Animal Production Science, 2023, **63**, 301–310
https://doi.org/10.1071/AN17494

Reproductive performance of northern Australia beef herds. 1. Survey of nutritional, breeding and herd health management practices and of the environment

K. D. McCosker[A,G,H], *S. Jephcott*[B], *B. M. Burns*[C], *D. R. Smith*[D], *G. Fordyce*[E], *P. K. O'Rourke*[F] *and M. R. McGowan*[G]

[A]Department of Primary Industry and Resources, PO Box 1346, Katherine, NT 0851, Australia.
[B]PO Box 11, Surat, Qld 4417, Australia.
[C]Department of Agriculture, Fisheries and Forestry, 25 Yeppoon Road, Rockhampton, Qld 4702, Australia.
[D]Department of Agriculture, Fisheries and Forestry, 1–5 Prior Street, Charters Towers, Qld 4820, Australia.
[E]The University of Queensland, Queensland Alliance for Agriculture and Food Innovation, Centre for Animal Science, Carmody Road, St Lucia, Qld 4072, Australia.
[F]Queensland Institute of Medical Research, 300 Herston Road, Herston, Qld 4006, Australia.
[G]The University of Queensland, School of Veterinary Science, Warrego Highway, Gatton, Qld 4343, Australia.
[H]Corresponding author. Email: kieren.mccosker@bigpond.com

Abstract. Data concerning the practices and policies of collaborating properties for nutritional, breeding and health management of herds were captured by survey of herd owners/managers (n = 78) at the commencement of a large observational study conducted across northern Australia to identify and quantify the effect of major animal-, management group- and property-level risk factors on measures of reproductive performance. The cooperating herds in this study were considered to be broadly representative of north Australian beef breeding enterprises in terms of geography, size and ownership. Using four broad regional categories, this paper presents descriptive summaries of the management practices and nutritional conditions of cooperating herds in what was known as the Cash Cow project. Property sizes were largest within the Northern Downs and Northern Forest, and smallest within the Southern Forest. The expected average annual growth of yearling steers was >50 kg less in the Northern Forest, compared with the other country types, which also appeared to be associated with the identified production system and turnoff animal. Despite the exacerbated nutrition and environmental challenges and likely increased time required for new managers within the Northern Forest to attain an in depth understanding of the cattle and property dynamics, this region had the greatest incidence of management changes. The nutritional information summarised in this study highlights that available phosphorus during the wet season, as indicated by faecal levels in proportion to dietary energy, was likely to limit animal production within the Northern Downs and Northern Forest. During the dry season, pasture digestibilty and protein levels were likely to be approaching maintenance for cows on ~50% of properties in each country type and that responses to rumen degradable protein were also likely on 50% of properties. Despite this finding, low use of dry season supplements was observed for the Northern Downs, which was partially explained by the high incidence of the management systems based on segregating cows on lactation status and pregnancy. In all country types, the ratio of bulls to cows was higher than the 2.5% recommended for extensively managed situations, while limited use of vaccines to control infectious causes of reproductive loss was also observed. The major conclusion of this study is that there was marked variation in the adaption of interventions to specific businesses, indicating considerable opportunity exists for further adaptation in the region.

Additional keywords: beef cattle, north Australia, production systems.

Received 20 July 2017, accepted 20 May 2019, published online 24 November 2020

Introduction

The north Australian beef herd represents 60% of the national beef herd and there are ~9000 beef producing properties in northern Australia (Martin *et al*. 2013). The beef industry in many parts of northern Australia has historically been an extensive, low-input system, with relatively low outputs per unit land area. Rainfall across northern Australia is highly variable between seasons with the majority (~80%) of the annual rainfall occurring during the wet season (November–April) (Lo *et al*. 2007). The 'onset', or

transition to the wet season, tends to vary between years and between regions. Both the timing of the 'onset' and the length of time that the wet season supports green pasture growth is highly correlated with animal production (Balston and English 2009).

The primary production activities conducted on northern beef properties are breeding, and growing and fattening weaned cattle (O'Rourke *et al*. 1992; Sullivan 1992; Bortolussi *et al*. 2005*a*). Generally, properties within the more intensively managed areas of southern Queensland primarily breed and fatten cattle whereas properties within the more extensive areas of north-western Australia are primarily breeding only (O'Rourke *et al*. 1992). Properties within the Northern Territory, northern Western Australia and parts of northern Queensland sell most, if not all their cattle to the live export market (Bortolussi *et al*. 2005*a*), whereas elsewhere producers have more flexibility being able to sell slaughter cattle to either the domestic or export markets, as well as some cattle on occasions to the live export market.

There is large variation in the reproductive performance of northern beef cattle herds (O'Rourke *et al*. 1992; Cowley *et al*. 2014) and this is identified as having an important association with business performance (McLean *et al*. 2013). The impact of numerous herd, management group and animal-level factors on measures of reproductive performance are widely documented in the literature and have been recently comprehensively reviewed (Hasker 2000; Burns *et al*. 2010). In order for herd managers and industry stakeholders to prioritise management and investment, there is increasing interest in the determination and quantification of the major factors responsible for lower than expected reproductive performance.

A study using population-based methodology was conducted in commercial beef breeding herds across northern Australia between 2007 and 2011 to describe reproductive performance of commercial beef herds, and determine and quantify the major associations between reproductive outcomes and herd management practices, nutritional and environmental factors and individual cow attributes. In this study we describe the demographics and the nutritional, breeding and herd health management practices and policies employed by study participants, known hereafter as the Cash Cow project.

Materials and methods

A full description of management of enrolled properties and data collection and management protocols are provided in McCosker (2016).

The target population for the study was north Australian beef breeding herds and involved 78 commercial beef properties (Fig. 1). At the commencement of the study, a face to face survey was completed by each cooperating property owner/manager with assistance from regional project co-ordinators (n = 6) to ensure a uniform interpretation of the questions and responses. Survey participants were identified through their participation in the Cash Cow project (McGowan *et al*. 2014) and are considered to represent a broad cross-section of the north Australian beef breeding industry.

In addition to the face-to-face survey, there was ongoing assessment of grazing resources utilised by study animals that included mapping of paddock infrastructure using GPS software (e.g. ArcView), longitudinal nutritional profiling of pasture quality and quantity, and using the GPS coordinates for either paddock or homestead to obtain interpolated daily records of environmental data (e.g. temperature and rainfall) from the Australian Bureau of Meteorology (BOM).

Survey structure

The survey was conducted to define property demographics, as well as management of grazing lands and breeding female management, including management of bulls and infectious

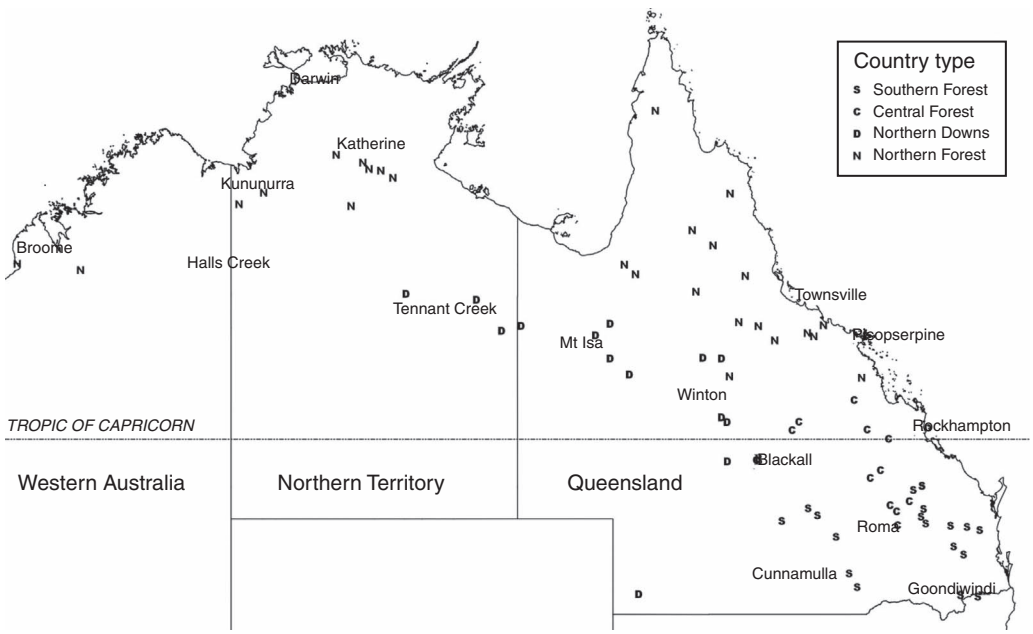

Fig. 1. Location of cooperating properties by country type.

diseases. The format of the questions was mostly tick-a-box allowing one response per question. Questions concerning property details were mostly formatted as single line text response or numeric values.

The survey was made up of four sections:

(1) general property information: property area, location, herd size, ownership structure, main beef production activity and estimated annual liveweight production from the pastures utilised by enrolled breeding groups;
(2) breeding female management: herd management practices and policies of the producer/owner including duration and timing of mating period, age at and timing of weaning, culling and selection criteria, and nutritional management;
(3) bull management: selection practices and policies including selection and culling criteria, relocation management, nutritional and health management; and
(4) herd vaccination policy: breeding herd vaccination policies against bovine viral diarrhoea virus (BVDV), campylobacteriosis (vibriosis), leptospirosis and botulism.

Regionalisation of properties

Properties were assigned to one of four broad country types according to geographical location and a subjective assessment of the production potential of the grazing land and cross-referencing with pasture and vegetation descriptions reported by the herd managers. Properties with forested land-types with fertile soils in the central and south-east regions of Queensland were differentiated by being outside (Southern Forest) and within (Central Forest) the northern Brigalow Forest. In the northern areas of Queensland, Northern Territory and Western Australia, properties with land types that were predominantly large treeless black soils plains (Northern Downs) were segregated from those with forested land-types and low fertility soils (Northern Forest).

Average annual growth of yearling steers

Property owners/managers were asked to provide an estimate of what they would expect the mean annual growth of yearling steers would be if they were to graze equivalent pastures of the enrolled management groups.

Pasture quality

Wet and dry season pasture quality assessments were based on faecal near infrared spectroscopy (F.NIRS) and wet chemistry faecal phosphorus (FP) analyses conducted on dung samples collected in January, March, May, August and November. Dry matter digestibility (DMD) and crude protein content (CP) were determined using FNIRS, and phosphorus status was estimated using a ratio of FP : ME (Zarcinas *et al*. 1987; Coates 2004). Pasture quality estimates were summarised by averaging data across both wet (1 November–30 April) and dry (1 May–31 October) seasons. Following estimation of the metabolisable energy (ME) content of the pasture using the equation: ME = 0.172 × DMD – 1.707 (Primary Industries Standing Committee 2007), the ratio of FP:ME was calculated for each sample (expressed as mg P/MJ ME) and averaged across the wet season (1 November–30 April) for each property.

Paddock area and distance to water

Paddock areas grazed by study groups were digitised from a paper-based map, satellite maps, existing digital maps, or global positioning system (GPS) points by project regional coordinators. Using the resulting digitised maps, paddock areas were estimated using the ArcMap GIS program. Paddock areas within 1.5, 2.5 and >2.5 km of permanent water points were estimated using AgData's Phoenix mapping software. Where short duration grazing using a series of small paddocks (e.g. 'cell' grazing) was practised those paddocks were classified as one paddock.

Average long-term wet season onset

The long-term wet season onset was derived for each property using 100-year interpolated daily rainfall information downloaded from the BOM using the GPS coordinates for either a paddock or the residence of the owner/herd manager on the property. The wet season onset was defined as the date at which an accumulation of 50 mm of rainfall was reached in 14 days or fewer, starting from any day after September 1 (but before March 31). The date of wet season onset in 50 and 75% of years was derived for each individual property and averaged across properties within country types to estimate an overall 'green date' for the country type.

Mating management

Mating management was categorised as follows: Control mated ≤3 months = females deliberately exposed to bulls for a period ≤3 months; Control mated 4–7 months = females deliberately exposed to bulls for 4–7 months (includes properties where bulls were removed at the 2nd annual muster and re-introduced early in the New Year); Mated >7 months without cow segregation = females continuously exposed to bulls for greater than 7 months of the year; Mated >7 months with cow segregation = females continuously exposed to bulls for greater than 7 m of the year with cows segregated annually on expected calving period calculated from fetal age.

Bull selection and management

Replacement bull selection was categorised as follows. 'Some best practice' was no veterinary bull breeding soundness examination (BBSE) used but at least two of the following used: replacement bulls vaccinated for tick fever, if required; annually vaccinated for vibriosis; and bovine ephemeral fever (BEF); body condition score (BCS) managed before first mating; introduced to property in cooler months; allowed ≥2 months to acclimatise before first mating. 'Most best practice' was as for 'Some best practice', but replacement bulls selected on basis of having passed a BBSE. 'Little best practice' did not meet criteria for either 'Some best practice' or 'Most best practice'.

Management of bulls was categorised as follows. 'Some best practice' was at least two of the following: same age bulls

mated together; vaccinated for BEF annually; BCS managed before mating; treated for external and internal parasites annually; annually vaccinated for vibriosis; bulls culled at ≤8years of age. 'Most best practice' was as for 'Some best practice', but bulls selected on the basis of having passed BBSE and at least three of the listed criteria. 'Little best practice' did not meet criteria for either 'Some best practice' or 'Most best practice'.

Data management and analysis

The main form of data analysis was simple descriptive statistics, frequencies by categories and cross-tabulation by country types. All analyses were completed using Stata for Windows (ver. 13.1, StataCorp, College Station, TX, USA).

Results

Surveyed owners/herd managers of the 78 properties managed in excess of 9 million ha of land and 250 000 breeding females. For the country types of Northern Downs and Forest, a greater percentage of properties were corporately managed (~20 percentage points), with corporately managed properties tending to be larger in area and cattle numbers (Table 1). Herd managers/owners of properties within the Northern Forest expressed the greatest interest to increase herd size with 67% of properties indicating an intention to do so, compared with 8–24% in other country types.

The mean reported annual rainfall was greatest and most variable within the Northern Forest (Table 2). The onset of the wet season or summer rains, generally occurred in a South to North direction, and occurred between November and December.

The major sources of income were the sale of weaned and feeder cattle for all country types (Table 1). There also appeared to be a positive association between expected average annual growth of yearling cattle and the occurrence of herd managers/owners declaring the sale of slaughter-weight steers (bullocks) as a major source of income, with 3 times the percentage of herd managers/owners in the Southern and Central Forest indicating this as a major income source compared with Northern Downs and Forest.

The expected average annual growth of yearling steers was >50 kg lower in the Northern Forest, compared with the other country types, and had the greatest variation between properties. However, based on mean and median values for the wet and dry season relatively small differences between country types were observed for pasture quality indicators dry matter digestibility and dietary crude protein content (Table 3). A clearer distinction between country types however was observed for average wet season FP:ME values calculated as ~200 mg P/MJ ME less in the Northern Downs and Forest, compared with the Southern and Central Forest. Over one-half of properties within both the Northern Downs and Forest were observed with average wet season FP:ME values <420 mg P/MJ ME, and 15% (95% CI, 4–47%) and 17% (95% CI, 7–36%) of properties within Northern Downs and Northern Forest, respectively, had average values <300 mg P/MJ ME.

Table 1. Summary of property demographics and management by country type

	Southern Forest	Central Forest	Northern Downs	Northern Forest
Property size (km²; 1 km² = 100 ha)				
n	16	13	13	23
Mean	652	168	3306	1528
Median	60	162	364	1250
Range	12–8900	49–410	130–16118	26–4500
Ownership and management structure				
n	22	12	13	30
Owner/Manager	18 (82%)	6 (50%)	8 (62%)	10 (33%)
Private Manager	1 (5%)	4 (33%)	0 (0%)	6 (20%)
Corporate Manager	3 (14%)	2 (17%)	5 (38%)	12 (40%)
Leasee/agistee[C]	0 (0%)	0 (0%)	0 (0%)	2 (7%)
Duration managing enrolled property				
n	14	12	7	21
<10 years	6 (43%)	7 (58%)	5 (71%)	18 (86%)
10 to <20 years	2 (14%)	3 (25%)	2 (29%)	2 (10%)
≥20 years	6 (43%)	2 (17%)	0 (0%)	1 (5%)
Breeding herd size (number of cattle)				
No. of responses	18	13	13	23
Mean	972	1192	8737	4614
Median	572.5	1200	2400	3700
Range	280–8056	350–3000	550–44000	220–15097
Properties wishing to decrease, maintain or increase herd size				
n	21	13	13	30
↓ ≥ 10%	3 (14%)	1 (8%)	2 (15%)	2 (7%)
↓ <10%	1 (5%)	0 (0%)	1 (8%)	1 (3%)
Maintain	12 (57%)	9 (69%)	9 (69%)	10 (33%)
↑ <10%	0 (0%)	0 (0%)	0 (0%)	3 (10%)
↑ ≥ 10%	5 (24%)	3 (23%)	1 (8%	14 (47%)
Major sources of income[A]				
No. of responses	16	13	13	25
Sale of weaners	5 (31%)	4 (31%)	2 (15%)	14 (56%)
Sale of feeder cattle	7 (44%)	4 (31%)	8 (62%)	8 (32%)
Sale of cows/bulls	7 (44%)	4 (31%)	5 (38%)	9 (36%)
Sale of bullocks[B]	9 (56%)	8 (62%)	3 (23%)	4 (16%)
Estimated mean annual growth of yearling steers (kg)				
No. of responses	12	6	5	17
Mean	195	179	168	116
Median	200	181.5	160	105
Range	140–250	140–220	150–200	75–220

[A]More than one major source of income was nominated by some respondents;
[B]A bullock is a mature desexed male.
[C]Owners of cattle who pay for access to grazing resources.

Paddock size varied enormously both within and across country types, with the distribution of data generally being positively skewed and some atypically large paddocks observed for each country type (Table 2). Overall, paddocks were smallest in size within the Southern Forest, and largest within Northern Downs and Forest. Less variation was observed for watered grazing area, with nearly all being within 2.5 km of a permanent watering point in Southern

and Central Forest, in contrast to the Northern Downs and Forest where ~75% of the grazing area was typically within 2.5 km of water.

Table 2. Summary statistics for derived nutritional and environmental factors by country type

Variable	Southern Forest	Central Forest	Northern Downs	Northern Forest
Reported annual rainfall (*mm*)				
n	12	7	4	15
Mean	588	611	461	916
Median	650	635	408	750
Range	175–825	520–700	350–680	500–2800
Long-term wet season onset (*1 September–31 March*)				
n	19	13	12	28
Mean date	3 Nov.	12 Nov.	25 Dec.	8 Dec.
Mean 75/100 year date	13 Nov.	23 Nov.	1 Jan.	12 Dec.
Paddock size (*ha*)[A]				
n	82	61	80	59
Mean	505	860	6857	4052
Median	415	714	2153	2611
Range	17–4550	63–2802	370–71160	202–16387
Proportion (%) *of paddock area within 2.5 km grazing radius of water point*[B]				
n	89	61	79	60
Mean	96	95	78	79
Median	100	100	94	96
Range	19–100	23–100	6–100	12–100
Dry season crude protein (%)				
n	21	13	13	30
Mean	6.8	5.8	6.2	5.7
Median	6.1	5.9	5.5	5.7
Range	4.4–14.1	5.3–6.4	4.8–12.5	3.9–8.0
Dry season dry matter digestibility (%)				
n	21	13	13	30
Mean	53	52	54	52
Median	52	52	53	52
Range	48–65	50–55	52–59	49–56
Wet season crude protein (%)				
n	21	13	13	29
Mean	9.4	8.3	8.4	7.6
Median	9.4	8.1	8.5	7.7
Range	7.5–11.8	7.6–10.7	6.6–10.5	5.0–9.5
Wet season dry matter digestibility (%)				
n	21	13	13	29
Mean	58	58	58	55
Median	58	58	57	56
Range	54–62	56–60	55–60	50–59
Wet season FP:ME (*mg P/MJ ME*)				
n	21	13	13	29
Mean	627	619	418	359
Median	557	540	389	347
Range	364–1080	421–1058	233–617	232–529

[A]Three uncharacteristically large paddocks drastically skewed the data within Southern Forest and were omitted from the analysis. When included the mean paddock area was 1448 ha and ranged between 17 and 46 437 ha.

[B]Data derived from GPS mapping.

Bos indicus content was generally increased from south to north. Whereas the majority of females had greater than or equal to 75% *B. indicus* content in the Northern Forest, in the Southern Forest the majority of females had less than 50% *B. indicus* content (Table 3).

Breeding females across country types were typically culled at 10 years of age (Table 3). This culling policy was

Table 3. Summary statistics of breeding herd management by country type

	Southern Forest	Central Forest	Northern Downs	Northern Forest
Properties with breeding females of different Bos indicus *content*				
n	21	13	13	31
<50% *Bos indicus*	14 (67%)	3 (23%)	1 (8%)	0 (0%)
50 to <75% *Bos indicus*	4 (19%)	8 (62%)	9 (69%)	4 (13%)
≥ 75% *Bos indicus*	3 (14%)	2 (15%)	3 (23%)	27 (87%)
Properties with different typical sizes of management groups (*number of cattle*)				
n	21	13	13	31
<150	9 (43%)	4 (31%)	3 (23%)	0 (0%)
150 to <400	11 (52%)	9 (69%)	6 (46%)	22 (71%)
≥ 400	1 (5%)	0 (0%)	4 (31%)	9 (29%)
Properties with different mating management				
n	19	13	13	30
Mated for <3 m	8 (42%)	5 (38%)	5 (38%)	1 (3%)
Mated for 4–7 m	8 (42%)	8 (62%)	3 (23%)	10 (33%)
Mated for >7 m	3 (16%)	0 (0%)	2 (15%)	18 (60%)
Mated for >7 m with cow segregation[A]	0 (0%)	0 (0%)	3 (23%)	1 (3%)
Properties that culled breeding females on the basis of age				
n	18	11	10	26
Yes	18 (100%)	10 (91%)	8 (80%)	20 (77%)
Age breeding females typically culled (*years*)				
n	18	10	8	20
Mean	10.2	9.9	10.1	10.1
Median	10	10	10	10
Range	9–12	8–12	8–12	8–12
Age at weaning (*months*)				
n	16	10	7	23
Mean	7.4	5.6	6.4	5.6
Median	7	6	7	6
Range	4.5–11	4–7	5–8	3–8
Properties that varied the time of weaning based on seasonal conditions				
n	17	11	11	24
Yes	13 (76%)	9 (82%)	5 (45%)	15 (63%)
Properties that routinely provided nutritional supplements				
n	21	13	13	31
Dry season (N)	11 (52%)	6 (46%)	4 (31%)	27 (87%)
Wet season (P)	6 (29%)	5 (38%)	4 (31%)	20 (65%)
Mustering technique				
n	19	13	13	26
Ground (horses/vehicles)	15 (79%)	8 (62%)	5 (38%)	4 (15%)
Air (helicopter, fixed-wing)	3 (16%)	5 (38%)	8 (62%)	20 (77%)
Trapping[B]	2 (11%)	1 (8%)	0 (0%)	8 (31%)

(*continued next page*)

Table 3. (*continued*)

	Southern Forest	Central Forest	Northern Downs	Northern Forest
Reported mustering efficiency[C]				
n	19	13	13	26
Mean	97%	97%	98%	89%
Median	99%	98%	98%	90%
Range	90–100%	90–100%	90–100%	70–100%
Properties with different vaccination policies for control of BVDV infection				
n	19	11	13	28
Not vaccinated	14 (74%)	10 (91%)	12 (92%)	28 (100%)
Heifers only vaccinated	2 (11%)	1 (9%)	1 (8%)	0 (0%)
Properties vaccinating heifers before first mating to control				
n	19	12	13	28
Vibriosis	1 (5%)	1 (8%)	1 (8%)	4 (14%)
Leptospirosis	11 (58%)	7 (58%)	0 (0%)	5 (18%)
BVDV infection	5 (26%)	1 (8%)	1 (8%)	0 (0%)
Botulism	2 (11%)	4 (33%)	6 (46%)	22 (79%)
Properties vaccinating cows to control infectious diseases				
n	19	12	13	28
Vibriosis	1 (5%)	1 (8%)	0 (0%)	0 (0%)
Leptospirosis	7 (37%)	7 (58%)	0 (0%)	2 (7%)
BVDV infection	3 (16%)	1 (8%)	0 (0%)	0 (0%)
Botulism	1 (5%)	4 (33%)	8 (62%)	22 (79%)

[A]Heifers and cows segregated based on either predicted month of calving or lactation status.

[B]Cattle can be passively mustered by trap yards set up at points of enticement, i.e. water or supplement. A common technique for mustering in timbered country or for capturing feral animals.

[C]Respondents estimate of percentage of cattle within a herd that are successfully mustered at a mustering event.

Table 4. Summary of bull selection and management

	Southern Forest	Central Forest	Northern Downs	Northern Forest
Bull to Female mating ratio (per 100 females)				
n	20	13	13	26
Mean	2.9	3.1	3.1	3.5
Median	3.0	3.0	3.0	3.8
Range	1.5–5.0	2.5–5.0	2.0–5.0	2.0–5.5
Properties vaccinating bulls to control in factious diseases				
n	19	12	13	22
Vibriosis	9 (47%)	9 (75%)	11 (85%)	20 (71%)
Leptospirosis	6 (32%)	5 (42%)	0 (0%)	1 (4%)
BVDV infection	1 (5%)	1 (8%)	0 (0%)	0 (0%)
Botulism	1 (5%)	3 (25%)	6 (46%)	22 (79%)
Properties where bull selection used best-practice protocols				
n	18	13	12	27
Nil	6 (33%)	0 (0%)	3 (25%)	17 (63%)
Some	5 (28%)	4 (31%)	3 (25%)	2 (7%)
Most	7 (39%)	9 (69%)	6 (50%)	8 (30%)
Properties where bull management used best-practice protocols				
n	18	13	12	27
Nil	1 (6%)	0 (0%)	5 (42%)	12 (44%)
Some	9 (50%)	3 (23%)	3 (25%)	7 (26%)
Most	8 (44%)	10 (77%)	4 (33%)	8 (30%)

less frequently enforced (10–20 percentage points) on properties within the Northern Forest and Downs, compared with Southern and Central Forest. Weaning typically occurred at 6–7 months of age across all country types. The tendency for properties to vary 'weaning' based on seasonal conditions was much greater in the Southern and Central Forest (76 and 82% of respondents respectively), compared with the Northern Downs and Forest (45 and 63% of respondents respectively).

With the exception of Northern Forest, the bull to female mating ratio was uniform across country types at ~3 bulls per 100 females (Table 4). Relative to other country types, breeding females within the Northern Forest tended to be mated for longer and at a ratio ~1 bull per 100 females higher. Approximately two-thirds of herd managers/owners within the Northern Forest declared the use of >7 month mating systems, compared with much shorter mating management systems for the Southern and Central Forest (Table 3).

The typical size of breeding management groups was usually greater and there was more frequent use of aircraft to muster management groups within the Northern Downs and Forest when compared with Southern and Central Forest (Table 3). The mean reported mustering efficiency was similar for the Northern Downs, Southern Forest, and Central Forest, averaging 97–98%. In contrast, approximately a 10 percentage point lower mustering efficiency was estimated for the Northern Forest, with estimates ranging between 70 and 100%.

The regular use of dry- and wet-season supplements was greatest in the Northern Forest (87 and 65% respectively) and lowest within the Northern Downs (both 31%) (Table 3). For the Southern and Central Forest, approximately one-half of properties reported the regular provision of dry-season supplements and approximately one-third provided wet-season supplements.

Generally, the management practice of vaccinating breeding cattle to control infectious causes of reproductive loss was low (Table 3). Despite widespread exposure to botulism in the Northern Downs and Forest, there was a low prevalence of properties vaccinating cows and heifers against botulism (50–80%). Across all country types, a low proportion of properties were vaccinating to control vibriosis. For example, in the Southern Forest, 95% and 53% of properties did not vaccinate heifers or bulls, respectively, against *Campylobacter fetus* var. *venerealis* infection (Table 4).

Discussion

This research has provided a unique contemporary understanding of beef business practices across northern Australia. There has been transformational change in the industry within this region over the past 50 years with the introduction of major interventions including fencing for segregation and controlled grazing, new palatable and productive grasses and legumes, weaning, *B. indicus* cattle,

control of bulls and mating, use of pregnancy diagnosis, supplementation to rectify energy, protein and phosphorus deficiencies, artificial waters to reduce grazing radii, eradication of bovine brucellosis and tuberculosis, and vaccines to control endemic diseases of economic importance. Interim snapshots of practices in the 1980s and 1990s are available for reference (O'Rourke *et al*. 1992; Bortolussi *et al*. 2005*a*). This most recent survey shows marked variation in the adaption of interventions to specific businesses, indicating considerable opportunity exists for further adaptation.

The cooperating herds in this study are considered to be broadly representative of north Australian beef breeding enterprises in terms of geography, size and ownership, and the results reported in the present study are largely consistent with previous surveys (O'Rourke *et al*. 1992; Bortolussi *et al*. 2005*a*). However, it is acknowledged that participating properties of the Cash Cow project were identified using a non-random process aimed at enrolling representative herds where good cooperation was highly likely to be achieved. These results therefore, may also be considered to reflect those of herd managers/owners that were seeking to improve their understanding of reproductive performance in commercial beef herds and factors affecting it.

Property sizes were largest within the Northern Downs and Northern Forest country types and these findings are not dissimilar to those reported by O'Rourke *et al*. (1992) and Bortolussi *et al*. (2005*a*). Larger properties were commonly managed by a corporate manager and less likely to be managed by their owners.

Within the Northern Downs and Forest where the percentages of properties managed by corporate managers was highest, the duration the current manager had been managing the property was lowest, and is potentially partially explained by the corporate practice of relocating property managers within the corporation on a regular basis. In contrast, 87% of participating properties in the Southern Forest were privately owned and also had the longest duration since the last change in management with 43% of respondents undertaking the role of herd manager/owner for >20 years. This potentially suggests that it is less common for managers to remain on an individual property for in excess of 10 years unless they own the property.

In the Northern Forest, where the nutritional and environmental challenges are likely to be the greatest for beef cattle production, the frequency of management changes appeared to be the greatest. Managers within this country type in particular, may take longer to attain an in-depth understanding of the cattle and property dynamics due to the heightened nutritional and environmental stressors, and increased property size. It may be that moving managers too frequently in this region may be counterproductive.

Generally, the size of the breeding herd and paddock size were correlated with property size and this is cofounded by the selection protocol of survey participants as all study participants were required to be primarily beef breeding enterprises. The median breeding herd size was largest for the Northern Forest and smallest for the Southern Forest. Within the Northern Downs country type, very large breeding herd sizes were observed for corporate enterprises on the Barkly Tableland with up to 44 000 breeding females. This is consistent with large land holdings of large carrying capacity, as Mitchell grass pastures in good condition can sustain stocking rates up to 13 animal equivalent units per square kilometre in 50% of years (Walsh and Cowley 2011).

The mean age that cows were culled was constant across country types at ~10 years of age. The occurrence of study participants culling cows based on age varied between country types, with the lowest proportion observed within the Northern Forest and highest in the Southern Forest. It is speculated that the reduced occurrence of producers practicing culling based on age within the Northern Forest is associated with the expressed interest (47% of respondents) in increasing cow numbers by more than 10%, providing cow mortality rates are constrained, which have previously estimated to range between 3–11% in this region (Henderson *et al*. 2013).

Investment in additional watering points potentially could support this increase in cattle numbers where prevailing stocking rates are not over-utilising the pasture currently accessible. Installing additional water points is a method of increasing the safe carrying capacity of enterprises by accessing underutilised areas and distributing grazing more widely across the landscape and reducing the risk of overgrazing pasture around watering points (Hunt *et al*. 2007). Comparable proportions of paddocks grazed within 2.5 km of water were estimated for the Northern Downs and Forest and overall represented a high level of development for most paddocks. However, within these country types, opportunities appear to exist for further development with ~20% of paddocks having capacity for further utilisation. These results are consistent with the findings reported by Cowley *et al*. (2014), who summarised Katherine and Barkly regions as utilising 75 and 89%, respectively, of surveyed property area. In contrast to the Northern Forest, a greater proportion of survey respondents within Northern Downs, despite having similar proportions of paddocks within 2.5 km of water, wanted to maintain their current breeding herd size and this potentially suggests that the motivation for development was to safeguard the property against climate variability.

In the seasonally dry tropics, under-nutrition during the dry season is a major constraint for production as cattle usually either maintain or lose weight in this period and later regain it during the wet season when pasture quality significantly improves (Dixon *et al*. 2011). However, as indicated by FP : ME, vast differences in phosphorus adequacy during the wet season were observed between country types. Animal production in Northern Downs and Forest country types are likely to be limited by the availability of P based on the observed FP:ME levels and the potential threshold value of 390–460 mg P/MJ ME for a 400 kg lactating cow (Jackson 2012). This also may partly explain the differences in expected annual growth rates.

The provision of P supplements during the wet season is recommended to increase animal production in marginally or acutely P-deficient situations (Hendricksen *et al*. 1994). Correspondingly, the routine provision of supplemental P to breeding females during the wet season was highest (65%) in the Northern Forest, where the FP:ME values were lowest. In

the Northern Downs where only 31% of producers reported the routine provision of supplemental P, production was likely to be limited by phosphorus inadequacy on approximately one-half of properties, and production gains for some properties in some years may be achieved by the provision of supplemental P to lactating cows.

The protein content of the pasture during the dry season was approaching maintenance of approximately half of the study herds in all country types. The provision of supplementary protein to the remaining herds was thought likely to result in a positive response as the levels were lower than either 60 g CP/kg (6%) (Minson 1990) to 1.3 g faecal N/kg (8%) (Winks *et al*. 1979). However, the lowest protein content observed during the dry season was in the Northern Forest and is consistent with the highest occurrence of herd owners/managers routinely providing dry season supplements, which is similar to findings reported by O'Rourke *et al*. (1992) and Bortolussi *et al*. (2005*b*).

Low use of dry season supplement was observed for the Northern Downs and was considered to be explained by the higher proportion of properties within this country type segregating cows based on lactation status and pregnancy which generally is accompanied by strategic rather than blanket supplementation practices or culling of out-of-season calving cows. The high dietary protein values during the dry season within the Northern Downs can potentially be explained by swamp areas of high nutritional value known to be present in the region.

The median values for dietary crude protein content of pasture during the wet season had been expected to be above maintenance in all country types and approximately comparable. However, some values observed within the Northern Forest during the wet season were indicative of a likely response to supplemental nitrogen which is consistent with previous reports (McCosker *et al*. 1991).

The bull to female mating ratios observed in the current study were generally lower than that reported by O'Rourke *et al*. (1992) and may be due to the adoption of more recent research findings that recommended their reduction such as Fordyce *et al*. (2002). However, the current bull percentages used still remain higher than the 2.5% recommended as adequate under extensively managed environments. With the exception of the Northern Forest, there was moderate use of best practice protocols for selection and management of bulls. It appears there remains significant scope for improving selection and management of bulls, especially within the Northern Forest region.

The use of controlled mating was least prevalent in the Northern Forest. More than half of respondents within each of the other country types mated bulls for less than 7 months, and controlled mating most prevalent within the Southern Forest. Of those properties mating cattle for longer than 7 months, 60% within the Northern Downs supported this management practice by segregating heifers and cows either on lactation status at their first annual muster or by expected periods of calving. However, within the Northern Forest, only 5% of producers who mated for greater than 7 months segregated heifers and cows.

Progeny were reported as being weaned at younger ages within the Northern Forest than other country types. This is most likely related to the lowest available nutrition through the year, with cows less able to sustain the high energy demands of lactation for extended periods.

The use of aircraft to muster cattle was consistent with larger size of property and paddocks as they offer efficiencies in mustering costs over other techniques due to a reduction in labour and time as well as being able to access difficult country to muster. The most use of aircraft was in the Northern Forest and is likely to be explained by large paddocks, dense vegetation and multiple creek and river systems common for this country type. These characteristics are also likely to explain the reduced mustering efficiency of Northern Forest, compared with other country types. Despite Northern Downs having similar paddock sizes, large areas of rolling grassland plains are present within this region increasing visibility and ease of mustering.

The percentage of properties declaring the sale of slaughter-weight steers (bullocks) as a major income source tended to reflect the expected annual growth of yearling cattle, which is consistent with the profitability of growing steers dependent on annual growth and relative prices of feeder cattle (Sullivan 1992). These results were further highlighted in the Northern Forest, where fewest producers indicated that the sale of bullocks was a major income source. Relative to other country types, average annual growth of yearling cattle was 50 kg lower while there is strong demand for cattle <350 kg in liveweight due to its close proximity to ports that export live cattle.

Generally, the proportion of properties vaccinating breeding cattle to control infectious causes of reproductive loss was low. Despite widespread evidence of botulism within both Northern Downs and Forest, one-third of properties were not vaccinating cows and heifers for botulism. This indicates that large number of cows are at risk of mortality from botulism within these country types as outbreaks generally occur in unvaccinated herds that are subjected to periods of protein and phosphorus deficiency (Tammemagi *et al*. 1967).

The most common management practice to control campylobacteriosis is the vaccination of bulls. In areas of low bull control, higher pregnancy rates in vaccinated heifer cohorts have previously been demonstrated (Schatz *et al*. 2006). Consistently low levels of vaccination in heifers and cows and moderate levels of vaccination in bulls were observed across all country types with the exception of Southern Forest where there was low prevalence of vaccinating against campylobacterosis in all classes of cattle. This suggests that infertility and abortion resulting from *Campylobacter fetus* var. *venerealis* infection is potentially more likely within Southern Forest and this could be a focus for extension activities in this region.

Conclusions

In this study we describe the ongoing change in management practices in north Australian beef businesses using a large group of businesses representing the four main country types.

Management of properties within and between country types varied greatly in management structure, size of breeding herds, property size and their degree of development. There were obvious differences in the expected annual production potential of properties between country types, which may be explained by varying environmental and nutritional constraints, such as risk availability of phosphorus during the wet season. Use of available interventions by herd managers/owners to boost productivity of heifers, cows and bulls remains highly variable within and between country types.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgements

The research described in this paper was conducted as part of a large Meat and Livestock Australia funded project (Northern Australia beef fertility project: Cash Cow) and has been fully described in The University of Queensland PhD thesis 'Risk Factors affecting the reproductive outcome of beef breeding herds in North Australia' by K. McCosker, senior author of this paper. The development and execution of this project could not have occurred without the extraordinary commitment and input from the co-operating producers and their staff, cattle veterinarians and the service and support provided by Outcross Agribusiness Pty Ltd, The University of Queensland and relevant State and Territory Departmental agencies. We especially acknowledge the contributions of Don Menzies, Tom Newsome, Di Joyner, Nancy Phillips, Nigel Perkins, John Morton, Louise Marquart, Tamsin Barnes and Whitney Dollemore.

References

Balston J, English B (2009) Defining and predicting the 'break of the season' for north-east Queensland grazing areas. *The Rangeland Journal* **31**, 151–159. doi:10.1071/RJ08054

Bortolussi G, McIvor JG, Hodgkinson JJ, Coffey SG, Holmes CR (2005*a*) The northern Australian beef industry, a snapshot. 1. Regional enterprise activity and structure. *Australian Journal of Experimental Agriculture* **45**, 1057–1073. doi:10.1071/EA03096

Bortolussi G, McIvor JG, Hodgkinson JJ, Coffey SG, Holmes CR (2005*b*) The northern Australian beef industry, a snapshot. 2. Breeding herd performance and management. *Australian Journal of Experimental Agriculture* **45**, 1075–1091. doi:10.1071/EA03097

Burns BM, Fordyce G, Holroyd RG (2010) A review of factors that impact on the capacity of beef cattle females to conceive, maintain a pregnancy and wean a calf-Implications for reproductive efficiency in northern Australia. *Animal Reproduction Science* **122**, 1–22. doi:10.1016/j.anireprosci.2010.04.010

Coates D (2004) Final report. Improving nutritional management of grazing cattle: Improving reliability of faecal NIRS calibration equations (NAP3.121). Meat & Livestock Australia, Sydney, NSW, Australia.

Cowley T, Oxley T, MacDonald N, Cameron A, Conradie P, Collier C, Norwood D (2014) '2010 Pastoral industry survey: NT wide.' (Department of Primary Industry and Fisheries, Northern Territory Government: Darwin, NT, Australia)

Dixon RM, Playford C, Coates DB (2011) Nutrition of beef breeder cows in the dry tropics. 1. Effects of nitrogen supplementation and weaning on breeder performance. *Animal Production Science* **51**, 515–528. doi:10.1071/AN10082

Fordyce G, Fitzpatrick LA, Cooper NJ, Doogan VJ, De Faveri J, Holroyd RG (2002) Bull selection and use in northern Australia. 5. Social behaviour and management. *Animal Reproduction Science* **71**, 81–99. doi:10.1016/S0378-4320(02)00027-1

Hasker PJS (2000) 'Beef cattle performance in northern Australia: a summary of recent research.' (Queensland Department of Primary Industries: Brisbane, Qld, Australia)

Henderson A, Perkins N, Banney S (2013) Determining property-level rates of breeder cow mortality in northern Australia, Final report no. B. NBP.0664. Meat & Livestock Australia, Sydney, NSW, Australia. Available at http://www.mla.com.au [Verified 6 October 2019]

Hendricksen RE, Turnouth JH, Punter LD (1994) Seasonal nutrient intake and phosphorus kinetics of grazing steers in northern Australia. *Australian Journal of Agricultural Research* **45**, 1817–1829. doi:10.1071/AR9941817

Hunt LP, Petty S, Cowley RA, Fisher A, Ash AJ, MacDonald RN (2007) Factors affecting the management of cattle grazing distribution in northern Australia: preliminary observations on the effect of paddock size and water points. *The Rangeland Journal* **29**, 169–179. doi:10.1071/RJ07029

Jackson D (2012) Producer phosphorus manual for the northern cattle industry. Meat and Livestock Australia final report no. B.NBP.0540, Sydney, NSW. Available at http://www.mla.com.au [Verified 6 October 2019]

Lo F, Wheeler MC, Meinke H, Donald A (2007) Probabilistic forecasts of the onset of the north Australian wet season. *Monthly Weather Review* **135**, 3506–3520. doi:10.1175/MWR3473.1

Martin P, Phillips P, Leith R, Caboche T (2013) Australian beef: financial performance of beef cattle producing farms, 2010–2011 to 2012–2013. ABARES research report 13.8, Canberra, ACT, Australia. Available at http://data.daff.gov.au/data/warehouse/9aabf004/abfpf/abfpfd9aabf00420130724/AustBeef_2013_v1.0.1_lr.pdf [Verified 6 October 2019]

McCosker KD (2016) Risk factors affecting the reproductive outcome of beef breeding herds in north Australia. PhD thesis, Australian Bureau of Agricultural and Resource Economics and Sciences, The University of Queensland, Gatton, Qld, Australia.

McCosker T, O'Rourke P, Eggington A (1991) Effects of providing supplements during the wet season on beef production in the Darwin district of the Northern Territory. *The Rangeland Journal* **13**, 3–13. doi:10.1071/RJ9910003

McGowan M, McCosker K, Fordyce G, Smith D, O'Rourke P, Perkins N, Barnes T, Marquart L, Morton J, Newsome T, Menzies D, Burns B, Jephcott S (2014) Northern Australian beef fertility project: CashCow. Meat & Livestock Australia final report no. B.NBP.0382, Sydney, NSW. Available at http://www.mla.com.au [Verified 6 October 2019]

McLean I, Holmes P, Counsell D (2013) Final report: the northern beef report, 2013 Northern beef situation analysis (B.COM.0348). Meat & Livestock Australia, Sydney, NSW, Australia.

Minson DJ (1990) 'Forage in ruminant nutrition.' (Academic Press: London, UK)

O'Rourke PK, Winks L, Kelly AM (1992) North Australian beef producer survey. Meat & Livestock Australia Ltd final report no. M.105, Sydney, NSW, Australia. Available at http://www.mla.com.au [Verified 6 October 2019].

Primary Industries Standing Committee (2007) 'Nutrient requirements of domesticated ruminants.' (CSIRO Publishing: Melbourne, Vic., Australia)

Schatz TJ, McColm R, Hearnden MN (2006) The benefits of vaccinating maiden heifers once against bovine vibriosis in northern Australia. In 'Proceedings of the Australian Society of Animal Production 26th biennial conference'. (Eds NR Adams, KP Croker, DR Lindsay, C Anderson, L Webb) p. 84. (University of Western Australia: Perth, WA, Australia)

Sullivan M (1992) Changing beef markets – should north Queensland producers change management to meet them. *Proceedings of the Australian Society of Animal Production* **19**, 53

Tammemagi L, Vet M, Grant KM (1967) Vaccination in the control of bovine botulism in Queensland. *Australian Veterinary Journal* **43**, 368–372. doi:10.1111/j.1751-0813.1967.tb04884.x

Walsh D, Cowley RA (2011) Looking back in time: can safe pasture utilisation rates be determined using commercial paddock data in the Northern Territory? *The Rangeland Journal* **33**, 131–142. doi:10.1071/RJ11003

Winks L, Laing A, O'Rourke P, Wright G (1979) Factors affecting response to urea-molasses supplements by yearling cattle in tropical Queensland. *Australian Journal of Experimental Agriculture* **19**, 522–529. doi:10.1071/EA9790522

Zarcinas BA, Cartwright B, Spouncer LR (1987) Nitric acid digestion and multi-element analysis of plant material by inductively coupled plasma spectrometry. *Communications in Soil Science and Plant Analysis* **18**, 131–146. doi:10.1080/00103628709367806

Handling editor: Di Mayberry