CSIRO PUBLISHING

Australian Journal of Experimental Agriculture

Volume 37, 1997

… a journal publishing papers (in the soil, plant and animal sciences) at the cutting edge of applied agricultural research

www.publish.csiro.au/journals/ajea

All enquiries and manuscripts should be directed to
Australian Journal of Experimental Agriculture
CSIRO PUBLISHING
PO Box 1139 (150 Oxford St)
Collingwood
Vic. 3066
Australia

Telephone: 61 3 9662 7614
Facsimile: 61 3 9662 7611
Email: chris.anderson@publish.csiro.au
lalina.muir@publish.csiro.au

CSIRO AUSTRALIA

Published by
CSIRO PUBLISHING
in co-operation with the
Standing Committee on Agriculture and Resource Management (SCARM)

A comparison of once- and twice-yearly weaning of an extensive herd in northern Australia
2. Progeny growth and heifer productivity

R. M. Sullivan[A], *P. K. O'Rourke*[BD] *and J. A. Neale*[C]

[A] Northern Territory Department of Primary Industry and Fisheries, PO Box 1346, Katherine, NT 0851, Australia.
[B] Queensland Department of Primary Industries, GPO Box 46, Brisbane, Qld 4001, Australia.
[C] Queensland Department of Primary Industries, Locked Mail Bag No. 4, Moorooka, Qld 4105, Australia.
[D] Present Address: Department of Social and Preventative Medicine, University of Queensland, Herston Road, Herston, Qld 4006, Australia.

Summary. Continuous mating is common in northern Australian beef herds. The resulting calves are born throughout the year making weaning and herd management difficult. Calves born late in the wet season do not reach suitable liveweight for weaning until late in the year. Low liveweight and poor feed conditions make management of these animals for subsequent turnoff or breeding more difficult.

We recorded the growth and survival of all progeny and reproductive performance of heifers from 2 groups of 250 *Bos indicus–Bos taurus*-cross cows grazing native pastures at Kidman Springs, Northern Territory, for 5 years from July 1985. Calves were weaned in June only (W1) or June and October (W2). Unweaned calves remained with their dams until June the following year and heifers entered the breeding herd as 2 year olds.

Calves weaned in June (WJ) were heaviest (157.1 kg; P<0.05) but gained least (84.6 kg; P<0.05) over the following year. Unweaned (UW) calves were lighter (51.1 kg; P<0.05) at branding time, in June, than those weaned in October (WO; 66.8 kg). However, they gained more weight (144.5 *v.* 112.4 kg; P<0.05) over the following year than WO calves because of a superior wet season growth rate, so that WO calves were lightest (P<0.05) at the yearling muster. Mortality rates of all calf groups were low (2.5%).

Liveweight at branding and liveweight gain to yearling stage affected whether heifers subsequently joined the breeding herd. More (P<0.05) heifers from WJ joined the herd than from WO and UW groups. Overall, 63.6% of heifers were selected as replacement breeders (no difference between W1 and W2). Bull control was difficult and many heifers (48%) conceived before the planned start of mating. Cumulative conception rate was 91.3% by 30 months post-branding. In the first year, 60% of heifers mated were confirmed pregnant, but reproductive losses of 25.6% from pregnancy diagnosis to branding contributed to a branding rate of 44.9%. The conception rate of heifers when lactating was 18.6%. Mortality during the first year in the herd was 11.7%. In general, WJ heifers had lower mortalities, higher conception, calving and weaning rates, and higher conception rates when lactating than WO or UW heifers.

Animals weaned in October were identified as the most difficult group to manage because of lower liveweight as 2 year olds compared with WJ and UW calves. This affected the numbers of heifers suitable for joining. Cost-effective management systems are needed to improve growth rates or delay onset of oestrus in these animals.

Introduction

More than 90% of breeding herds in the extensive regions of northern Australia are continuously mated (O'Rourke *et al*. 1992). When conception rates of lactating cows are low and weaning is carried out with continuous mating, cows may conceive 'out-of-season' (Sullivan *et al.* 1992), making management of weaners and breeders difficult because calves are born throughout the year. With 2 annual musters, out-of-season calves can be weaned at a muster late in the year (Sullivan and O'Rourke 1997), though the calves weaned at this time are likely to be smaller than those weaned at the end of the wet season. Early post-weaning growth may be affected by poor feed conditions and reduce the animal's ability to reach target liveweights for mating or sale.

Target liveweights for heifers of around 270 kg at the start of mating are generally required for conception rates ≥80% in controlled mating situations (Doogan *et al*. 1991). Under continuous mating, calves are born throughout the year and heifers are likely to be at

10.1071/EA95098

varying stages of development depending on time of birth, weaning and subsequent growth rates. Target liveweights for continuous mating of heifers may not need to be as high, because once mating commences, they may have an extended period in which to conceive. Where bull control is difficult, heifer segregation may not be successful or not attempted at all, with consequent early conceptions. About 70% of properties in the more extensive regions of northern Australia do not segregate heifers from the breeder herd up to 2 years of age (Robertson 1982; O'Rourke *et al*. 1992).

Heifers conceiving at low liveweights and subject to nutritional stress are vulnerable to liveweight loss and subsequent mortality (Stockwell and Norton 1990; MacDonald 1994). This may be a substantial source of female wastage in extensive herds in northern Australia but little information is available.

The effects of once- and twice-yearly weaning on cow liveweight, fertility and mortality have been reported by Sullivan and O'Rourke (1997). This study reports the growth and survival of the progeny and examines the survival and reproductive performance of heifers which joined the breeding herd.

Materials and methods

Site details

Site details for this study, conducted at Kidman Springs over 5 years from 1985, have been reported by Sullivan and O'Rourke (1997). Briefly, the site is 220 km south-west of Katherine in the Victoria River District of the Northern Territory. The climate is hot and seasonally dry with mean annual rainfall of 672 mm. Soils are a mixture of cracking clays, calcareous red earths and sandy red earths with neutral to slightly alkaline pH and low fertility. Major grass species are: *Chrysopogon fallax*, *Iseilema* spp., *Enneapogon* spp., *Heteropogon contortus* and *Sehima nervosum*.

Paddocks (Table 1) were spelled when not grazed by experimental animals and were not burnt.

Experimental design

Progeny with liveweight ≥100 kg from 2 breeding herds were weaned in either June only (W1), or June and October (W2). Steers were retained for 1 wet season after branding and then sold or transferred. Heifers were retained until 2 years of age and either selected to join the breeding herd or culled. The effects of weaning treatments were measured on liveweight changes or on reproduction and survival for heifers which joined the breeding herd.

Animals and their management

Calves were branded, individually identified and males castrated at the June muster. After weaning, calves were fed in the yards on good quality hay before being placed in Weaner paddock. All weaners ran together until December when the steers and heifers were drafted and run in separate paddocks. Animals grazed native pastures at all times. Supplements containing lupins, urea and molasses were fed to a random selection of weaners in 1985 and 1986 as part of weaner nutrition studies (Sullivan 1988). Data from these animals did not distort the liveweights and liveweight changes between cohorts or weaning treatments and were retained in the analysis. No supplements were fed during 1987 and 1988. In 1989, all weaners received a dry season supplement of meat and bone meal, cracked sorghum and salt as part of an experiment on prevention of coccidiosis (*Eimeria* sp.). During 1990, weaners and yearlings received a strategic mineral supplement containing salt, monoammonium phosphate, urea and sulfate of ammonia.

Replacement heifers were selected in August 1986 and 1987 for mating in the following December–January and immediately before mating in March 1989 and February 1990. Selected heifers entered the breeding herd as 2 year olds after selection on conformation and liveweight. A target liveweight of 250 kg was set initially but was varied according to heifer growth each year. Each treatment group was self-replacing and heifers were culled if they failed to conceive by 3.5 years of age. Calves were vaccinated against botulism (type C and D) at weaning, their next muster and again the following year.

Measurements

Liveweights were recorded after a 12 h curfew the day after mustering in April, June and October each year. Pregnancy and lactation status of heifers was recorded at each muster after mating.

Data treatment and analyses

Data were analysed using the method of least squares for unequal subclass numbers (Harvey 1960, 1982). Pairwise differences between treatments were tested for

Table 1. A summary of paddocks and grazing management for young cattle at Kidman Springs, 1985–90

Paddock name	Area (ha)	Dominant soil type	Class of stock grazed	Time of year grazed	Stocking rate (ha/animal)
Weaner	900	Cracking clay	Weaners	Dry season	3–4.5
Gutta Percha	1000	Sandy red earth	Weaner heifers	Wet season	6–9
Boab	1200	Sandy red earth	Weaner steers	Wet season	8–12
Little Rosewood	900	Cracking clay	Yearling heifers	Dry season	6–9

Table 2. Overall and annual mean calf liveweight at branding in June, and growth during 4 periods over the following year

Means within columns followed by the same letter are not significantly different at $P = 0.05$

	No. of calves	Liveweight (kg)	Liveweight change (kg)			
			June–Oct.	Oct.–Apr.	Apr.–June	June–June
Mean (± s.d.)	1597	96.3 ± 32.6	26.2 ± 10.9	68.2 ± 16.8	20.5 ± 11.2	114.7 ± 24.6
1985–86	229	100.1a	37.6a	79.4b	2.6d	118.9bc
1986–87	322	94.5a	26.5b	60.3c	13.6b	101.6d
1987–88	228	93.0a	19.0c	61.5c	9.0c	89.8e
1988–89	255	90.6a	20.3c	49.7d	46.4a	115.6c
1989–90	277	103.8a	27.4b	98.0a	8.0c	137.8a
1990–91	286	95.7a	26.1b	60.4c	43.4a	124.3b

significance using the protected l.s.d. procedure. Heifer liveweights were adjusted for stage of pregnancy using the correction factors of O'Rourke *et al*. (1991). Time to conception was estimated by counting back from the first confirmed pregnancy diagnosis and liveweight at conception was interpolated from liveweights recorded at musters before and after estimated time of conception.

The statistical model included main effects for cohort, management group and sex. Although the cohort x group interaction was often significant ($P<0.05$), it was minor in comparison with the main effects and did not distort the patterns in comparisons within either main effect. Other interactions were minor. Data from 6 cohorts were used for progeny and from 4 cohorts for heifers.

Progeny data were allocated to 3 management groups depending on time of weaning: WJ, calves weaned in June; WO, calves weaned in October; and UW, unweaned calves.

Heifer data were also allocated to management groups depending on herd of origin and time of weaning: WJ1, heifers weaned in June from W1; WJ2, heifers weaned in June from W2; WO2, heifers weaned in October from W2; UW1, unweaned heifers from W1; and UW2, unweaned heifers from W2. Data from heifers culled as yearlings were excluded from the analysis but retained for those culled as 2 year olds.

Results

Seasonal conditions

Rainfall and seasonal conditions at Kidman Springs during the study, have been described by Sullivan and O'Rourke (1997). Briefly, compared with the mean annual rainfall (23 years) of 672 mm; 1985–86, 1986–87 and 1989–90 were below the mean; 1987–88 was well below; 1988–89 was near the mean and 1990–91 was well above the mean.

Calves

Growth. Average calf liveweight at branding in June was 96 kg and was similar each year. Liveweight gain in the year following branding averaged 115 kg with considerable variation between years (Table 2). The highest liveweight gain occurred between October and April.

The proportion of progeny in each management group was 18.4% in UW, 7.4% in WO and 74.2% in WJ. The unweaned group (UW) was lightest ($P<0.05$), WO calves intermediate ($P<0.05$) and WJ calves heaviest ($P<0.05$) at branding in June (Fig. 1). Annual liveweight gain in order of highest to lowest was UW (144.5 kg), WO (112.4 kg) and WJ calves (84.6 kg).

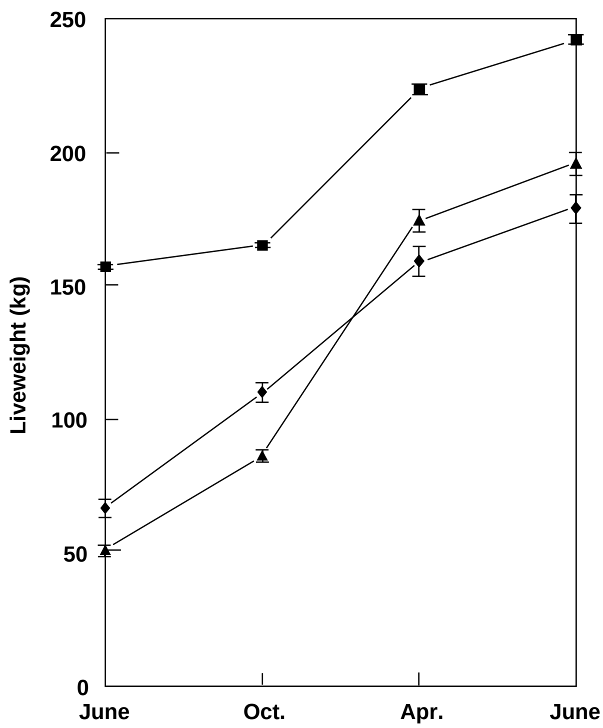

Figure 1. Growth of calves at Kidman Springs over 12 months from branding in June. ▲ Unweaned; ◆ weaned in October; ■ weaned in June. Vertical bars indicate standard errors.

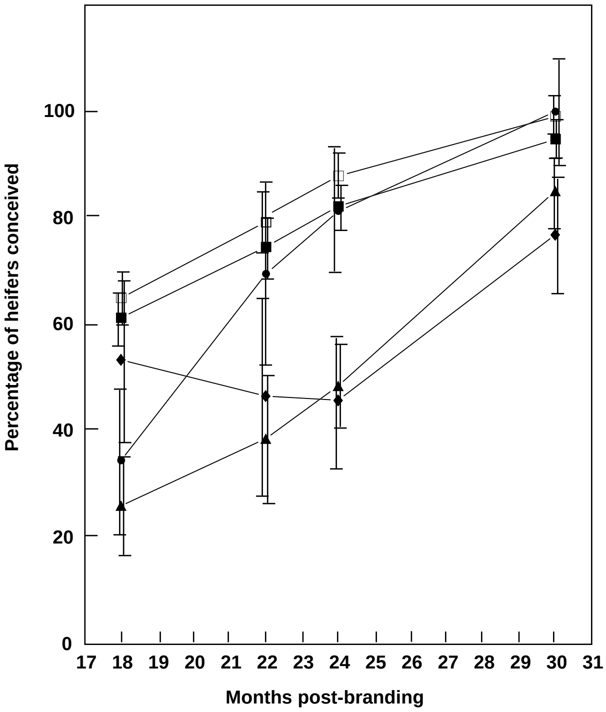

Figure 2. Cumulative conception rate of heifers from different weaning groups at Kidman Springs until 30 months post-branding. ▲ Unweaned from W1; ● unweaned from W2; ◆ weaned in October from W2; ■ weaned in June from W1; □ weaned in June from W2. Vertical bars indicate standard errors.

Differences between sexes were minor and inconsistent and supplement treatments did not affect comparisons between management groups. There were no differences in initial liveweight or growth during any period between unweaned calves from the W1 and W2 cow groups. However, of calves weaned in June, those from W2 were heavier in June (159.5 *v.* 154.1 kg; $P<0.05$), gained more between June and October (9.7 *v.* 6.6 kg; $P<0.05$) and over the whole year (86.9 *v.* 81.9 kg; $P<0.05$) than those from W1.

Mortality. The mortality rate of progeny over all years was 2.5% with little variation from year to year (1.3–3.6%). Mortality of unweaned calves was higher than that of weaned calves (6.5 *v*. 1.5%; $P<0.05$). Mortalities of groups weaned in June and October were similar. Mortalities of unweaned calves occurred earlier ($P<0.05$) than those of weaned calves; 70.6% of deaths in the unweaned groups occurred between June and October, while 62.5% of deaths among weaners occurred between October and April.

Heifers

Any differences in growth between treatments from branding to 2.5 years of age occurred during the branding to yearling period. Liveweight gains from branding to 2.5 years of age in order of highest to lowest were UW2 and UW1 (229.2 and 210.8 kg respectively), WO2 (185.6 kg), and WJ2 and WJ1 (154.2 and 146.9 kg respectively). Yearling liveweights of WJ2 heifers (233.7 kg) were higher ($P<0.05$) than those of WJ1 (223.8 kg) and both groups were heavier ($P<0.05$) than WO2, UW1 and UW2 (180.5, 192.3 and 188.7 kg respectively). Liveweight changes from yearling to 2.5 years of age were: June–October, –1.6 kg; October–April, 61.0 kg; April–June, 14.9 kg; giving a total gain of 75.8 kg for the year. All treatment groups were similar. Heifer mortality was 1.6% from branding to 2.5 years of age.

Overall, 63.6% of heifers were selected as replacement breeders but there was no difference between heifers from W1 or W2 cow groups. The proportion was high for the 1985, 1987 and 1988 cohorts (75.2, 67.2 and 68.9% respectively) and lower ($P<0.05$) for the 1986 cohort (49.1%) but the total number selected each year was similar (n = 79–84). About three-quarters of heifers from WJ1 (73.7%) and WJ2 (74.2%) were selected to join the breeder herd. This was higher ($P<0.05$) than WO2 (27.7%), UW1 (48.6%) or UW2 (41.0%). Heifers which were subsequently selected as replacements were 19.6 kg heavier ($P<0.05$) at branding and 35.7 kg heavier ($P<0.05$) as yearlings than those subsequently culled.

Liveweight at first conception was consistent between weaning groups (258.0–267.1 kg) except for UW2 (234.9 kg; $P<0.05$), but was affected by season. Liveweight of the 1987 cohort was lowest (231.0 kg; $P<0.05$) at conception, the 1985 and 1986 cohorts were intermediate (259.1 and 249.7 kg respectively) and the 1988 cohort was highest (293.5 kg; $P<0.05$).

Conceptions before the planned start of mating occurred in all years. They were lowest in the 1986 cohort (25.0%) and highest in the 1987 cohort (68.6%). For the 1985 cohort, 50% of the early conceptions occurred within 12 months of branding and most of these had calved before the planned start of mating. There was no difference between years in cumulative conceptions by 30 months post-branding (88.0–94.0%). Time from branding to first conception was lowest in the 1987 cohort (19.2 months; $P<0.05$) compared with other years (22.2–22.6 months). Heifers from WO2 and UW1 had lower ($P<0.05$) early conception rates than the other weaning groups (Fig. 2).

Mortality in the first year after joining averaged 11.7% (Table 3) and the proportion confirmed pregnant (>3 months pregnant) was similar in all years except 1989 when it was lower than average ($P<0.05$). Branding percentages were higher for heifers mated in 1988 (1986 cohort) and 1990 (1988 cohort; $P<0.05$) than for heifers mated in 1987 (1985 cohort) and 1989 (1987 cohort). Pregnancy and branding rates were highest ($P<0.05$) for WJ2 and lowest for WO2. Foetal and calf

Table 3. Mortality and reproductive performance of heifers up to 36 months post-branding

Reproductive losses represent those from pregnancy diagnosis to branding
WJ1, weaned in June from W1; WJ2, weaned in June from W2; WO2, weaned in October from W2;
UW1, unweaned from W1; UW2, unweaned from W2
Means within columns followed by the same letter are not significantly different at $P = 0.05$

	Mortality (%)	Confirmed pregnant (%)	Branding (%)	Reproductive losses (%)	Reconception (%) Rearing a calf	Reconception (%) Not rearing a calf
Mean (± s.d.)	11.7	60.0 ± 41.8	44.9 ± 47.4	25.6 ± 42.4	18.6 ± 26.8	50.0 ± 49.6
Year of mating						
1987	7.3	65.5a	31.7b	47.1a	54.5a	30.8
1988	13.8	62.4a	51.6a	18.6bc	5.4b	61.0
1989	21.5	47.0b	34.9b	27.2b	7.2b	55.2
1990	4.8	65.0a	61.5a	9.4c	7.3b	53.0
Weaning group						
WJ1	11.6	73.7a	52.5ab	29.6	13.7	74.1
WJ2	9.8	80.8a	57.8a	27.5	18.4	71.3
WO2	15.4	31.1c	19.5c	34.4	44.6	0
UW1	17.1	47.6bc	39.4bc	18.1	3.8	61.5
UW2	12.5	66.6ab	55.4ab	18.3	12.4	54.1

losses from pregnancy diagnosis to branding were high (25.6%) particularly for heifers mated in 1987 (P<0.05). Dam mortality was a minor component of losses in 1987 but substantial for the other years. There were no differences between weaning groups for reproductive losses from pregnancy diagnosis to branding, and dam mortality was a substantial component of losses, particularly for UW1.

Conceptions up to 36 months post-branding for heifers which had completed 1 pregnancy were higher for those not rearing a calf to branding than for those which reared a calf (Table 3). For those rearing a calf, the conception rate was higher (P<0.05) in 1987 than in other years. Other differences between years and weaning groups were not significant.

Discussion

Calves

The growth patterns of calves in this study were consistent with reports by other authors (Arthur and Mayer 1975; Sullivan 1988; Stockwell 1989; Holroyd *et al*. 1990; Sullivan *et al*. 1992). Weaned calves grew more slowly than unweaned calves, particularly the WO group which grew least over the wet season. Consequently, this group had the lowest yearling and 2-year-old liveweights despite gaining more weight than the WJ group from yearling to 2 years of age. Only 27% of heifers from the WO group met the selection criteria as replacement breeders compared with >40% for UW and 75% from the WJ group.

Calves weaned in June were the largest group (74.2%). Calves weaned in October were only a small proportion (14.4%) of the calves from the W2 herd. This was due to the first weaning round being late (June) and insufficient time between musters to allow late-born calves to reach the target liveweight for weaning in October (Sullivan and O’Rourke 1997). If mustering times were adjusted to allow most out-of-season calves to reach the target weaning liveweight at the second round, late-weaned calves could potentially comprise 25% of the annual weaner crop. This would result in a significant proportion of heifers not reaching target liveweight for mating by 2 years of age. Such animals might require extra feeding or holding for a further year before mating, with associated costs and delayed returns. Similarly, cash flows may be affected where a proportion of the annual steer crop has to be held over or supplemented in order to achieve sale liveweights.

There were very low mortalities among calves and weaners in the first year, similar to the report of Sullivan *et al*. (1992). The higher mortality rate of unweaned calves was probably due to death of the dam or mismothering after the June muster. The mortality rate among lactating cows during the dry season was high (Sullivan and O’Rourke 1997). The average liveweight of unweaned calves at the muster before death was 49 kg and they would be unlikely to survive alone. The pattern of mortality of weaned animals was similar to that reported by Holroyd *et al*. (1990) where animals died some months after weaning, making further investigation difficult.

Heifers

Liveweight at branding and liveweight gain to yearling stage determined whether heifers subsequently joined the breeder herd. Heifers from both the unweaned groups (UW1 and UW2) and the October-weaned group (WO2) were lighter at branding time and, despite some compensatory weight gains, not as likely to be heavy enough at mating for selection as replacement breeders compared with animals weaned in June (WJ1 and WJ2). The target liveweight for mating (250 kg) was only reached in 1 year (1990), thus many heifers, which did not meet the target liveweight, were joined to maintain breeder numbers. In 1987 and 1988, mating occurred in December at the start of the wet season, and heifers were expected to reach 250 kg during the wet season. In 1989, heifers were mated in late March, at the end of the wet season with an average liveweight at mating of 234 kg. Conception rate by June was the same as in other years. A combination of low liveweight and out-of-season calving may have been responsible for the 21% mortality rate in this group.

Average liveweight at first conception was lower overall than the ranges reported by Goddard *et al*. (1980). In 1989, heifers conceived at 231 kg, on average. This group of heifers gained least from branding to yearling stage and was lightest at yearling and 22 months post-branding. However, the flush of green feed during the wet season may have enabled heifers to cycle despite their relatively low liveweight. In contrast, the 1990 cohort had an average liveweight of 293 kg at conception. These heifers had the highest growth rate after the yearling muster. Liveweight at first conception was similar for all weaning groups except UW2. Low numbers of animals in the UW2 group may have affected the result.

Level of conception was consistent between years with about 90% of heifers conceiving by 30 months post-branding. The breeder groups were joined continuously and heifers would have conceived as they started cycling. The resultant year-round calving created problems managing weaning and survival. These problems were pronounced for heifers from the lighter weaning groups (UW1, UW2 and WO2) which took longer to conceive. Holroyd *et al*. (1990) attributed lowered fertility in early-weaned heifers to the indirect effect of liveweight. Many heifers conceived before joining the breeder herd, despite segregation. Some of these conceptions, within 1–2 months of the start of mating, could be inaccuracies in pregnancy diagnosis. This could explain all of the early conceptions in the 1988 cohort but only a 25% of those in other years. The shortest average time to conception from branding was measured in heifers mated in 1987. Half of this group conceived within 12 months of branding and most of these had calved by the start of mating, making the start of mating a redundant term. Despite electrified fencing used in the paddocks for this study, both station and feral bulls gained access to the heifers. This emphasises the difficulties of bull control in extensive areas. Oestrus-suppressing drugs or vaccines have been suggested to prevent early conceptions. However, a recent study at Katherine (MacDonald 1994), using an anti-reproductive vaccine, suggested that suitable technology is not yet commercially available.

Heifer mortality during the first year in the breeding herd was similar to that of older cows (Sullivan and O'Rourke 1997) and of similar magnitude to that reported by Stockwell and Norton (1990). In both of these studies nutritional stress was thought to be a major factor. The low mortality rate of heifers joined in 1990 may reflect earlier time of weaning in April 1991 and mineral supplementation of all breeders which commenced in July 1990. Taylor *et al*. (1982) reported reductions in mortality of heifers supplemented with a non-protein nitrogen, mineral and energy supplement while pregnant–lactating, and supplementation in this instance may have reduced nutritional stress from out-of-season calving.

Percentages of heifers confirmed pregnant were similar in all years except for those mated in 1989. This may have been a result of later mating and lower liveweight of heifers that year and hence, later conception. Pregnancy levels varied across weaning groups, probably due to the timing of conception because of differences in liveweight rather than any treatment effects. Foetal and calf wastage from surviving heifers was high for all weaning groups and all years except 1990. This was similar to older cows in the same herd (Sullivan and O'Rourke 1997) and probably due to similar factors. Higher liveweight at conception and calving, and mineral supplementation may have contributed to the lower reproductive losses in 1990. Rudder *et al.* (1976) reported lower foetal survival rates for 2-year-old cows compared with older animals, while Burns *et al*. (1992), found similar prenatal losses, but higher peri- and post-natal losses for maiden heifers compared with older cows.

The conception rate of lactating heifers in 1987 distorted the mean. In the other years the conception rate was about half that of older cows. This is similar to the results of Goddard *et al*. (1980) and McCosker *et al*. (1991). Low conception rates in lactating, first-calf heifers are well documented (Holroyd and O'Rourke 1989) and may be increased with improved nutrition (McCosker and Eggington 1986). The early calving of the 1987 group may have given heifers more time to cycle and conceive. Evidence for this is the fact that all of the conceptions of wet heifers in 1987 were from WJ1 and WJ2 groups. These animals were heavier than heifers from other weaning groups. They conceived and calved earlier and, with the benefit of an entire wet season after calving, more conceived for a second time. Low animal numbers affected the conception percentages for some weaning groups, particularly WO2. If the result for WO2 is ignored, then the trend was for animals that were heavier at mating to have higher conception rates when lactating, leading to more conceptions from the WJ1 and WJ2 groups. This is consistent with the results reported by Goddard *et al.* (1980).

While weaning is a well-accepted practice in extensive areas, we have outlined some of the management problems caused by continuous mating and out-of season calving. Out-of-season calves weaned late in the year present a problem because of low liveweight and growth rates, affecting their ability to meet liveweight targets for joining or sale. We believe cost-effective systems for managing these animals to improve growth rates or delay onset of oestrus are required to improve the efficiency of extensive beef enterprises in northern Australia.

Acknowledgments

Technical assistance by staff at Kidman Springs is gratefully acknowledged. The study was funded by the Northern Territory Department of Primary Industry and Fisheries.

References

Arthur, B. A., and Mayer, B. G. (1975). More beef through early weaning. *Queensland Agricultural Journal* **101**, 216–21.

Burns, B. M., Tierney, T. J., Rudder, T. H., Esdale, C. R., Howitt, C. J., and O'Rourke, P. K. (1992). Productivity of Hereford, highgrade Simmental and Belmont Red beef herds in central Queensland. 1. Pregnancy, calving and weaning rates. *Australian Journal of Experimental Agriculture* **32**, 551–7.

Doogan, V. J., Fordyce, G., Shepherd, R. K., James, T. A., and Holroyd, R. G. (1991). The relationships between liveweight, growth from weaning to mating and conception rate of *Bos indicus* cross heifers in the dry tropics of North Queensland. *Australian Journal of Experimental Agriculture* **31**, 139–44.

Goddard, M. E., Entwistle, K. W., and Dixon, R. (1980). Variables affecting pregnancy rate in *Bos indicus* cross cows. *Proceedings of the Australian Society of Animal Production* **13**, 65–7.

Harvey, W. R. (1960). Least squares analysis of data with unequal subclass numbers. United States Department of Agriculture, Agricultural Research Service, No. ARS-20-8.

Harvey, W. R. (1982). Least squares analysis of discrete data. *Journal of Animal Science* **54**, 1067–71.

Holroyd, R. G., and O'Rourke, P. K. (1989). Collation of basic biological data on beef cattle production in North Australia. Australian Meat and Livestock Research and Development Corporation, Sydney.

Holroyd, R. G., O'Rourke, P. K., Tyler, R., Stephenson, H. P., Mason, G. W. J., and Schroter, K. L. (1990). Effects of different weaning strategies on post-weaning growth rate, mortality and fertility of *Bos indicus* cross cattle. *Australian Journal of Experimental Agriculture* **30**, 1–6.

MacDonald, R. N. (1994). Control of reproductive activity in extensively managed cattle in the semi-arid tropics. *Proceedings of the Australian Society of Animal Production* **20**, 100–3.

McCosker, T. H., and Eggington, A. R. (1986). Supplementation of breeders on native pastures at Mount Bundey Station (1979 to 1984)—procedures, management and major results. Northern Territory Department of Primary Production (Darwin), Technical Bulletin No. 90.

McCosker, T. H., O'Rourke, P. K., and Eggington, A. R. (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.

O'Rourke, P. K., Entwistle, K. W., Arman, C., Esdale, C. R., and Burns, B. M. (1991). Fetal development and gestational changes in *Bos taurus* and *Bos indicus* genotypes in the tropics. *Theriogenology* **36**, 839–53.

O'Rourke, P. K., Winks, L., and Kelly, A. M. (1992). North Australia beef producer survey 1990. Queensland Department of Primary Industries and Meat Research Corporation, Brisbane.

Robertson, J. A. (1982). The Victoria River District cattle industry survey. Northern Territory Department of Primary Production (Darwin), Technical Bulletin No. 66.

Rudder, T. H., Seifert, G. W., and Maynard, P. J. (1976). Factors affecting reproduction rates in a commercial Brahman crossbred herd. *Australian Journal of Experimental Agriculture and Animal Husbandry* **16**, 623–9.

Stockwell, T. G. H. (1989). The productivity of cattle and pastures in the semi-arid tropics of the Northern Territory. MAgrSc Thesis, University of Queensland, Brisbane.

Stockwell, T. G. H., and Norton, B. W. (1990). Effect of pasture type on animal productivity on the Sturt Plateau, N.T. *Proceedings of the Australian Society of Animal Production* **18**, 557.

Sullivan, R. M. (1988). Weaner supplementation and management in the Victoria River District of the Northern Territory. *Proceedings of the Australian Society of Animal Production* **17**, 342–5.

Sullivan, R. M., and O'Rourke, P. K. (1997). A comparison of once- and twice-yearly weaning in an extensive herd in northern Australia. 1. Cow liveweight, mortalities and fertility. *Australian Journal of Experimental Agriculture* **37**, 279–86.

Sullivan, R. M., O'Rourke, P. K., Robertson, D. J., and Cooke, D. (1992). Effects of once-yearly weaning on some aspects of herd productivity in an extensive herd in the semi-arid tropics of northern Australia. *Australian Journal of Experimental Agriculture* **32**, 149–56.

Taylor, W. J., Holroyd, R. G., and Rebgetz, J. G. (1982). Influence of nitrogen based supplements on liveweight, fertility and mortality of heifers grazing dry season native pasture. *Proceedings of the Australian Society of Animal Production* **14**, 277–80.

Received 9 June 1995, accepted 13 February 1997