B. bovis* infection, based on the criteria of parasite levels and the degrees of anaemia and fever that resulted. All the breeds, even pure *Bos indicus* and crossbred groups, were quite susceptible to infection with *Anaplasma marginale*.

Conclusion

Whilst pure *Bos indicus* breeds are quite resistant to the effects of *B bovis* infection, this effect declines quite quickly as the *Bos taurus* content increases. Alternatively, as the *Bos indicus* content decreases, the tick fever risk will increase. All breeds of cattle, even pure *Bos indicus*, are very susceptible to anaplasmosis. Even exotic and tropically adapted *Bos taurus* breeds such as Tuli and Senepol are susceptible to all forms of tick fever.

Reference

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Genetic variation of tick burdens of cattle in central Queensland

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Introduction

Although it is well known that cattle differ in their resistance to ticks, the genetic basis for tick resistance is largely unknown. Recent studies have begun to identify some of the genes that may influence tick burdens. However before any DNA tests for tick resistance could become available, it is necessary to generate large samples of cattle of different breeds to evaluate whether the DNA markers have consistent effects.

Materials and methods

Tick counts were obtained for two populations. First, multiple tick counts and archived DNA samples for 707 animals of the Belmont Red breed and 307 animals from a Charolais x Brahman cross over Belmont Red dams from the Belmont Property in Central Queensland were used. Ticks with the size range 4.5 – 8 mm were counted on one side of the animal. Due to the large variations in tick counts within a season and at different times of the year, animals were included in the study if they had been counted more than once. These tick counts were collected between 1978 and 1997. Second, multiple tick counts and DNA samples for 1,012 animals from the Mt Eugene property in Central Queensland were collected for Senepol, Senepol cross, Belmont and Bonsmara animals between 2009 and 2011. The data were analysed using a mixed model of ANOVA, average ln(ticks+10) ~ mean + fixed effects + animal + error. The fixed effects were breed, paddock, sex and year, and the random effects were animal and error. Full pedigree information for the samples from Belmont was used to generate a relationship matrix. For the animals from Mt Eugene, a realised relationship matrix was calculated based on genotypes.

Results and Discussion

The average trait values for Belmont and for Mt Eugene were different (Table 1).

Table 1. Trait values for the two properties in the study.

Property	mean ticks[†]	SD	min	max	CV	h^2
Belmont	3.40	0.638	2.303	5.305	0.188	0.35
Mt Eugene	3.11	0.526	2.303	4.728	0.169	0.42

†average ln(tick counts + 10)

The heritability of tick counts was found to be similar (0.35 at Belmont and 0.42 at Mt Eugene). The breed was of lesser importance than the sex of the animal and paddock location. The breed for these animals was not significant once the genetic relationships between animals were determined.

Conclusion

The moderate heritability of tick counts indicates that selection on tick resistance is viable across breeds. The large amount of variation found between paddocks suggests that integrated control methods for tick burdens need to be applied. These populations will be used in the discovery and validation of gene markers for tick resistance.

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Observations on the impact of buffalo flies on liveweight gain of cattle in a cell grazing operation in the Douglas Daly region, NT

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Introduction

There is little published information on the effect of stocking density on the impact of buffalo flies (*Haematobia irritans exigua*) on cattle growth. Within an experiment at the Douglas Daly Research Farm comparing the growth of cattle in cell grazing (CG) and set stocked (SS) management systems, it was observed that buffalo flies were affecting the behaviour of cattle more in the CG treatment. The average liveweight gain of the treatments was compared to assess the impact of buffalo flies.

Materials and methods

The experiment was conducted in a lattice of almost identical 6 Ha paddocks of buffel grass pasture. Three replicate paddocks of the SS treatment were randomly distributed among the 29 paddocks used in this experiment. The stocking rate was 1.3 hd/ha in each of the SS paddocks and in the total area of CG treatment, however all 208 CG animals were only ever in 1 paddock at any time as they rotated around the 26 CG paddocks. Brahman weaner steers were randomly allocated (weight stratified) to the treatment paddocks in July and they remained in the experiment for a year. They were weighed at various times throughout the post weaning year (Fig. 1).

In December 2009 it was observed that Buffalo flies appeared to be affecting the CG cattle much more than the SS animals. The CG cattle were observed milling around in an agitated manner, to the extent that they churned up areas of soil. As a result all cattle were fitted with insecticidal ear tags on 7 January 2010. The liveweight change between weighing periods was used to assess the effect of buffalo flies during the period when they were seen to be affecting the cattle.

Results and Discussion

Analysis of data collected at several weighing dates showed that average liveweight change during the post weaning year was similar in both treatments except during the period from 26 November 2009 to 6 January 2010 (Fig. 1). During this period average liveweight change was 28 kg lower in the CG than the SS treatment. This difference was mostly maintained until the end of the post-weaning year when liveweight change was 23 kg lower in the CG treatment. These results suggest that buffalo fly control measures should be considered where cattle are at high densities eg. in cell grazing.

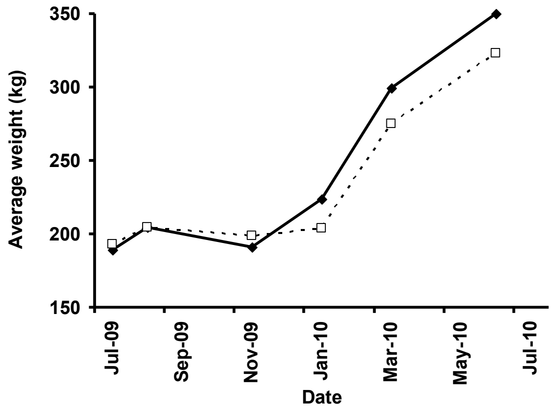

Fig. 1. Average liveweight change in the SS (solid line) and CG (dashed line) treatments.

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Bio-control for ticks and buffalo flies

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Introduction

Both the cattle tick (*Rhipicephalus* (*Boophilus) microplus*) and the buffalo fly (*Haemotobia irritans exigua*) are serious pests of cattle in Northern Australia. Current control strategies for ticks and buffalo flies rely on extensive chemical usage which is fraught with negative issues. Fungal biopesticides have emerged as realistic non-chemical control options for a range of pests. DEEDI and UQ researchers have investigated the potential of a *Metarhizium* based fungal biopesticide to control ticks and buffalo flies.

Methods

Thirty one Queensland isolates of *Metarhizium anisopliae* were subjected to intensive screening in the laboratory to find the best isolates and dose for a fungal biopesticide to be applied to cattle for tick control. Formulation studies were conducted to develop the best carrier for the fungal spores. Further studies investigated the effect of the fungal formulation on ticks at alternating high and low temperatures. Three small field trials and one pen trial were conducted to evaluate the efficacy of the fungal biopesticide against all stages of ticks on animals. Surface temperatures of selected animals were monitored during the trials as were the ambient temperature and relative humidity. The capacity for buffalo flies to take up lethal doses of *Metarhizium* spores from treated surfaces was investigated in the laboratory and in two of the field studies.

Results

Two *Metarhizium* isolates were selected for animal trials based on their high optimal growth temperature; good spore production characteristics and ability to kill adult and larval ticks in the laboratory in minimum time. Formulation investigations found that fungal spores suspended in an emulsified oil - water mix halved the time to 100% tick mortality compared to spores suspended in aqueous mixtures. Larval studies showed that even at varying temperatures alternating up to 38°C for 12 hours per day the formulation was extremely potent towards larval ticks. It was also shown that many acaricide resistant tick strains are susceptible to the fungal formulation. At each trial the formulation caused 100% mortality in semi-engorged ticks removed from treated animals and incubated under laboratory conditions. In the field, the fungal formulation was able to reduce ticks on animals by up to 80%. However the results varied between trials and between tick stages. The best results occurred under conditions with cooler nights. The fungal treatment was also shown to infect engorged ticks which dropped from animals in the first days after treatment increasing their mortality and subsequently decreasing egg production by these ticks. Laboratory investigations showed that buffalo flies are highly susceptible to *Metarhizium* infection. Buffalo flies netted after the biopesticide application to cattle showed very high levels of *Metarhizium* infection and increased mortality after laboratory incubation compared to buffalo flies netted in the weeks prior to treatment. This effect was noteworthy as only six out of a total of fifteen animals had been sprayed with the fungal treatment in these trials.

Conclusion

This research has shown that a *Metarhizium* based biopesticide offers real potential as a non-chemical control option for cattle ticks with the added benefit of controlling buffalo flies.

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Field evaluation of a *Metarhizium* based biopesticide for nuisance fly control in cattle feedlots in Australia

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Introduction

Nuisance flies including *Musca domestica* are an on-going problem for intensive animal holdings. Uncontrolled fly populations may lead to reduced production, annoyance stress to feedlot workers and complaints from residents in urban areas adjacent to feedlots. In addition flies can vector diseases. Repeated use of insecticides for fly control can result in residues in produce and the environment and the development of resistance in flies. Fungal biopesticides are a novel biological tool with potential for use in nuisance fly control. Research carried out from 2004 until 2008 developed a fly control formulation based on *Metarhizium* spores which was trialled in cattle feedlots over two consecutive fly seasons (late 2006 - 2008).

Methods

Australian isolates of *Metarhizium anisopliae* and *Beauveria bassiana* were screened against adult and immature flies (*M. domestica*). Further bioassays with selected isolates investigated spore uptake from food or sprayed surfaces, efficacy of spray and bait formulations, spore levels required to kill flies and combinations of fungal species. An aqueous formulation of *Metarhizium* spores suspended in emulsified vegetable oil with added fly attractants was sprayed onto targeted areas in feedlots. Samples of flies netted in the feedlots were incubated in the laboratory to assess the impact of the fungal formulation on flies in the feedlots. Samples were taken before and after spraying in the treated feedlots and in the control feedlot. Dead flies were investigated for *Metarhizium* infection. The density of flies in the feedlots was estimated through trapping with alsynite traps.

Results

The mortality of and *Metarhizium* isolations from flies netted after spraying were much higher than in flies netted in control feedlots. This confirmed that flies contacting the freshly sprayed formulation were taking up lethal doses of spores. The increased fly mortality and presence of *Metarhizium* infections were still evident, though at lower levels, in flies netted one week after spraying. This showed that fungal applications can remain effective for at least seven days post spraying. Fly trapping indicated lower numbers of flies in treated feedlots.

Table 1. Average percent mortality in netted *Musca* flies and percent flies infected with *Metarhizium* in Brisbane Valley feedlots during 2006-2007 and 2007-2008.

Feedlot sample	Av % mortality in netted flies after 7 days incubation	Percent dead flies with *Metarhizium*
After spray treatment	76.9 (±1.0) a	77.0 (±1.7) a
One week after spray treatment	27.9 (±0.7) b	19.8 (±1.2) b
Control feedlot	20.7 (±0.6) c	5.8 ((±1.7) c

Value with different superscripts are significantly different (P<0.05)

Conclusion

These results confirm the potential for a fungal biopesticide as an effective and environmentally friendly tool for fly control.

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Reduced efficacy of macrocyclic lactone treatments in controlling gastrointestinal nematode infections of weaner beef calves in SE Qld

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Introduction

The tropical gastrointestinal parasites *Haemonchus placei* and *Cooperia punctata* are not generally considered to be a constraint to productivity of beef cattle in pasture-based systems in Queensland. Sporadic outbreaks of disease in higher rainfall zones are usually treated with macrocyclic lactone (ML) anthelmintics at weaning. Failure of ML anthelmintics to control these parasites of weaner dairy calves in south east Queensland was identified and was the first report of resistance in cattle in Australia (Lyndal-Murphy *et al.* 2010). Investigations into ML failure on beef farms in the same region are reported here.

Method

Faecal Egg Count Reduction Tests (FECRTs) were conducted on four beef cattle properties. Calves aged between seven to ten months and carrying natural infections were randomly allocated to either an untreated control group or a treatment group of benzimidazole (BZ), levamisole (LEV) or a macrocyclic lactone (ML) group, either an ivermectin (IVER) or moxidectin (MOX). The number of treatment groups on each property varied according to availability of calves. Faecal samples were collected from individual animals at day 0 and day 10 post-drench for laboratory analysis and anthelmintic resistance calculations.

Results and Discussion

Anthelmintic resistance is said to occur when an anthelmintic fails to reduce the worm burden by at least 95 per cent. *C. punctata* was the dominant infecting nematode on all properties although significant numbers of *H. placei* were also present. ML resistance, in particular IVER resistance in *H. placei* (property 2) and IVER and MOX resistance in both genera (property 4) was identified (Table 1).

Table 1. Overall reductions for all parasite genera (%) and *C. punctata* (%).

Property	Benzimidazole (BZ)	Levamisole (LEV)	Ivermectin (IVER)	Moxidectin (MOX)
1	99	98	99	99
2	99.6	99.7	87 (<u>99</u>)	
3				100
4	100	99	92	79 (<u>73</u>)

Repeated use of anthelmintic treatments inevitably leads to resistance in target nematodes. The current level of resistance in beef cattle nematode parasites emphasises the importance of integrated management strategies for worm control to slow the further development of anthelmintic resistance.

Reference

Lyndal-Murphy M, Rogers D, Ehrlich WK, James PJ, Pepper PM (2010) Reduced efficacy of macrocyclic lactone treatments in controlling gastrointestinal nematode infections of weaner dairy calves in subtropical eastern Australia. *Veterinary Parasitology* **168**, 146–150.

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Welfare outcomes for tropically adapted calves dehorned with three instruments

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Introduction

The process of dehorning is known to be stressful and painful for cattle (Stafford and Mellor 2005). This study was conducted to compare the welfare outcomes of calves dehorned by scoop dehorners, dehorning knife or hot-iron cautery.

Methods

Forty-four Brahman, tropically adapted composites and Belmont Red/Brahman crossbred calves (2–6 months old; mean liveweight ± S.D., 135kg ± 25.8) were allocated to 4 treatments: scoop dehorner (Sc); dehorning knife (K); hot-iron dehorner (HI); and sham-dehorned polled calves (C) (Animal ethics approval RH255/08). Animals were blocked for liveweight, genotype and flight time (n=11/treatment). Behaviours during dehorning and on 1, 2, 3, 7, 8, 11 and 14 days post-treatment were modelled using a Generalised Linear Model. Plasma cortisol concentrations, wound areas and liveweight changes post-treatment were analysed using general ANOVA.

Results

Age and horn base area had a positive linear relationship (P=0.02). Vocalisations during dehorning were lower (P<0.05) in the HI group (counts ± s.e.; 4.0 ± 1.2) than Sc (9.8 ± 1.9) and K (10.0 ± 1.9). Pre-treatment plasma cortisol concentrations (nmol/L ± s.e.) did not differ among treatments (mean 28.3 ± 3.9). At 30 minutes post-treatment, cortisol concentrations of all 3 dehorning treatments (64.6, 62.0, and 62.2nmol/L for Sc, K and HI, respectively) were greater (P<0.05; s.e. 4.4) than C (45.7nmol/L) and at 5 hours post-treatment, Sc and K (57.3 and 61.3nmol/L, respectively) were greater (P<0.05; s.e. 7.7) than C and HI (38.8 and 39.7nmol/L, respectively). Wound size was initially largest in Sc, was largest for HI at 4 weeks, and did not differ by 8 weeks. More (P=0.04) HI wounds (82%) had not formed a scab (and were possibly infected) at 4 weeks compared with Sc (30%) and K (38%). The duration of comfort behaviours (e.g. head shaking, scratching and rubbing) 14 days post-treatment was significantly (P=0.02) longer in the HI treatment (168 seconds) than in C (29 seconds), with K (131 seconds) and Sc (65 seconds) intermediate. Liveweights increased for all treatments, and were similar (P>0.05) at 4, 8 and 12 weeks post-treatment. Horn removal with HI was least effective with regrowth found in 15 (of 22) horns compared with 4 and 5 for Sc and K groups.

Discussion/Conclusions

The relationship between age and horn base area indicates calves should be dehorned as soon as possible. Hot-iron dehorning caused less stress on dehorning day compared with the scoops or knife, but was largely ineffective, resulting in more animals requiring dehorning again, which is detrimental to their welfare. HI wounds were slower to heal and were prone to infection after dehorning. It was concluded that hot-iron dehorning should not be used for dehorning calves in northern Australia.

References

Stafford KJ, Mellor DJ (2005) Dehorning and disbudding distress and its alleviation in calves. *The Veterinary Journal* **169**, 337-349

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Automated animal control collars for pasture management

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Introduction

Recent advances in GPS technology (high fix-rates) can provide producers and researchers with the tools to accurately determine where animals are in the paddock. Automated animal control (AAC) technology offers an alternative method of controlling both where and when animals graze without the need for physical barriers, which are costly to erect and maintain, particularly along riparian areas. Automated animal control collars utilise GPS to monitor position and provide cue (audio) and control (mild electric shock) stimuli to deter animals from entering an exclusion zone. This paper describes a replicated experiment which investigated the effectiveness of AAC collars in reducing the presence of cattle in riparian areas.

Methods

The experiment was conducted at Belmont Research Station (150º 13′E, 23º8′S), located 20 km NW of Rockhampton. The four paddocks used for this experiment were each 24 ha and had approximately 260 m of Fitzroy River riparian zone. The water trough was located on the east side of the paddock and the river on the west side of the paddock. Twenty Brahman steers (*Bos indicus*) were fitted with neck collars. To reduce the power consumption of the AAC collars, the radio and GPS were duty cycled so that they were on 16% of the time. Once the cattle had become familiar with the paddock, collars were fitted to the individual animals for two weeks and background-monitoring data was collected. Once the background data had been collected, the coordinates of the exclusion zone were sent to the collars to start the control phase of the experiment. The collars were removed from the animals 4 weeks after being fitted. Cattle were observed from a distance regularly and had *ad-libitum* access to grazed forage and trough water throughout the experiment.

Results

On average, GPS collars functioned for 25 days and collected 98% of possible records. During the monitoring phase of the experiment, cattle spent 6% of their time in the exclusion zone, but less than 0.01% in the exclusion zone after the virtual fence was enabled. With access to the riparian area the cattle were dispersed across the paddock compared to the concentrated distribution of animals in the southeast corner of the paddock when access to the riparian area was removed.

Discussion

The results showed that cattle used the riparian area less when the automated cattle control collars were turned on. The distribution of cattle needs to be investigated further to determine the effect on pasture cover and utilisation across the entire paddock. The data collected in this study provided an opportunity to evaluate the benefits of using automated animal control collars to keep cattle away from environmentally sensitive areas. Due to the GPS units taking longer than expected the obtain lock and the unsuitability of the current AAC collars for long duration trials, the goal of three months of exclusion from the riparian area was not achieved. Work is ongoing to reduce power consumption and extend the length of time the AAC collars are operational. The ability to modify the distribution of grazing livestock is a common desire among farmers, either to protect sensitive areas or to more closely match feed demand with supply.

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Automatic monitoring of cattle behaviour to assess the relationships with performance in the rangelands

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Introduction

Beef cattle production in northern Australia is carried out extensively in large paddocks with large herds and little human intervention. Environmental stressors include heat, forage quality and quantity, parasites, and diseases. Cattle cope with environmental stressors through physiological and behavioural adaptations which make certain individuals more successful, resulting in faster growth rates, longer survival or better reproductive performance. Some behavioural attributes can now be automatically measured with novel technology, such as GPS collars, allowing the study of grazing strategies of individual animals. The objective of this work was to assess the relationship between behaviour from GPS collars and growth rate in tropically adapted beef cattle breeds, i.e. Brahman, Brahman cross, and Tropical Composite.

Methods

A preliminary study was conducted at the Lansdown Research Station near Townsville (Qld) using 26 steers weighing 302 ± 20 kg LBW (mean ± SD; 10 Brahman, 8 crossbred Brahman, and 8 Tropical Composites). Animals were fitted with CSIRO Fleck collars and allowed to graze in a 110 ha paddock for 14 days in March 2011. The collars contain a GPS board which collected the location and speed of individuals 4 times per second, and motion sensors collecting information 10 times per second. Live weight was taken at the start and the end of the experiment and daily LW gain calculated. Distance travelled per day was calculated from consecutive location data. The relationships between behaviour (distance and speed) and growth rate within the mob was analysed with SAS software.

Results

There were no differences among breeds ($P > 0.66$) in growth rate (2.0 ± 0.11 kg/d), distance travelled per day (18.2 ± 0.42 km/d) and mean speed (0.55 ± 0.008 km/h; mean ± SE). Size of the animals (LW) was not related to distance travelled per day ($P = 0.92$) or to average speed ($P = 0.71$). However, animals that grew faster travelled longer distances ($P = 0.002$) and at faster speed ($P = 0.005$) and these variables explained 36 and 30% of the variation in growth rate among animals, respectively. Interestingly, the relationship between growth rate and distance seemed to be stronger in Brahman ($r = 0.82$; $P < 0.01$) compared to Brahman crosses ($P = 0.68$) and Composites ($P = 0.18$). There was a close relationship between distance travelled per day and average speed ($r = 0.88$; $P < 0.001$). The hourly distribution of walking and speed did not differ among breeds and showed the typical peaks from 0800 till 0900 and then from 1600 till 2000.

Discussion

Grazing strategies of individual cattle in the northern rangelands seemed to be related to growth rate, especially in Brahman cattle. Animals that walked further and faster may be able to spend more time grazing and select best quality plant species which may explain their faster growth rate. However, such results need to be confirmed in relation to season and paddock size, and using more and larger groups of cattle. The use of motion sensors to estimate grazing and ruminating behaviour would also help confirming if distance travelled is related to feed intake.

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Real-time monitoring of livestock, vegetation, environment and management in the dry tropics: CSIRO Lansdown Research Station

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Beef cattle production in the Northern Australian rangelands is usually characterized by large paddocks with large herds and little human intervention. Furthermore, there is often considerable variation across and within paddocks and mobs. Productivity and sustainability can be reduced due to difficulties in managing these systems in a precise and efficient way, in addition to the detrimental effects of environmental stressors on livestock (e.g. heat, parasites, diseases, nutritional and water deficiencies). Novel technologies may help in overcoming some of these limitations by allowing detailed monitoring of livestock, vegetation, environment and management.

CSIRO is developing novel technologies and tools to work as an integrated Precision Livestock Management System at the Lansdown Research Station in Townsville (Qld). Sensors are being deployed to monitor each component of the beef cattle production system, i.e. livestock, vegetation, environment and management. The objective of this work is to identify which characteristics to measure, what methods to use, and to develop tools that could be incorporated into Precision Livestock Management Systems (PLM) for the northern rangelands.

PLMS are expected to improve productivity, sustainability, animal health and welfare, social life in rural communities, and the ability to adapt to changing conditions including climate change. For example, animal monitoring could improve productivity if the characteristics measured are related to growth rate, feed utilisation efficiency and reproductive efficiency, and if they allow for the improvement of management and selection of individuals and herds. For instance, work presented in this congress has reported a close relationship between distance travelled per day and growth rate. Thus, distance travelled could be used as an indicator of the degree of success of individuals or management practices. Further research is being considered to identify other relationships between grazing ecology measurements and production outcomes and animal health and welfare.

The group has been, and it is currently, carrying out numerous projects to improve environmental sustainability. Automated animal movement control collars have successfully been used to limit the utilisation of environmentally sensitive areas (e.g. riparian areas) to reduce erosion, and therefore improve water quality. Automatic monitoring of behaviour using GPS collars has also increased our knowledge about resource selection and helped develop strategies that, for example, discourage animals from using riparian areas or encourage better grazing distribution and pasture utilisation rates. Pasture monitoring sensors (such as satellite images and proximal sensors) have been developed to autonomously measure forage quantity and coverage. These technologies are allowing the development of novel ways to improve grazing management and environmental stewardship.

Environmental monitoring, including sensors for real-time temperature and humidity measurements, is allowing us to quantify the effects of climate change on both cattle and pastures. Water quality and soil condition will be measured and integrated into the system to develop tools that allow the industry to respond to climate change in a timely manner.

Ultimately, the goal is to integrate the technologies described above into an end-to-end system to improve productivity, sustainability and the ability to adapt to ever changing conditions. Many of these technologies are being deployed at the Lansdown Research Station (near Townsville) using wireless sensor networks and information technologies. This facility will provide researchers from a diverse range of disciplines with the facilities to advance the scientific knowledge of cattle production systems in northern Australia and to help face the challenges of coming decades.

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Diet quality of cattle grazing grass or Leucaena-grass pastures in Central Qld

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Introduction

Beef production from Leucaena-grass pasture can be double that from grass-only pasture due to both increased amount and nutritive value of the forage. However limited information is available on diet selection and nutrient intake of cattle grazing Leucaena-grass or grass-only pastures.

Methods

Two drafts of weaner cattle grazed paddocks of either nominally buffel grass (n = 8 and 5) or a Leucaena-buffel grass pasture (n = 9 and 25) on the Brigalow Research Station in central Qld from May 2008 to May 2009 and June 2009 to June 2010 respectively. Faecal samples collected each 6 weeks were analysed by faecal NIR spectroscopy to measure diet selection and quality.

Results

In the buffel pasture diet non grass was consistently <26%, and was likely woody browse species. Leucaena generally contributed 8-35% of the diet in the Leucaena-grass pasture during spring and summer, but increased to 83% during autumn when grass quality was rapidly declining. Similar seasonal changes in digestibility and crude protein occurred in both pastures. Digestibility was predominately >50%, and was consistently high (>65%) late summer in the Leucaena-grass pasture. Diet crude protein was likely limiting in cattle grazing the buffel grass between July to December 2009, but was not likely limiting in cattle grazing Leucaena-grass pasture (Fig. 1).

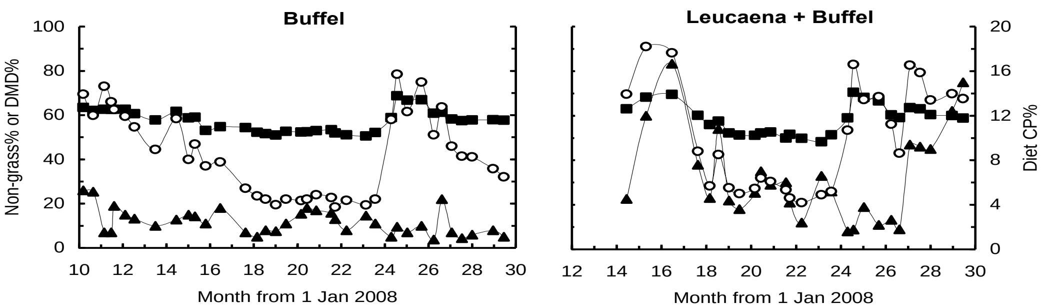

Fig 1. The diet non-grass (▲), crude protein (CP) (○) and digestibility (DMD) (■) of steers grazing buffel or Leucaena + buffel pastures.

Discussion and Conclusions

In this study when stocking rate matched feed availability, beef production increased from 51kg/ha.yr on buffel to 103kg/ha.yr on Leucaena + buffel (Thornton and Buck 2011). This is attributable to an increased amount and nutritive value of the forage in Leucaena-grass pastures.

Reference

Thornton C and Buck S (2011) Beef production from buffel grass pasture compared to leucaena-buffel grass pasture in the brigalow belt of Central Queensland. *Proceedings of the Northern Beef Research Update Conference, Darwin, 2-5 August 2011.*

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Innovative methods of establishing legumes to increase diet quality and address sown pasture rundown

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Introduction

Sown pasture rundown is an ongoing problem for pastoralists in central Queensland. Introducing legumes has the potential to improve pasture quality; however establishing legumes in buffel pastures is difficult. An MLA funded producer demonstration site (PDS) in the Arcadia Valley, Queensland is investigating innovative techniques to address the issue in a cost effective manner.

Methods

Three legume species (butterfly pea, burgundy bean and siratro) were planted together across 2 50 ha paddocks of uniform buffel grass pastures on brigalow clay soils in December 2010. Each paddock contained 5 sowing treatments; broadcast, broadcast near water point, direct drill seeder, "crocodile" seeder and control. One paddock had intensive herd impact applied by stocking at 50 head/ha for 12 hours immediately following sowing, whilst the second did not. Legume plant population and total biomass were recorded prior to the end of the first growing season and baseline soil fertility tests undertaken at the end of the first growing season. Plant populations, end of growing season biomass and soil fertility will continue to be monitored annually for 3 years.

Results and Discussion

Total leguminous plant establishment counts indicate no apparent difference between broadcast treatments (with or without herd impact). Direct drill seeding treatments achieved twice the establishment of broadcasting and herd pressure appeared to have no effect. "Crocodile" seeding applied with herd impact appears to be the most effective establishment technique, followed by direct drill seeding (Table 1).

Table 1. Leguminous plant establishment (seedlings/ha) at April 2011.

Treatment	**Herd Impact**		**Mean**
	With	**Without**	
Control	0	0	0
Broadcast	32,683	34,386	33,535
Broadcast near water point	54,167	38,095	46,131
Direct drill seeder	59,907	61,410	60,659
Crocodile seeder	118,000	62,517	90,259
Mean	66,189	49,102	57,646

Treatments that increased soil disturbance or placed the seed directly into the soil ("crocodile" seeder and direct drill seeder) doubled establishment when compared with broadcasting. Herd pressure only demonstrated an effect in the "crocodile" seeder treatment. This may be due to the herd impact increasing soil-seed contact within a relatively well-tilled seed bed. Herd impact had no benefit to establishment when seed was broadcast. Due to relatively low sampling density and lack of replication the results of this demonstration can only be considered indicative. More comprehensive research into legume establishment in buffel grass pastures is warranted.

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Establishment and growth of Leucaena is improved by pre-sowing ripping

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Introduction

Leucaena is a highly productive perennial legume, however it can be slow and expensive to establish. Deep ripping the soil prior to sowing is generally recommended, however limited information is available on the establishment and growth benefits to Leucaena.

Methods

Two central Queensland MLA funded Producer Demonstration Site trials: trial 1 was on a non-cracking loam soil native bluegrass pasture; trial 2 was on a cracking clay soil buffel grass pasture. Soil moisture and nutrient was measured directly before deep ripping (2 tynes, 1m apart, 65cm deep) and re-measured at planting. Leucaena plant population and total biomass were measured prior to the end of the first growing season, and edible biomass measured prior to the first graze.

Results and Conclusions

Greater soil-moisture accumulated at planting after ripping on the loam soil (Fig. 1). No difference occurred on the cracking clay soil (Fig. 2).

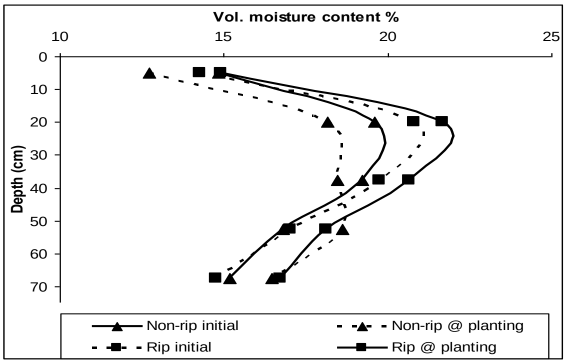

Fig 1. Soil moisture Trial 1 (loam soil)

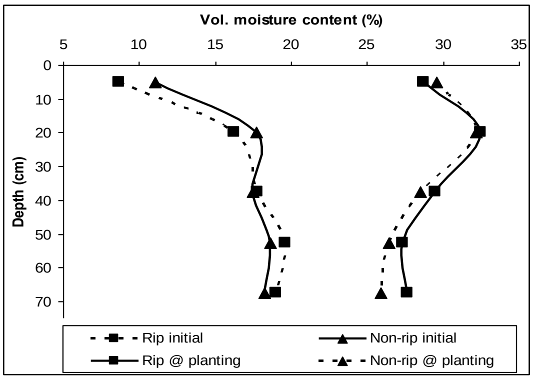

Fig 2. Soil moisture trial 2 (clay soil).

On the loam soil, establishment and initial Leucaena yield was significantly higher due to deep ripping, however similar yield was recorded prior to first graze. On the cracking clay soil, similar establishment and initial yield occurred, however more edible biomass was measured prior to first graze (Table 1).

Table 1. Leucaena yield and establishment.

Trial	Treatment	Initial Leucaena yield (kg/ha)	Establishment (plants/m of row)	Leucaena yield 1st graze (kg/ha)
1	Rip	418 a	13.5 a	1,090 a
(Loam soil)	Non-rip	240 b	10.2 b	956 a
2	Rip	246 a	13.6 a	1,320 a
(Clay soil)	Non-rip	244 a	12.9 a	1,205 b

Deep ripping on a non-cracking loam soil improved Leucaena establishment, however on a cracking clay soil only improved Leucaena yield to first graze.

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Beef production from buffel grass pasture compared to leucaena-buffel grass pasture in the brigalow belt of Central Queensland

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Introduction

Establishing leucaena pastures requires significant financial investment, which is expected to be recouped via increased beef production. This study compares beef productivity from grass-only pasture and grass-leucaena pasture at two set stocking rates.

Methods

Two drafts of weaner cattle grazed paddocks of either nominally buffel grass or a leucaena-buffel grass pasture on the Brigalow Catchment Study in central Qld from May 2008 to May 2009 and June 2009 to Mar 2011 respectively. The pastures were stocked at similar stocking rates for the first grazing period (2.1 ha/hd grass only *vs* 2.2 ha/hd grass-leucaena). In the second grazing period stocking rate was decreased in the grass only pasture and increased in the grass-leucaena pasture (3.4 ha/hd grass only and 1.5 ha/hd grass-leucaena) to match feed availability.

Results

During the first grazing period (similar stocking rates) the two pasture types had similar total weight gain and maximum average daily gain. However, beef production per hectare from the grass only pasture was 87% of the of the grass-leucaena pasture (82 kg/ha/yr cf. 95 kg/ha/yr). During the second grazing period when stocking rate was adjusted to match feed availability, beef production per hectare on the grass only pasture was half that of the grass-leucaena pasture (51 kg/ha/yr cf. 103 kg/ha/yr) (Fig. 1), again with similar total weight gain and maximum average daily gain.

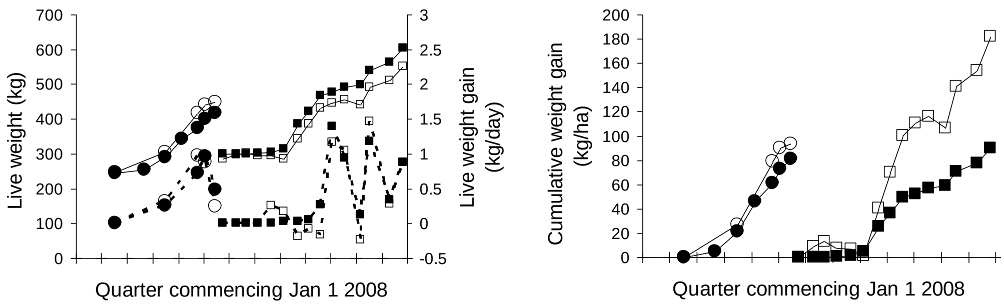

Fig 1. Liveweight (-), average daily gain (¨) and cumulative weight gain/ha for cattle grazing grass (●, ■) and grass-leucaena (○, □) at similar (circles) and feed on offer (squares) stocking rate.

Discussion and Conclusions

Similar total weight gain and maximum average daily weight gain were observed for all drafts of cattle irrespective of pasture type. When stocking rate was set based on feed availability, the higher quality grass-leucaena pasture (Buck *et al.* 2011) could be stocked at more than double the stocking rate of the grass only pasture, doubling the amount of beef produced per hectare.

Reference

Buck S, Thornton C and Dixon R (2011) Diet quality of cattle grazing grass or Leucaena-grass pastures in Central Qld. *Proceedings of the Northern Beef Research Update Conference, Darwin, 2-5 August 2011.*

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Mitchell grass drought and recovery

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Introduction

Severe drought conditions occurred across Queensland's 328,000km^2 of Mitchell grasslands from late 2001 until the 2008/9 summer. Despite its' ability to become dormant during drought, a large proportion of Mitchell grass (*Astrebla* spp) plants appeared dead rather than dormant by the end of the 2002/03 summer. *Astrebla* spp generally failed to respond to widespread average summer rains in early 2004. However, at some locations (e.g. laneways) the plants did respond—apparently in relation to management. Subsequently, MLA funded research to help explain this variable response through monitoring plant recovery and to provide clues for improved drought management.

Methods

Forty-nine sites of contrasting response were assessed in winter 2006 and again in 2009. *Astrebla* spp density, vigour and basal area (Orr 1998) were measured within 30 quadrats, 1x1 m, along two 75 m transects for each site. Plant density and basal area were classified as dead or living to allow previous and current basal area to be assessed. ABCD Land Condition was recorded. Photographs were taken of site conditions and quadrats. Botanical composition was determined through soil seed banks. Data were analysed using ANOVA, correlations and discriminant analysis.

Results/Conclusions

Astrebla spp density and basal area was lower ($P<0.05$) in 2006 at sites which had experienced at least one failed summer compared with sites that had not. Live *Astrebla* spp plant density and basal area was higher in good (A or B) than poor (C) condition sites ($P<0.001$) in both 2006 and 2009 whilst dead tussock density and dead basal area were higher in poor condition sites in 2006. *Astrebla* spp plants increased in size and vigour—but not density—between 2006 and 2009. Dead *Astrebla* spp plants decayed and disappeared. *Astrebla* spp soil seed bank density was higher ($P<0.001$) in good condition sites than poor condition sites in 2006. *Astrebla* spp seedlings were absent from soil samples collected in 2009; further research is underway to check for seed in duplicate soil samples.

Twenty-four sites (12 pairs) demonstrated differences ($P<0.05$) in 2006 due to burning or grazing, based on *Astrebla* spp seedling and plant density, basal area and soil seed bank functional groups. These differences persisted into 2009. There was a positive correlation between live *Astrebla* spp basal area in 2009 and increased historical frequency and duration of spelling.

Land which remains in good condition during drought has a greater chance of recovering quickly, although one or more failed summers within extended drought conditions can be enough to kill *Astrebla* spp plants. Drought recovery management probably needs to concentrate on recovering existing Mitchell grass plants—rather than relying on seedling recruitment—to ensure improvement in land condition and a return to full productivity. Whilst good growing conditions are a prerequisite for drought recovery and improved land condition, evidence suggests that spelling can speed the response.

References

Orr DM (1998) A life cycle approach to the population ecology of two tropical grasses in Queensland, Australia. In 'Population Biology of Grasses'. G.P. Cheplick. Cambridge, University of Cambridge Press: 366-89.

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Black spear grass in the Kimberley

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Introduction

Data collected across the Kimberley since 1994 indicates that there has been an increase in the average frequency of black spear grass *(Heteropogon contortus)* over this period. Black spear grass is very palatable when young and green however, in its mature state, is generally unpalatable and stock appear to prefer grazing other more palatable grasses to meet their nutritional requirements.

Most producers in the Kimberley plan to burn black spear grass every two to three years to improve forage quality (promote green pick) and reduce wildfire risk. Dray *et al.* (2010) recorded that 30% of Kimberley managers use fire to improve diet quality and control grazing distribution. In comparison 85% of managers on leases known to have significant areas of black spear grass use fire for the same purpose.

Results and Discussion

Sixty-two sites in the Kimberley recorded black spear grass in the last Western Australian Rangeland Monitoring System cycle between 2006 and 2008. Fig.1 displays the average frequency of black spear grass recorded between 1994 and 2010. Average frequency has generally increased since 1994 across all sites, although a decline was recorded in 2006. It is unknown what has caused this general increase. It is suspected that a number of factors including altered fire regimes, grazing pressure and seasonal conditions may be involved.

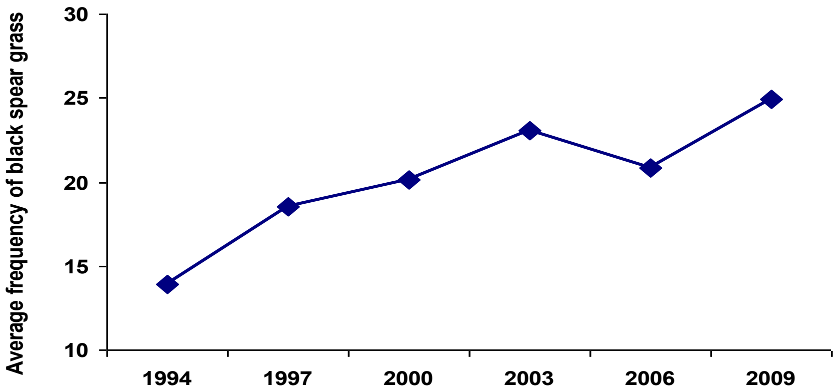

Fig.1. Average black spear grass frequency/site (Values for 2009 represent 2/3 of all sites)

Black spear grass is expected to continue to increase in frequency in the short term due to the high fire frequency associated with its current management. It is also expected that with an increase in black spear grass frequency there will also be an increase in the use of dry season supplements to better utilise this resource and improve animal production.

Reference

Dray R, Huey AM, Fletcher M, Stockdale M, Smith PC (2010) Final report B.NBP.0628 - Pastoral Industry Survey of the Kimberley and Pilbara regions, Western Australia - 2010. Meat and Livestock Australia, North Sydney, NSW 2059.

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Durable grazing systems in a changing environment

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Financial pressures and land productivity challenges

The *Aristida-Bothriochloa* country, commonly referred to as the "sandy forest" by producers, is the predominant pasture community by land area in the Queensland. Set stocking and overgrazing has led to a significant decline in productive native grasses and this, combined with native woodland thickening and exotic weeds, currently threatens the profitability of beef enterprises in the region. In addition to declining land productivity, family beef businesses are carrying average debts approaching $1M with direct costs per head more than doubling over the last decade. The challenge for producers is to implement grazing practices that maximise productivity gains in the good seasons and minimise productivity losses in drought or after prolonged flooding events.

Enhancing business resilience in a tough climate

The Climate Savvy Grazing and $avannaPlan projects provide producers with the knowledge, skills and confidence to improve grazing management, land condition and herd productivity in the face of increasing climatic variability. Representatives from 16 properties attended two industry workshops in the Normanton-Croydon area to discuss and document typical grazing management practices in the area. There was particular emphasis on best practice in relation to stocking rates, wet season spelling, infrastructure development and the use of fire. Strategies to cope with increasing climatic variability, such as the prolonged regional flooding in 2009, were also discussed. This industry experience and local agency knowledge formed the basis of a bio-economic modelling exercise to estimate the impact of stocking rates and wet season spelling on pasture composition, weight gain and overall profitability.

High, medium and low stocking rates were modelled on a 60 000 ha property running 3300 Adult Equivalents (AE) against 30 years of rainfall data to predict the impact on perennial grass composition and annual liveweight gains. Over the modelled period, pasture composition declined under the high stocking rates (1AE:14ha) while the proportion of perennials remained static under medium stocking rates (1AE:18ha). Under light stocking rates (1AE:22ha), perennial grass populations increased from 20 percent to 50 percent after 14 years which results in a 30 kg annual liveweight increase and $38.29 improvement in gross per AE. These modelled results mirror those of the Wambiana grazing trial near Charters Towers which has seen a five fold increase in the biomass (kg/ha) of desirable perennial species in the moderate stocking rate treatment (1AE:8ha) compared to the heavy stocking rate treatment (1AE:4ha) over the 13 year trial period. In addition, the Wambiana grazing trial has displayed a difference of $100/ha in accumulated gross margin between the moderate and heavy stocking rate treatments.

Modelling information resulting from the industry workshop is being implemented on a family-run breeding enterprise near Croydon to demonstrate practical and profitable grazing practices in the sandy forest. In addition to substantial productivity decline caused by Tea Tree thickening, this property lost fifty percent of available feed during the ten week flood inundation in 2009. Wet season spelling, stocking rate and fire strategies will link with water infrastructure development and pregnancy testing programs to recover land condition and lift breeder performance. A case study detailing the impact on productivity and profit will be compiled and this property will become an awareness raising hub for neighbouring enterprises.

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Sustainability and profitability of different grazing strategies for managing rainfall variability

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Introduction and Methods

Grazing strategies such as moderate or variable stocking are widely recommended to manage for rainfall variability. However, there is a paucity of data on their performance relative to conventional management strategies such as heavy stocking. A grazing trial was established in 1997 in *Eucalypt* savanna near Charters Towers (MAR: 650 mm), Australia. Strategies tested were (i) *moderate stocking* (MSR), stocked at the long term carrying capacity of about 8 ha/animal equivalent (AE= 450 kg steer), (ii) *heavy stocking* (HSR), stocked at about 4 ha/AE, (iii) *variable stocking* (VAR) - stock numbers adjusted according to end-of-wet season pasture availability (range: 4-12 ha/AE), (iv) a *Southern Oscillation Index* (SOI)-variable strategy – stock numbers adjusted in November according to available pasture and SOI seasonal forecasts (range: 4-12 ha/AE) and (v) *rotational wet season spelling* (R/Spell), stocked at about 6 ha/AE. Paddocks were stocked with Brahman-X steers; treatments were replicated twice.

Results and Discussion

After 13 years, accumulated gross margin (AGM) was highest in the MSR and VAR followed by the R/Spell and SOI (Fig. 1a). AGM was by far the lowest in the HSR due to higher drought and interest costs and reduced product value; this equates to an advantage of these strategies over the HSR of about AU$2 million for a 20 000 ha property. The density of 3-P (palatable, perennial and productive) grasses in the HSR in 2010 was also by far the lowest of all strategies (Fig. 1b).

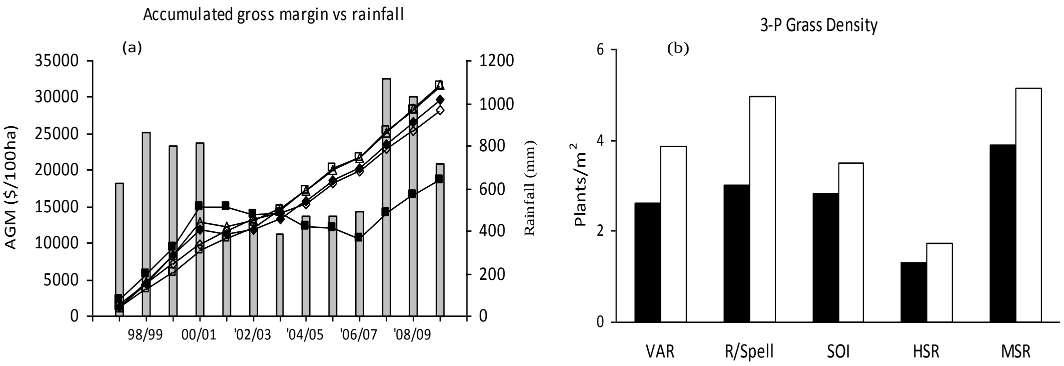

Fig. 1. (a) Annual rainfall (bars) and accumulated gross margin (AGM) over 13 years for the VAR (△), (R/Spell (◇), SOI(◆), HSR (■) and MSR (□) strategies. (b) 3-P grass density in different strategies in 2006 (■) solid) and 2010 (□).

These results give clear, long-term evidence of the profitability and sustainability of recommended strategies such as moderate or variable stocking relative to heavy stocking.

We thank the Lyons family of 'Wambiana'. The trial was funded by MLA and DEEDI.

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Adjusting stocking rates annually to improve profitability and sustainability of extensive beef enterprises in northern Australia

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Introduction

Annual climate variability results in large swings in forage availability for cattle in northern Australian rangelands, causing similar swings in pasture condition and animal productivity if cattle numbers are not adjusted. While land managers are encouraged to vary stocking rates annually, many prefer to keep herd size relatively constant. As part of a bio-economic modelling project (funded by MLA and DAFF), we investigated the impact of varying stocking rates annually on the profitability and sustainability of a cattle property in Queensland.

Methods

A bio-economic modelling framework (modified versions of the GRASP pasture production and ENTERPRISE herd economic models) was used to compare four stocking rate management strategies on a breeding enterprise at Mitchell in southern Queensland over 25 years (1986 to 2010). The four management strategies varied in the extent that long-term safe stocking rates could be adjusted annually in relation to end of growing season forage availability. These were: (1) fixed stocking rate (no change); (2) low stocking rate flexibility (increases ≤10% and decreases ≤20%); (3) moderate flexibility (increases ≤10% and decreases ≤40%); and (4) full flexibility (increases and decreases directly proportional to changes in forage supply). Low flexibility approximates current practice, and the moderate strategy was chosen after comparison of a wide range of stocking rate flexibilities.

Results

The moderate flexibility strategy produced the highest average annual profit of $419,000, and was better at maintaining or improving both pasture condition and cattle productivity. The low flexibility strategy resulted in the next highest average annual profit of $346,000, followed by full flexibility and fixed strategies ($264,000 and $235,000 respectively). For the full flexibility strategy, 10 of the 25 years had negative profit, whereas only two to four years of negative profit were experienced with each of the other three strategies.

Discussion

The low and moderate flexibility strategies were more profitable due to better pasture condition and higher animal productivity. When stocking rate is changed once annually and when rainfall over the following 12 months is variable and unpredictable, strategies involving small increases of ≤10% after good seasons and larger decreases of 20-40% after poor seasons were more effective. Moderate flexibility was more successful because it could decrease stocking rates by ≤40% at the end of poor seasons. There was no limit to the extent that full flexibility could decrease stocking rates annually, but the lack of a limit in increases after good seasons resulted in pasture degradation and poor livestock productivity when low rainfall was experienced over the following 12 months. Fixed stocking resulted in deterioration of pasture condition and livestock productivity during poor years.

This moderate flexibility strategy may offer a form of risk management for extensive beef operations that experience variable and unpredictable climate. The optimum stocking rate flexibilities for different levels of climate variability and climate change are being investigated.

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Testing Management Options: a calculator making grazing economics easy

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Introduction

Most producers want to better understand the economics of their current business and if they were to change, would they be better off? TMO (Testing Management Options) is a simple static herd model integrated with a whole farm economics spreadsheet, making it easy for producers to answer questions like:

- What is my current economic position?
- What is the economics of breeding versus trading or selling cattle younger or older?

TMO originates from DPI&F economists, James Gaffney and Tony Koch, as part of the 'Bridging the Business Gap' and 'Future profit' projects. It has been adapted to record and compare multiple scenarios. It is now FarmReady registered, with 19 workshops (263 people) run in the last two years.

What is it?

The *TMO spreadsheet* is a simple static herd averaging model where people represent their land and animals, together with associated capital, income and costs. As a simple averaging model it won't represent anyone's property exactly, though it gives a quick easy guide to many situations.

The *TMO process* is based on James Gaffney's "with" and "without" approach of doing steady state comparisons imagining the enterprise is up and running in a stabilised, year in-year out situation. The current situation "without" a change is compared to an alternative "with" a change. TMO stops at steady state comparisons, however if the alternative looks attractive, a detailed assessment of changes in risk, lifestyle, budgets and cash flow over years is needed to see if it is achievable.

The *TMO Workshop* helps participants learn the process and spreadsheet by working as one group in the morning to set up an average property and then test alternatives. In the afternoon individuals practice entering figures in their own or training laptops and then take the spreadsheet home.

Benefits of TMO

TMO is user-friendly with a short learning curve. It allows you to easily assess:

1. The current system e.g. land, stock, assets, liabilities, income, variable/fixed costs, profit.
2. Model alternatives - enterprises e.g. breeding, trading, agisting, age of turnoff; and management practices e.g. better pastures, early wean, feeding P, preg test, better bulls.
3. Test profit drivers e.g. carrying capacity (land condition), fertility, growth, carcase (prices), costs.

TMO records 14 scenarios all equalising grazing pressure and capital invested. Each scenario can be reloaded. Macro buttons allow easy navigation and comment boxes provide instructions.

Participants' feedback

Participants rated TMO workshops 6.3/7 for usefulness to their business. 100% would recommend the workshop to others. 96% say TMO is an easy introduction to whole farm economics.

"It's a good, handy, easy to use and robust tool"; "Opens every page to your business"; "It's easy to follow, requires limited computer knowledge to establish and identify important information"; "Pulls together learning from lots of other courses and puts it into an objective economic measure – almost holistic"; "Great to see it links land condition to the bottom line"

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Using commercial cattle records and pasture growth models to determine sustainable pasture utilisation rates

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Introduction

A "sustainable pasture utilisation rate" is the proportion of annual forage growth that can be consumed without adversely affecting land condition in the long-term. Sustainable pasture utilisation rates are the cornerstone of the grazing industry because they directly determine carrying capacity. Until recently, the only objective information on safe utilisation rates in the NT was from grazing trials and case studies on fertile cracking clays in the Victoria River District. Grazing trials are expensive and time-consuming and it is unrealistic to expect that they can be conducted on all important land types in the NT. This study thus tested a quick, cost-effective approach based on a method used previously in Queensland.

Methods

We used a method similar to that described by Johnston *et al.* (1996) to retrospectively calculate utilisation rates for 3 paddocks in the Alice Springs district, 11 paddocks in the Barkly district and 8 paddocks in the Sturt Plateau district. Pasture intake was calculated by converting station cattle records to adult equivalents and multiplying by a standard daily intake figure to determine herd intake. Pasture growth was estimated using the AussieGRASS (for the Alice Springs paddocks) and GRASP pasture growth models. GIS was used to estimate the amount of pasture growth available for consumption within 3km and 5km of water for each paddock. Utilisation rates were subsequently calculated for each year, starting at the beginning of the pasture growing season.

Results and Discussion

The Barkly results showed that an average utilisation rate of up to 25% appears to be safe for highly uniform Mitchell grass pastures in good land condition but this rate of utilisation is too high in mixed country, and less robust soil types. The utilisation rates for the Sturt Plateau paddocks supported current DoR recommendations of 10% for less fertile red soils, 15% for more fertile red soils and 20% for fertile clay soils. Average utilisation rates ranging from 78-124% were calculated for the three Alice Springs paddocks, which are clearly erroneous. We believe that the pasture growth figures from AussieGRASS are underestimates of real growth for these paddocks and will use recently calibrated GRASP models to re-calculate utilisation rates in 2011. We also intend to investigate the influence of top-feed on utilisation rates in the Alice Springs region.

Conclusions

The study confirmed that a quick, cost-effective method for determining utilisation rates is suitable for application in the NT. DoR intends to use this method to continually refine its recommendations on sustainable utilisation rates.

Reference

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Keep it hot but burn a bit more frequently to manage woody increase

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Introduction

Woody vegetation thickening has been widely documented across northern Australia since the 1970s. It can lead to a decline in pasture condition and production, and reduced animal performance and enterprise profitability (Dyer and Stafford Smith 2003). Late dry season fire is seen as the most cost effective method of controlling woodland thickening in northern Australia (Dyer and Stafford Smith 2003) and is currently recommended every 5-7 years. This 15 year trial presents an opportunity to review the effectiveness of these recommendations.

Methods

The study sites are located on Victoria River Research Station in the Victoria River District, NT. Two trial plots were established in 1993 on an arid short grass (AGS) site on calcareous red earths and a ribbon-bluegrass (RBG) site on grey cracking clays. Eight treatments varying in frequency of burning (none, 2, 4, 6 years) and season of burning (early – June and late dry season - October) were randomly allocated to each site, with each treatment replicated. Canopy cover and tree basal area (TBA) were estimated prior to burning in June 2009. The impact of season of burn, frequency of burning, and pasture type on woody variables was analysed using a factorial ANOVA. *Post hoc* pair-wise means comparisons were carried out using Tukey's HSD tests.

Results

In 2009 the AGS site had double the canopy cover (18% vs. 9%, $P<0.001$) and TBA ($3m^2$/ha vs. $1.2m^2$/ha, $P<0.001$) of the RBG site. There was a significant interaction between pasture type and season of burn for canopy cover ($F_{1,114}=7.75$, $P<0.01$). *Post hoc* comparisons showed that canopy cover was significantly lower in both the late and early burn plots compared to the control in the RBG pastures. However, only late fires reduced canopy cover in AGS pastures. TBA was significantly reduced by late burns ($F_{1,114}=5.57$, $P<0.02$). Burning frequencies of 2 and 4 years were equally effective in reducing canopy cover compared to 6 years or no burning for AGS and RBG pastures. TBA was not significantly affected by burning frequency despite a trend towards decreasing TBA with increasing frequency of fire.

Discussion and Conclusions

This long term fire trial has demonstrated that late burns every 4 years are required to manage woody thickening in ASG and RBG pasture communities, which is more frequent than currently recommended (5-7 years). While canopy cover results for the RBG site suggest that early burns are also effective, this finding needs to be viewed with caution as canopy cover is impacted by recent fire whereas TBA is not. Detailed pasture composition analysis is currently being undertaken to ensure that these regimes are not negatively impacting on pasture dynamics.

Reference

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A burning and spelling trial at Delamere Station, NT

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Introduction

Native pastures are a valuable resource for the grazing industry in northern Australia. Improving our understanding of the management requirements of different pasture types is critical if the health of this resource is to be maintained. A long-term pasture management research project has recently commenced on Delamere Station in the northern Victoria River District to investigate ways to improve and maintain pasture health using burning and spelling. The work is a partnership between Australian Agricultural Company, Team Savanna, the NT Department of Resources and Greening Australia, with funding from the Caring for our Country and Climate Change Research Programs.

Continuous grazing, especially during the growing season, reduces the ability of palatable perennial grass species to regenerate. Wet season spelling is a way of increasing the abundance and health of desirable species, improving overall pasture health and resilience, and increasing long term productivity (McIvor *et al.* 2010).

Many perennial grass species also respond well to being burnt and grow and seed prolifically in the months following a fire (Dyer *et al.* 2001). Burning pastures is also a practical way of maintaining the tree/grass balance (Dyer *et al.* 2001). However, pastures are at a vulnerable stage in the months after burning and the fresh growth is often selectively grazed.

Burning and spelling at Delamere

The Delamere project is situated on black soil pastures dominated by Curly Bluegrass (*Dichanthium fecundum*), Flinders Grass (*Iseilema* sp.) and Wire Grass (*Aristida latifolia*). The area has been divided into two 66ha paddocks. Paddock 1 will be spelled every 2 years, and Paddock 2 every 3 years. Each paddock is divided into 6 11ha plots. Three plots in each paddock will be burnt immediately before spelling, with 3 plots in each paddock remaining unburnt.

Burning is carried out in the late dry/early wet season, after the first rains. Burning at this time of year ensures that the re-sprouting perennial grass tussocks are able to take full advantage of the growing season. Cattle are excluded from the trial area over the wet season immediately following burning. Spelling the paddock in this way will ensure that the desirable perennial grass species are able to grow unhindered, allowing mature plants to set seed and also allowing new plants to establish from seed already in the soil.

The key questions that will be investigated through the Delamere burn and spell project are:

1) Can a burn and spell management program result in:
   a) A shift in grassland community composition towards desirable perennials?
   b) Increased pasture productivity?
2) Is burning followed by spelling more effective than spelling alone for achieving these outcomes?

References

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Practical applications of fire in the Mitchell grasslands of the Barkly region

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Introduction

The Mitchell grasslands of the Barkly Tablelands are resilient to fire if followed by moderate stocking post burning, even under less than favourable growing conditions (Phelps 2006). This challenges the historical view that Mitchell grasslands are too valuable as a feed resource to be burnt and suggests that burning has the potential to provide production and land management benefits. This paper aims to provide points of consideration for land managers contemplating the use of fire as a cost effective pasture and cattle management tool on the Barkly Tablelands.

Practical applications of fire

Fire has been successfully implemented by managers for numerous purposes including wildfire mitigation, modification of pasture and woody plant composition and to influence cattle grazing behaviour. More recently, the use of fire as an option to control invasive weed species has gained momentum (G. Murrell pers. comm.). Direct control of fire sensitive species such as prickly acacia (*Acacia nilotica*), mesquite (*Prosopis pallida*) and parkinsonia (*Parkinsonia aculeata*) is possible, while populations of species such as rubberbush (*Calotropis procera*) can be knocked back with fire as part of a holistic control approach.

Recent fire research in the Barkly region has provided the following recommendations:

- Have clear aims for what you wish to achieve and construct a comprehensive fire management plan for the property. This will improve the chances of success and reduce any risks (e.g. loss of feed or over-grazing a burnt area).
- Burn as close to the wet season as possible (e.g. November) or after the opening rains.
- Only burn pastures in good land condition that have a good density of perennial tussocks.
- Manage post fire grazing by burning enough country to cater for the expected increase in grazing pressure (i.e. burn at least one third of a watered area, but no closer than 2 km from the water point), and employ conservative stocking rates.
- Be flexible and responsive. Different outcomes require different fire regimes (e.g. low or high intensity), and climatic/weather conditions can play a major role in the effectiveness of a prescribed burn.
- Don’t burn too often - allow 5-6 years between burns.
- For advice and assistance contact Bushfires NT or DoR Pastoral Production staff.

Conclusion

Cost effective options for managing vast areas of Mitchell grasslands on the Barkly Tablelands are limited. Due to the resilience and quick recovery of these grasslands, managers should consider using fire as a tool for multiple land management and production benefits.

Reference

Phelps DG (2006) Controlling *Aristida latifolia* (feathertop wiregrass) in *Astrebla* spp. (Mitchell grass) grasslands with fire and grazing. PhD thesis, University of New England, Armidale, NSW 2350.

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Spelling strategies for recovery of land condition

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Introduction

Reduced condition of pasture and soil, through decline in density and growth of desirable perennial grasses, is evident in most pasture communities across northern Australia. Wet season spelling of grazing land is a key recommendation for improved grazing management across northern Australia, especially for accelerating recovery of pasture that has declined in condition. However, there is little reliable and relevant information on which to guide the design of cost-effective and practical regimes of wet season spelling for recovery of pasture condition. This project seeks to improve the evidence base and modelling capacity underpinning recommendations for use of wet season spelling to recover poor condition grazing land and design more reliable and cost-effective spelling options for producers.

Methods

Site 1 has a study on the key combinations of timing, duration and frequency of spelling within a 'C' land condition grazed paddock in Central Queensland for a five year period. Site 2 will be established in the 2nd year of the project at the Wambiana grazing trial in northern Queensland. A smaller combination of spelling strategies will be tested on 'C' land condition sites subject to moderate and heavy grazing. Data from field trials will used to improve the capacity of GRASP to simulate the impacts of different spelling and stocking rate regimes on pasture conditions over a range of pasture community types and seasons. The project will engage with producers and field staff through awareness raising activities at each site and linkage to the Northern Grazing Systems project work.

Results

Site 1 has had variable rainfall over the previous decade with predominantly dry or very dry conditions. Good growing conditions, prior to and during the first summer of recordings has resulted in high pasture yields and crown cover. Pasture yields have been high for both *Bothrichloa ewartiana* and *Aristida spp*. There have been minimal changes in density of either species to date.

Discussion

A significant reduction of the high contribution of *Aristida spp* to the pasture composition and crown cover is a key desired outcome of this study. At Site 1, the lack of early change in pasture parameters with spelling treatments and good growing conditions, highlights the significant problem that land managers face when dealing with poor pasture condition. Minimal recruitments of *B. ewartiana*, and the impression of an ephemeral nature of the seedlings is a concern, in terms of the ability of the pasture to change composition and thus land condition. Good growing conditions appear to have had an overriding effect on the pasture parameters recorded compared to treatment effects. This is expected to change in the longer term.

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Pasture spelling to improve pasture condition, carrying capacity and profitability of a modelled grazing enterprise

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Introduction

Pastures can be spelled or rested from grazing to improve pasture productivity, maintain or improve land condition, or to accumulate herbage. The benefits of spelling pastures are dependent on land type and on the timing (season), duration and frequency of rest periods. In northern Australia, most benefits from spelling pastures have been demonstrated on single paddocks and have not attempted to assess impacts on the profitability of a whole property. Simulations using the pasture production model (GRASP) and a herd economic model (ENTERPRISE) allow the benefits of rotational spelling regimes to be evaluated on extensive grazing enterprises.

Methods

A representative property in the Maranoa-Balonne region was developed to explore the biological and economic implications of implementing a spelling regime. It consisted of 15,863 ha; 7 paddocks; mixed land types; native and sown pastures; 1400 breeders; and sold weaners. All paddocks were initially stocked so that pasture condition was maintained over the 25-year simulation period (1986-2010). A fixed, rotational spelling regime was simulated on four poor condition paddocks (less than 30% perennial grasses) stocked with breeders. Each paddock was sequentially spelled from grazing from 1st December for six months, once every four years. Stock from spelled paddocks were agisted.

Results

Spelling pastures, one year in every four for 6 months over the growing season, improved pasture condition, carrying capacity and animal productivity. All spelled paddocks had recovered to good pasture condition (80% perennials) after four summer spells (16 years); some recovered after two spells (8 years). The more rapid recovery of pasture condition occurred when spells coincided with good growing seasons (eg. above average annual rainfall) and were on the more productive land types (eg. poplar box on duplex soils sown with buffel grass). After 25 years, the carrying capacity of spelled paddocks had improved by 58-68%. Spelling improved average annual gross margins on a whole property basis by about $55,000 (14%), and average annual profits by about $100,000 (32%).

Discussion

Land types and the timing of spells, particularly with regard to the amount of rainfall received during the growing season, were important factors determining the rate pastures recovered to good condition. The simulated recovery of pasture condition in spelled paddocks led to improved carrying capacity and marked improvements in property profitability. In practice, the effectiveness of spelling pastures may be better than that of the fixed, sequential rotation regime modelled here. Managers of extensive grazing businesses could adopt more flexible or opportunistic approaches by commencing spelling to coincide with grass-growing rains, by choosing a length of spell appropriate to their goals, and by avoiding spelling in poor seasons where little benefit would be gained from spelling pastures. Such changes are likely to improve results compared with a rigid spelling regime.

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Pasture modelling in the NT. 1. Customising GRASP for NT pastoral land types

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Introduction

Increased development of Northern Territory pastoral land has highlighted a need for objective ways to measure pasture growth and calculate safe carrying capacities on different land types.

Methods

Pasture growth was measured on significant pastoral land systems across the Sturt Plateau, Barkly and Alice Springs regions. Pasture, soil and climate data collected from 50 sites using SWIFTSYND methodology (Day & Philp 1997) were used to calibrate the GRASP pasture growth model (Scanlan *et al*. 2008). Similar site models were combined to create average land system and land type models.

Results and Discussion

The NT now has objective pasture growth information on which to base safe carrying capacity recommendations for 4 major pastoral regions (including previous work in the VRD). Table 1 shows median pasture growths and commonly changed GRASP parameters between regions and land types. Further data will be collected to independently validate the accuracy of model outputs. There is potential to extend the data collection to other pastoral regions of the NT.

Table 1. Median pasture growth and GRASP parameters for land types across the NT.

Parameters	Sturt Plateau Region		Barkly Region		Alice Springs Region	
Soil type	Vertosol	Kandosol	Vertosol	Rudosol	Tenosol	Calcarosol
Pasture type	Mixed	Tall grass	Mitchell	Spinifex	Buffel	Oat grass
Tree Basal area (m^2/ha)	2.5	4.7	0	2.5	0.5	0.3
Grass basal area (m^2/ha)	2.5	2.2	4	7.5	1.5	1
Median growth (kg/ha)	3300	2500	1700	900	600	500
Soil water holding capacity (mm/10cm)	17	13	19	10	7	10
Maximum nitrogen uptake (kg/ha)	22	17	28	8	13.5	26
Nitrogen content at which growth stops (%)	0.50	0.46	0.88	0.40	0.75	0.80
Transpiration use efficiency (kg/ha/mmT)	11	14	16	12	15	1
Pasture regrowth (kg/ha/day)	20	20	34	15	30	17.5

References

Day KA, Philp MW (1997) Appendix 3 Swiftsynd Methodology for Final Report DAQ-124A: Evaluating the risk of pasture and land degradation in native pastures in Queensland. RIRDC.

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Pasture modelling in the NT. 2. Carrying capacity for pastoral development applications in a variable climate

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Introduction

We now have objective estimates of pasture growth to calculate locally specific long term safe carrying capacities (SCC) for a range of land types across the NT. This provides an objective basis for industry to assess development options and manage climate variability. A watering point development application is demonstrated on the poster.

Methods

The Grazing Land Management (GLM) methodology (Chilcott *et al.* 2005) and current Department of Resources (DoR) recommended safe utilisation rates were used to estimate long term SCC figures for a selection of land types. SCC = long term median pasture growth * utilisation rate / intake. These were compared to "historic expert SCC" from published and unpublished reports.

Results and Discussion

Table 1 compares SCC figures from the 3 alternative sources, including our modelled estimates. The differences between previous and modelled estimates are probably due to differences in safe pasture utilisation rate assumptions, watered area and inclusion of drought years. Our estimates assume all land is within 3 or 5km from water (depending on land type), whereas previous estimates may not have taken watered area into account. Where paddocks are not fully watered actual SCC will be lower. Practical testing of the SCC methodology is occurring on the Victoria River and Old Man Plains Research stations. We aim to standardise the current SCC methodology across the NT.

Table 1. Comparison of SCC estimates derived from modelled and historic methods for 'A' land condition.

Region	Soil Type	Pasture Type	Historic Expert (AE/km^2) [DGC][D]	GLM Expert (AE/km^2)	Modelled (AE/km^2) [UR][E]
Sturt Plateau	Vertosol	Mixed	7.3[F]	n/a	18.1 [20%]
Sturt Plateau	Kandosol	Tall grasses	6.1[F]	n/a	10.3 [15%]
Barkly	Vertosol	Mitchell	5.5[G]	n/a	9.3 [20%]
Barkly	Rudosol	Spinifex	1.9[G]	n/a	1.2 [5%]
Alice Springs	Calcarosol	Oatgrass	2.9 [1.0][H]	3.7	1.6 [10%]
Alice Springs	Dermosol	Buffel grass	4.7 [0.7][H]	2.5	3.1 [15%]

[D]DGC = Drought grazing capacity; [E]UR = Current DoR recommended utilisation rates;
[F]R. Sullivan (pers. comm.); [G]Christian *et. al*. (1951); [H]Condon *et al.* (1969)
Note: These figures are for specific climate locations and may not be applicable to entire regions.

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Pasture modelling in the NT. 3. Spelling options for the beef industry

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Introduction

Customising the pasture growth model GRASP has enabled us to model land condition effects of land management options for major land types in the NT. Land condition recovery in response to spelling was investigated as part of the Northern Grazing Systems Project funded by MLA and DAFF.

Methods

The spelling regime investigated was a six-month spell, starting on the 1st of December, once every 4 years. This spelling regime was modelled for 20 different 30-year climate windows, between 1900 and 2009. Modelling methods including how the safe long term set stocking rate was derived are further described in Scanlan *et al.* (2011).

Results

Time to recover from C to B condition (70% perennials) varied greatly and depended on the run of seasons, land type, stocking rate and model assumptions for rate of recovery and threshold utilisation for land condition change (Table 1). A six-month spell once every 4 years was not always enough to facilitate land condition recovery.

Table 1. Effect of spelling on recovery of C condition land in the Northern Territory.

Region	Land type	Modelled safe long term set stocking rate (AE/km^2)	Average number of years (and range) to recover land condition from C to B with spelling	% runs land condition did not reach B within 30 years
VRD	Basalt cracking clay	11	12 (3- >30 yrs)	5%
VRD	Basalt red earth	4	15 (3- >30 yrs)	15%
Barkly	Southern Mitchell grass	9	11 (3-27 yrs)	5%
Barkly	Southern red earth	2.5	11 (3-17 yrs)	15%
Alice	Open woodland	1.5	>30 (7->30 yrs)	65%
Alice	Mulga	1	>30 (9- >30 yrs)	70%

Discussion

The extremely variable climate in the Alice Springs region meant a preset one-in-four year spell was usually of little benefit. More frequent or more opportunistic spelling while pastures are growing, with lower or variable stocking to match seasons between spells, is required to promote land condition recovery in central Australia. The modelled safe set stocking rates are for A condition pasture. Stocking rates will sometimes need to be lowered for C condition recovery even with four-yearly spelling. Further validation of simulated recovery of land condition timeframes against known examples is required.

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Application of bio-economic simulation models for addressing sustainable land management issues for northern Australia.

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Introduction

Sustainable use of northern grazing lands is a principal concern following past pasture degradation and projected future climate change. From 2009 MLA has funded a study of best-practice land management strategies centred on reviews of past research and producer workshops in 9 regions. A range of potential herd and land management strategies and a representative beef enterprise have been specified for each region. The production, resource condition and financial implications are being screened through an innovative simulation process that combines a pasture production model (GRASP) and a herd economic model (ENTERPRISE). Simulation allows many strategies to be screened quickly and economically using longer term climate sequences and management strategies that were not achievable under conventional grazing and resource management trials.

Example - Fitzroy Region

The model is calibrated for a 10,500 ha property at Duaringa comprising native and sown pastures carrying ~1200 breeders and turning off 590-600kg bullocks to north Asian markets. Simulations of 26 years (1980 to 2006) were carried out using Duaringa climate records for 3 practices - variable versus set stocking rate, wet season spelling of 4 degraded paddocks, and prescribed fire for woody regrowth control in 4 paddocks.

Simulation Results

Profit estimates are presented as average gross margin/ha (Table 1) with minimum and maximum values and Net Present Value at 4% discount rate.

Table 1. Gross margin/ha for 3 management strategies for 26 year simulations (1980-2006).

	Stocking Rate			Wet Season Spelling		Prescribed fire	
	Fixed	Constrained variation	Fully responsive	No spell	Spelling	No fire	Fire
Average	$31.97	$39.25	$33.79	$27.58	$31.31	$21.59	$24.87
Minimum	$8.50	$7.07	$1.53	$5.57	$1.01	$0.49	$3.83
Maximum	$58.70	$74.91	$78.89	$49.00	$57.16	$49.67	$52.44
NPV@ 4%	$559	$688	$626	$466	$515	$386	$429

In each case the proposed practice suggests an improvement in enterprise profitability. Variable stocking rate strategies were better than fixed stocking rate strategies although the fully responsive strategy intermittently incurs forced selling penalties and crisis feeding when high animal numbers have to be liquidated in dry seasons. Both spelling and fire strategies offered economic advantages over the alternative 'does nothing' strategies.

Conclusion

Bio-economic modelling of 'representative' enterprises offers considerable scope for defining sustainable management practices with economic potential. With declining funds for conducting on-ground trials, simulation is a useful alternative for screening large numbers of management options for future application in research or practice.

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Climate Clever Beef. 1. Improving beef business resilience

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What is Climate Clever Beef?

The Climate Clever Beef project aims to help northern Australian beef cattle businesses in target regions (Fig. 1) to improve their production efficiency and business resilience. In doing so, beef businesses will be better equipped to improve their greenhouse gas emission efficiency and manage their response to current and future climate variability while maintaining or improving their productivity. Producers will be engaged through on-farm demonstrations that will equip them with the knowledge and tools to:

• **Evaluate** their business in terms of profitability, productivity, land condition, greenhouse gas emissions and climate change risk.

• **Identify practices** that will improve business resilience through improvement in profitability, productivity, land condition, greenhouse gas emissions and climate change risk and identify synergies or conflicts between these factors.

• **Implement** appropriate practices and model expected business performance with and without management change.

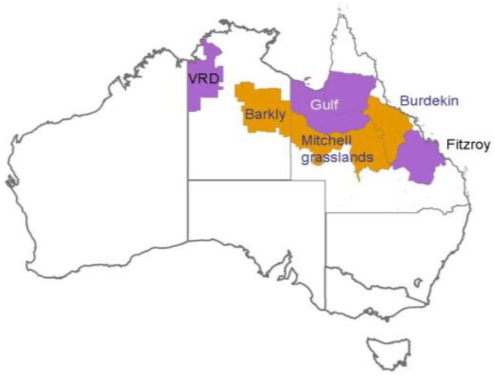

Fig. 1. Map of Climate Clever Beef regions. Fitzroy, Qld Gulf and VRD/Top End regions will evaluate strategies with expected greenhouse gas mitigation and climate change adaptation outcomes. Mitchell Grasslands, Barkly and Burdekin regions will evaluate strategies with expected climate change adaptation outcomes.

The adaptation strategies are aimed at a resilient resource base for sustainable beef production through maintaining good land condition and improving poor land condition. The adaptation strategies are: stocking rate management; wet season spelling; prescribed burning for woody vegetation management and improving grazing distribution through infrastructure development.

The mitigation strategies are aimed at ensuring an efficient herd to reduce greenhouse gas emissions and increase carbon sequestration. The mitigation strategies are; improving breeder herd efficiency, improving diet quality and woody regrowth management.

This project is a joint initiative of State Agencies (Qld DEEDI and NT DoR), CSIRO, Meat and Livestock Australia's Northern Grazing Systems Initiative, Department of Agriculture, Fisheries and Forestry's Climate Change Research Program 2. Website http://www.dpi.qld.gov.au/27_20060.htm

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Climate Clever Beef. 2. A pasture spelling and stocking rate demonstration at Alexandria Station

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Introduction

The Northern Grazing Systems (NGS) initiative, developed by Meat and Livestock Australia (MLA) aims to promote practical, region-specific grazing land management options to address issues impacting on the profitability, sustainability and productivity of beef enterprises in northern Australia. Through consultation with local producers, researchers, and a collation of all grazing management research, 4 key land management priorities have been identified: infrastructure development to improve grazing distribution, stocking rate management, pasture spelling and prescribed burning. The NGS initiative aims to demonstrate how improved implementation of these practices can enhance animal productivity and economic performance, maintain or improve land condition and improve risk management in relation to climate variability.

Aims of the demonstration

As part of the NGS initiative, the Department of Resources has established a demonstration site at Alexandria Station, on the eastern side of the Barkly Tableland. The aim of the site is to demonstrate the benefits of wet season spelling and sustainable stocking rates for maintaining good land condition at new bores and for improving land condition at old bores. The demonstration site objectives fit well with the priorities identified during consultation with producers in the region and with the overall NGS aims.

Methods

Three transects have been established in East Ranken paddock (1 at each of 3 bores of different ages). No. 10 Bore is believed to have been drilled sometime in the early 1900s and has, until recently, been grazed continuously. More recently, it has been spelled for 2 entire wet seasons (in 2008 and 2009). The second bore, No. 124 is 6 years old and has not yet had a wet season spell. The third bore, No. 153, is a new bore that was first put into use just prior to the first trial sampling. Changes in land condition are being monitored via changes in cover, pasture yield and species composition. Cattle data are also being collected to calculate effective stocking rates and pasture utilisation rates so that an economic assessment of the spelling and stocking rate regime can be completed. Demonstration of the economic benefits of these management practices is essential for increasing their adoption in the region.

Outputs

The demonstration site will increase our understanding of the interaction between pasture spelling, stocking rates and land condition in the Mitchell grasslands of the Barkly region. A field day will be held in late 2011 to present the results obtained from the pasture monitoring conducted at the end of the dry season in 2010 and end of the wet season 2011. A project report and industry fact sheets will be available in mid 2012.

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Climate Clever Beef. 3. Soil health comparisons between remnant forest and cleared pasture in the Fitzroy catchment

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Climate Clever Beef in the Clarke Creek District

Seven grazing businesses in the Clarke Creek district of Central Queensland are working together within the Climate Clever Beef Project. The groups aim is to evaluate the impact of management on soil health including soil carbon levels and soil microbiology. Soil health is important for maintaining resource sustainability, supporting resilient productive pastures and storing carbon. Nineteen management comparisons across 7 properties have been assessed by installing a permanent StockTake monitoring site and sampling the surface soil (0-10cm)(30 cores sampled per site). Soil microbial activity and pasture biomass results from three comparisons on different properties are presented in this poster. Comparisons include:

1. Remnant Brigalow softwood scrub (ungrazed) v's stickraked cleared buffel pasture.
2. Remnant alluvial brigalow forest v's pulled and graslan cleared buffel pasture (flooded).
3. Remnant alluvial brigalow forest v's cleared pasture (flooded).

The cleared pasture sites were all in good land condition (A) and considered by the landholders to be appropriately managed. The flooded sites receive a spell each summer when stock are removed during the period of high flood risk and following a major flood event are allowed to recover. The cleared sites were first treated in the 1970s with subsequent retreatment of woody regrowth.

Microbial activity was similar between remnant forest and cleared pasture, however there were major differences in pasture biomass (Table 1).

Table 1. Microbial activity and pasture biomass (in brackets) (t/ha) in remnant forest and cleared buffel pasture on three land types. Microbial activity calculations are based on carbon dioxide evolution. The indicator is unit less and the target is 80 for agricultural soils.

Land type	Remnant forest	Cleared pasture
1. Brigalow softwood scrub	80 (0.04)	89 (3.6)
2. Alluvial Brigalow (flooded)	59 (0.3)	62 (2.7)
3. Alluvial Brigalow (flooded)	86 (1.1)	70 (4.7)

Soil health, as measured by microbial activity, provides an indication that with appropriate grazing management, cleared pasture is sustainable and can maintain soil health similar to remnant forest. Similarly, no difference in microbial activity and other microbial indicators was found when comparing a remnant brigalow forest with 30 year old cleared pasture in the Brigalow Catchment Study (Radford *et al.* 2010). The ongoing challenge for the grazing businesses is to ensure the appropriate grazing management sampled in these comparisons is undertaken across their properties to ensure resource sustainability. More information is available at http://www.dpi.qld.gov.au/27_20060.htm

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Methane emissions from grazing cattle in northern Australia using open-path laser and Near Infrared Reflectance Spectroscopy methodologies

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Beef production in Australia accounts for a major proportion of total greenhouse gas (GHG) emissions from the agriculture sector. Cattle in northern Australia are predominantly raised on extensive pastures with marked seasonal variation in botanical composition, availability and nutritive quality. This results in marked seasonal variation in animal productivity and methane (CH_4) emissions (Charmley *et al.,* 2008). Recent results have confirmed the use of sulphur hexafluoride (SF_6) tracer gas (Ramírez-Restrepo *et al*., 2010) and open-path laser (McGinn *et al.,* 2010) techniques to assess ruminant CH_4 emissions in grazing conditions. However, both techniques have limitations and CH_4 emissions cannot be directly related to dry matter intake (DMI). Significant improvements in faecal near infrared reflectance spectroscopy (F.NIRS) techniques have demonstrated the ability of algorithms for predicting DMI, component and chemical composition of the diet and digestibility parameters for tropical pastures (Dixon & Coates 2009). The complementary use of CH_4 and F.NIRS measurement techniques could be used to study GHG emissions for northern Australian beef production systems.

Methane concentration was measured using open-path lasers in November 2010 at Douglas Daly Research Farm (13°50' S, 131°11' E) Northern Territory. A herd of 69 Brahman cows and heifers were used in the study and were confined daily for 4 – 5 h at a water point for measurements after grazing a 100 ha sward containing Buffel (*Cenchrus ciliaris*) and Sabi (*Urochloa mosambicensiss*) grass and Wynn cassia (*Chamaecrista rotundifolia*). Rectal samples were collected for F.NIRS analysis to estimate DMI, component and chemical composition of the diet. Methane emissions were estimated using WindTrax model based on mixing ratio and micrometeorological data. These were measured over 17 d and averaged 212.6 ± 8.9 g/day. Predicted proportion of legume (7%) and total nitrogen concentration (24 g/kg DM) in the diet were similar for heifers and cows. Predicted DMI was 10.3 ± 1.55 kg/day for cows and heifers combined. As a function of feed intake, estimated CH_4 emissions (g/kg DMI) from cows and heifers was 21.0 ± 3.57 and comparable to the value of 19.7 obtained for a range of tropical forages using calorimetry (P Kennedy, pers. comm.). It also compares well with data from temperate forages obtained using the SF_6 technique. Complementary methodologies could make a significant contribution for assessing CH_4 emissions from pastoral systems.

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Realising a whole farm systems approach to measuring and managing carbon for beef production: Lansdown Research Station

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Australia's northern rangelands are dominated by beef production and cattle numbers have increased consistently since 2002-03. Beef production systems account for a significant proportion of total greenhouse gas (GHG) emissions from the agriculture sector. However, nearly 70% of cattle are managed extensively across northern rangelands. Pastures are large, often > 120 km^2 (Hunt *et al.* 2007) and seasonal fluctuations in rainfall significantly influence pasture quality and quantity, herd fertility, grazing distribution, management practices and overall animal productivity. Lansdown Research Station, near Townsville, is 638 ha of native and improved pastures with an average annual rainfall of 809 mm. The facility is being developed into a modern R&D hub focusing on methane measurement and mitigation research, application of emerging genomic technologies and development of property scale wireless sensor networks.

The ability to continuously monitor livestock behaviour and productivity is challenging. Technologies that allow for remote measurement of animal physiology, behaviour and energetic status are already possible (Cooke *et al.* 2004), but their application to livestock production systems is yet to be fully realised. Opportunities are available to embed current technologies based on wireless sensor networks to monitor not only livestock movement, but grazing behaviour, herd health and fertility, water use, edaphic variables and establish remote drafting platforms to achieve production efficiencies in extensive heterogeneous environments. More specifically, methodologies have now been validated that allow for measurement of herd greenhouse gas emissions (McGinn *et al*. 2011), which, with measures of pasture and tree growth can be used to calculate on farm C fluxes. Four open circuit respiration chambers for measuring individual animal methane emissions are currently under construction which, with the validation of novel non-invasive methodologies, will provide the beef industry with opportunities to measure herd scale GHG emissions and quantify the effect of GHG mitigation strategies. Development of wireless sensor network technologies will also allow for continuous and real time monitoring of animal behaviour and spatial grazing patterns. This technology will facilitate dynamic management of contrasting livestock genotypes as influenced by seasonal fluctuations associated with climate change. Research conducted on Lansdown will underpin sustainable animal production systems across heterogeneous pastures characteristic of northern Australia.

The application of new and emerging technologies for a carbon constrained northern Australia will target improvements in production efficiencies based on metagenomics, animal behaviours, economics and environmental sustainability. Validation and demonstration of technologies with spatial and temporal resolution will be the main focus of activities at Lansdown Research Station.

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Adapting to beef business pressures in the Gulf

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Gulf beef business challenges

There are significant economic and environmental threats to the short and long term viability of family-run breeding enterprises in the Queensland Gulf. While cattle prices remain static, a recent analysis shows overheads and direct costs per Large Stock Unit (LSU) have increased by 54 and 150 percent respectively (McCosker *et al*, 2010). With more than a two-fold increase in land values over the last decade, debt levels now average $976, 000 per business (ABARE, 2010). Many producers increase stocking rates to deal with cost-price and loan repayment pressures impacting on land condition and threatening future enterprise profitability. Adding to these pressures, the wider community expects a long term reduction of beef industry greenhouse gas emissions.

Building enterprise resilience

The $avannaPlan, Climate Clever Beef and Climate Savvy Grazing projects equip beef producers with skills to analyse and build resilient beef production systems in a variable climate. Through these projects successful pasture management, herd management and marketing practices were identified on Blanncourt Station in the Queensland Gulf. Blanncourt is a typical family-run breeding enterprise with 2600 head on 18,753 ha which has adapted to the changing pressures on the beef business. When purchased in 1996, only 15% of the property was in desirable A and B land condition with 2270 breeders and heifers producing only 1066 weaners each year (46% weaning rate). In response to reduced stocking rates, wet season spelling and pasture improvement over fifteen years, approximately 85% of Blanncourt is currently in A and B land condition with 1533 cows and heifers producing 1060 weaners each year (69% weaning rate). Improved pasture productivity together with wet season phosphorus, targeted dry season M8U and silage feeding to sale cattle have increased annual live weight gains from 60-80 kg/head in 1996 to 140-180 kg/head in 2011. Reduced cow deaths (190 in 1996 and 38 in 2010) provide greater opportunities for herd selection and female sales and total gross margins, after interest, have increased by 93 %. Greenhouse gas modelling indicates the current herd turns off 405.7 tonnes of liveweight equating to 11.7 kg CO_2e /kg of liveweight sold. This compares to the 1996 production system turning off 222.6 t liveweight with emissions of 25.1 kg CO_2e /kg of liveweight sold. Overall Greenhouse gas emissions are down by 15% and greenhouse gas emission/kg of liveweight sold is halved when compared to 1996.

Analysis of the business has raised the dilemma that while the relatively costly feeding program has greatly improved productivity and greenhouse gas emissions efficiency, it is impacting on profitability and requires consideration for the business moving forward.

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The project team acknowledges the Connolly family for their hospitality, time and willingness to provide sensitive production and financial information.

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CQ BEEF – The right balance

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Introduction

The CQ BEEF project has been operating in the Fitzroy Basin region of Central Queensland since 2007 and has developed a network of eight active producer groups. The producer groups encompass a total of 137 members from 67 businesses, covering an area of 47,900 ha and running approximately 128,700 head of cattle. The project was developed by DEEDI and FBA and has received support from Caring for our Country and the Beef CRC. The aim of the project is to improve the performance of beef businesses by increasing the adoption of sustainable and profitable grazing practices.

Method

The project is based on a model of self-directed participatory action learning groups. The beef cattle producers that make up these groups work in partnership with DEEDI and FBA staff to:

- Objectively analyse their businesses
- Identify opportunities for enhanced performance, and
- Develop and implement strategies to improve economic and environmental business performance.

Objective analysis and group direction has been underpinned by the use of Resource Consulting Services (RCS) business analysis ProfitProbe™ and the Breedcow and Dynama Herd Budgeting Software Package. Group activities included training, field days, study tours and Producer Demonstration Sites.

Detailed benchmarking surveys have been used to demonstrate improved producer performance in business, resource and information management, adaptation and change and effective communication.

Results and Conclusion

CQ BEEF has measured a positive response from participants in the form of:

1. Objective enterprise analysis has confirmed improved business performance.
2. Increased producer confidence in the future profitability and sustainability of their businesses.
3. Stronger networks and project activities have helped CQ BEEF producers improve their ability to manage information and stay up to date.
4. Improved record keeping and analysis.
5. Achieving better grazing management has been a major focus.
6. The groups have developed five Producer Demonstration Sites. Producers have also become involved in other industry projects.

Businesses involved in the project have undertaken a range of activities to evaluate their enterprises and develop strategies to improve their economic and environmental performance. The project monitoring and evaluation has found that producers have developed their knowledge and skills and implemented improved management practices. The project has increased beef extension activities in the region and has also strengthened the engagement between industry, agribusiness, FBA and DEEDI.

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Environmental accounts and benchmarking in the Northern Gulf rangelands

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Introduction

The Northern Gulf Resource Management Group (NGRMG) is initiating a long-term, region-wide environmental monitoring and evaluation (M&E) project to report on the health of environmental assets of the region. This information will underpin long-term land management and planning, and improve the cost effectiveness of investments in environmental management and repair.

For the Northern Gulf graziers, consultations have identified that they would like an M&E program that provides: a knowledge base to pass on through succession; a management decision tool; a benchmarking system for environmental management; linkages between grazing practices and economics; detailed condition and productivity information useful when selling the property; and a means to compare management systems. Land managers envisage a monitoring program enabling management information sharing and forewarning of environmental threats to the region.

What will be monitored and how

The M&E Program will track changes in the following environmental asset themes: 1. Land; 2. Water; 3. Air, atmosphere and climate change; and 4. Coastal and marine. These will be supported by 2 information themes; Natural resource management practises and Socio-economic indicators.

Within these themes, the environmental asset health indicators are likely to include datasets for landscape function, sustainable management, biodiversity, grazing pressure, fire, dust, climate variables, water flows, groundwater, marine environment and marine primary production.

The main monitoring issues of relevance nominated by Northern Gulf graziers are: feral pigs and shootout effects; woody thickening, weed spread and management; sustainable stocking rates on various landtypes; population dynamics of pasture grasses and legumes; ground cover and land condition; carbon in the landscape; biodiversity on grazing land versus unwatered park land; and above and below surface soil health on burnt and unburnt country. These issues align closely with the key themes in the Northern Gulf's Natural Resource Management Plan 2008-2013.

The program will be set up as environmental accounts (Wentworth Group, 2008), in the same way economic accounts monitor a business' asset performance against benchmarks or previous years. With minimal resources and a huge area, the monitoring program design relies on existing monitoring datasets from external agencies, in combination with statistically valid on-ground point monitoring to interpolate region-wide datasets. Into the future, changes seen in some indicators may link to the health of other indicators in the region eg. land condition change may be tracked through water quality changes, which affect marine production and community socio-economics.

Additional producer environmental benchmarking

Volunteer graziers participating in a benchmarking process would provide their management and productivity information to underpin more intensively monitored environmental trends. Environmental health values for participating properties can then be benchmarked against surrounding areas, similar landtypes or management systems. Properties involved in benchmarking may be able to market their beef under a sustainably produced "green beef banner".

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A BMP program for the grazing industry: Grazing BMP

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Introduction

The future competitiveness of Australia's grazing industry will be influenced by increasing consumer and community scrutiny of the sustainability at a social, economic and environmental level. The primary drivers of adoption for landholders will continue to be increased production and/or reduced costs along with improved long term sustainability.

The Grazing BMP (Best Management Practices) project will be modelled upon the successful Grains BMP program, a partnership between Fitzroy Basin Association (FBA), AgForce, and DEEDI (Department of Employment, Economic Development and Innovation, Queensland). The same partners will again combine resources to develop and pilot the Grazing BMP, first in the Fitzroy NRM region, with the intent to expand the initiative across Queensland.

What is Grazing BMP?

Grazing BMP is a voluntary online self assessment tool to develop and implement a Best Management Practice program for the grazing industry, enabling:

- producers to identify and access training to improve knowledge and skills which will enable adoption of best practice.
- producers and industry to accurately monitor and report upon improvements in management practice at a range of levels, including catchment and industry scale outcomes.
- producers to benchmark their own practices against industry accepted best practice, and design and implement actions to improve.

How will it work?

Producers can use the Grazing BMP website to conduct a self assessment during group workshops. Self assessments are recorded and automatically link to action plans and further resources such as information and/or training options. The action planning component assists producers to develop actions to improve their enterprise performance. Working online enables producers to review or add to their assessments at any time. The online reporting functions mean that producers are also able to instantly compare how their own management relates to an industry accepted BMP, and where they sit in relation to others in their catchment or State. Individual data will only be available to those that enter it, with each producer being allocated a username and password to ensure the privacy of their information.

What's in it for landholders?

This program is designed to assist landholders improve the economic and environmental performance of their enterprises. The modules are designed to present the best available information and management principles at three levels – above, minimum and below standard for the whole business. The action plans developed will assist landholders to focus and prioritise on the most profitable and sustainable practices and identify training requirements. Landholders will be able to demonstrate and document good land management and environmental stewardship.

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Pastoral industry survey of the Kimberley and Pilbara - 2010

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Introduction

During 2010 managers of 77 (64%) pastoral businesses throughout the Kimberley and Pilbara of northern WA were interviewed to determine the current productivity, profitability and management practices of pastoral businesses (Dray *et al.* 2010). In addition to providing a broad ranging 'snapshot' of the industry, further analysis of the information collected provides the opportunity to identify groups of businesses performing better than average for different production and business criteria.

Results and Discussion

The weaning percentage recorded for first mated heifers for the whole survey averaged 66% and 57% for first lactation females. Average weaning rates of 72% for maiden heifers and 69% for first lactation heifers were recorded by the top ten percent of businesses.

By looking at the practices these top ten percent of producers employ, it will be possible to identify what contributes to the improved productivity they achieve from their animals. High conception rates in heifers mated for the first time and improving reconception rates of young breeders during their first lactation will reduce the burden that young breeders have on a business.

Segregation of heifers following weaning and into their breeding life allows for more focused management techniques to be carried out (Smith *et al.* 2010). All of the top producers segregated heifers until the first mating and a further 50% kept them segregated for longer. This compares to the survey average of 54% of managers segregating heifers until first mating.

Liveweight is one of many factors which determine when heifers reach puberty. It is generally accepted that Bos indicus cattle on average reach sexual maturity at around 300kg. The average weight of heifers when first mated recorded during the survey was 260kg on average. The initial mating weight of heifers recorded by the 'top ten' averaged 300kg. According to survey results the use of control mating was not a contributing factor in these pastoralists having higher than average weaning rates but this may be a reflection of the generally low adoption rate of controlled mating recorded in the northern rangelands.

Campylobacter (Vibrio) commonly affects the reproductive efficiency of young females. The survey recorded that 16% of managers used vibrio vaccine to protect their heifers, compared to 30% of the 'top ten' group. Sixty percent of the 'top ten' group also vaccinated bulls compared to the survey average of only 34% vaccinating bulls.

Sixty-nine percent of pastoralists feed supplements to their cattle; 75% of the managers that feed supplements do so throughout the dry season, with 28% feeding during the growing season. Eighty percent of the 'top ten' managers feed supplements throughout the dry season; 63% of these include phosphorus as a main ingredient in their supplements. Twenty-five percent of the 'top ten' group feed supplements for the entire year.

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Control of *Calotropis procera* (rubber bush, calotrope) in northern Australia

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Introduction

Infestations of the exotic shrub *Calotropis procera* (Aiton) W.T. Aiton (commonly referred to as rubber bush or calotrope) are increasing in northern areas of Queensland, the Northern Territory and Western Australia (Grace 2006). Many landholders in these regions are concerned that this is resulting in reduced pasture production and increased management costs on affected properties.

C. procera has a large fleshy taproot which acts as a storage organ and appears to confer considerable resilience with respect to fire and soil moisture stress. It also re-shoots from nodes at the base of the stem after it has been physically damaged or following the application of some herbicides (Grace 2006, Vitelli *et al.* 2008).

Due to a paucity of information on *C. procera*, Meat and Livestock Australia (MLA) has funded a multi-agency project to investigate its rate of spread (at several locations), invasiveness, biology and control. Some research has already been undertaken to improve control options (Vitelli *et al.* 2008), but on-ground results appear to be mixed due to considerable variation in efficacy within individual techniques.

As part of the MLA project a major focus of control work will be to improve foliar spraying through the testing of several new formulations and refinement of rates for existing chemicals that have shown promise in the past. Affected stakeholders have also asked for a technique that is easy and economical to use on isolated plants, which will include testing several residual herbicides (particularly tebuthiuron) and a picloram based herbicide formulation (Vigilant® herbicide Gel) that is available in a squeeze tube. The susceptibility of *C. procera* to mechanical control will also be explored by measuring the response of plants that have had their roots cut at different depths below ground. In this paper we have focussed on the methodology and measurements associated with the foliar herbicide research.

Methods

An initial foliar trial is being implemented in Queensland's Gulf of Carpentaria region using a split plot design, incorporating 22 main plots (herbicide treatments), two sub plots (plant size) and three replications. Either one or two rates of the currently available herbicides metsulfuron methyl, 2,4-D amine, 2,4-D amine + metsulfuron methyl, 2,4-D/picloram, fluroxypyr, fluroxypyr/aminopyralid, triclopyr, triclopyr/picloram, and glyphosate will be tested. In addition, one new formulation from Dupont Australia and three from Dow AgroSciences will be included. The herbicides will be applied to both 10 small (< 1.5 m) and 10 medium to large plants (> 1.5 m) per replicate.

Results

Assessments will be made at 10, 30, 60 and then every 90 days after application. Plants will be assessed for mortality and regrowth.

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Latest developments in wild dog and feral pig management

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Introduction

The Invasive Animals Cooperative Research Centre (IACRC) was funded in 2005 to bring together 41 national and international partners into a $90M 7-year joint venture. Two key species of focus for the IACRC are wild dogs and feral pigs. A new suite of management tools has been developed for both species over the last 6 years. All products have been developed with animal welfare, price, useability, target specificity and reversibility (antidote) in mind. This paper details their attributes.

Wild dogs

Para-aminopropiophenone (PAPP) was initially investigated in the USA 30 years ago when it was likely that sodium fluoroacetate (1080) was to be banned for use in Livestock Protection Collars. Fifteen years later PAPP, a cyanide antidote, was investigated in Australia as a 'Felid Specific Toxin' for feral cats. In 2003 research commenced to investigate PAPP as an additional toxin to 1080 for wild dogs and foxes. PAPP has since been shown to possess many beneficial attributes for canid control, including humaneness and an effective antidote (Blue Healer™). PAPP wild dog (DOGABATE®) and fox baits (FOXECUTE®) are now undergoing the national regulatory process and should be available by 2013.

Mechanical ejectors (also known as M-44's) have been used in the USA for 40 years for coyote control. The spring-loaded device fires the contents of a toxic capsule into the throat of canids that pull on a lure head. 1080 mechanical ejectors are now registered for use in NSW National Parks. National 1080, cyanide and PAPP ejector registrations are now being pursued, with potential availability by 2013. Ejectors have high target specificity and good field longevity, and are an excellent supplement to baiting.

The Lethal Trap Device (LTD) is a strip of cyanide capsules that attaches to the jaw of wild dog and fox traps. Once bitten the cyanide rapidly euthanizes trapped canids, improving animal welfare and reducing trapping labour requirements. Prototypes of the device are currently being trialled.

Feral pigs

Sodium nitrite, a meat preservative, has been developed and patented as a new feral pig toxin. Nitrite, like PAPP, causes rapid and humane methaemoglobinemia in susceptible animals. Nitrite will initially be registered as the active ingredient in HOG-GONE® baits, however a concentrate version is currently being developed. HOG-GONE® baits have high target specificity, safe tissue residues, are potentially reversible with the Blue Healer™ antidote and should be available through rural merchants.

The HogHopper™ target-specific feral pig bait delivery device was launched in 2010. It offers peace-of-mind feral pig baiting, reduced labour requirements for effective feral pig control, and protects bait from the elements. The units can deploy PIGOUT® (launched by IACRC in 2009), grain bait or PIGOUT® Econobait; a bite-sized economical manufactured 1080 bait currently being developed.

Conclusion

The IACRC has or will deliver a suite of new wild dog and feral pig management tools that will give graziers more humane, species-tailored and environmental benign control options for these economically, socially and environmentally costly invasive species into the future.

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