Calving system and weaning age effects on cow and preweaning calf performance in the Northern Great Plains[1,2]

E. E. Grings[3], R. E. Short[4], K. D. Klement[5], T. W. Geary, M. D. MacNeil, M. R. Haferkamp, and R. K. Heitschmidt

USDA-ARS, Fort Keogh Livestock and Range Research Laboratory, Miles City, MT 59301

ABSTRACT: A 3-yr study evaluated late winter (Feb), early spring (Apr), and late spring (Jun) calving systems in conjunction with varied weaning strategies on beef cow and calf performance from Northern Great Plains rangelands. Crossbred cows were randomly assigned to one of three calving systems (on average n= 168·calving system^{-1}·yr^{-1}) and one of two weaning times (Wean 1, 2) within each calving system. The Feb and Apr calves were weaned at 190 and 240 d of age, whereas Jun calves were weaned at 140 and 190 d of age. Breeding by natural service occurred in a 32-d period that included estrous synchronization. Cows were managed throughout the year as appropriate for their calving season. Quantity and quality of hay and supplements were provided based on forage and weather conditions, physiological state of the cows, and available harvested feed resources within a year. After weaning, two-thirds of the early weaned steers were fed in confinement in Montana, and one-third were shipped to Oklahoma and were grazed or fed forage. One-half of the early weaned heifers grazed seeded pastures, and the other half was fed in confinement. Early weaned calves were weighed on approximately the same day as late-weaned calves. Birth weight and overall rate of gain from birth to weaning did not differ for calves from the three calving systems. Calf weaning weight differed by weaning age within calving system (P = 0.001), and calves from the Jun calving system that were weaned at 190 d of age tended (P = 0.06) to be lighter than calves of the same age from the Feb or Apr calving systems. Cow BW change and BCS dynamics were affected by calving system, but the proportion of cows pregnant in the fall was not. Cows suckled until later dates gained less or lost more BW during the 50 d between the first and second weaning than dry cows during this period. The previous year's weaning assignment did not affect production in the following year. Estimated harvested feed inputs were less for the Jun cows than for the Feb and Apr cows. We conclude that season of calving and weaning age affect outputs from rangeland-based beef cattle operations.

Key Words: Beef Cattle, Calving Season, Rangelands, Weaning

©2005 American Society of Animal Science. All rights reserved. J. Anim. Sci. 2005. 83:2671–2683

Introduction

Rangeland forage quality in the Northern Great Plains is very dynamic and exhibits a narrow period of high quality in May and June, when temperature and precipitation conditions are optimal for growth of native cool-season forages. As quantity of precipitation decreases and temperature increases in late summer, forage quality declines rapidly and generally stays low through autumn and winter, creating a long period when nutritional quality may limit maximal beef production (Adams and Short, 1988). As nutritional requirements for beef cows vary with physiological states such as gestation and lactation, the adequacy of Northern Great Plains forage quality for meeting beef cow nutrient requirements depends on season of calving. Optimal calving times may vary for beef operations in this region depending on the particular goals of an individual operator. Understanding the relative performance of cattle born during different seasons of the year is important to meet specific goals and optimize economic returns (Reisenauer et al., 2001). Choice of calving seasons also may influence the most appro-

[1]This research was conducted under a cooperative agreement between USDA-ARS and the Montana Agric. Exp. Stn. Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA, Montana Agric. Exp. Stn., or the authors and does not imply its approval to the exclusion of other products that also may be suitable.

[2]The authors express appreciation to Pharmacia & Upjohn, Kalamazoo, MI, for providing the prostaglandin used in this study.

[3]Correspondence: 243 Fort Keogh Road (phone: 406-874-8202; fax: 406-874-8289; e-mail: elaine@larrl.ars.usda.gov).

[4]Retired.

[5]Current address: USDA-ARS, University Park, PA 16802.

Received November 10, 2004.

Accepted July 8, 2005.

Table 1. Age structure and cow numbers for calving system and weaning age treatments across years[a]

Item		1999	2000	2001
2-yr-old				
Feb	Wean 1	14	20	14
	Wean 2	14	19	13
Apr	Wean 1	16	20	14
	Wean 2	17	20	14
Jun	Wean 1	10	16	15
	Wean 2	10	15	16
3-yr-old				
Feb	Wean 1	21	13	13
	Wean 2	21	12	11
Apr	Wean 1	24	13	14
	Wean 2	22	13	14
Jun	Wean 1	14	9	12
	Wean 2	15	8	10
≥4-yr-old				
Feb	Wean 1	57	51	49
	Wean 2	57	47	46
Apr	Wean 1	57	46	50
	Wean 2	59	45	47
Jun	Wean 1	79	55	50
	Wean 2	75	55	53

[a]Cow numbers decreased throughout the study as a result of culling related to forage conditions and are not reflective of treatment effects. Calving systems were late winter (Feb), early spring (Apr), and late spring (Jun). Wean 1 = 190 d after calving for Feb and Apr and 140 d after calving for Jun; Wean 2 = 240 d after calving for Feb and Apr and 190 d after calving for Jun.

priate time of weaning for optimal production. For example, in a simulation model developed using data from ranches in southeastern Montana, Julien and Tess (2002) suggested that the greatest profitability was realized when spring-born calves were older at weaning and the grazing season was extended. The objective of the current study was to evaluate the effect of calving during late winter, early spring, or late spring, as well as the effect of two weaning times within each season, on cow and calf performance in a rangeland-based beef operation in the Northern Great Plains.

Materials and Methods

This study was conducted at the Fort Keogh Livestock and Range Research Laboratory (**LARRL**) near Miles City, MT (46°22′ N 105°5′ W). The potential natural vegetation on the 22,500-ha station is a grama-needlegrass-wheatgrass (*Bouteloua-Hesperostipa-Pascopyron*) mixed-grass dominant rangeland (Kuchler, 1964). Regional topography ranges from rolling hills to broken badlands, with small intersecting streams that flow into large permanent rivers meandering through broad, nearly level valleys. Climate is continental and semi-arid. Average annual rainfall in this area is 338 mm, 60% of which is received during the 150-d, mid-April to mid-September growing season. Average daily temperatures range from −10°C in January to 24°C in July; daily maximum temperatures occasionally exceed 37°C during summer, and daily minimum temperatures occasionally fall below −40°C during winter.

Herd Management

Initially (1997), approximately 600 cows from an early spring calving herd were assigned randomly to calve in one of three seasons of calving. Cows remained with their calving season assignment throughout the study. Exogenous hormone treatments were used to aid in altering calving dates, and cows were bred by artificial insemination in 1997. No data were used from 1997 while breeding seasons were being altered. Beginning in 1998, cows were mated by natural service in a 32-d breeding season that included an injection of prostaglandin 7 d after bulls were turned in with cows. Eighteen to 25 bulls were used for breeding, and cow-to-bull ratios averaged 12:1 throughout the study. The same bulls were used in each of the three calving herds within a year. Different bulls were used for breeding in 1998 and 1999, whereas the same set of bulls was used in 2000 and 2001. Bulls were at least one-quarter composite breeding (one-half Red Angus, one-quarter Charolais, one-quarter Tarentaise) crossed primarily with Hereford; however, actual breed combinations varied by year. Breeding occurred from approximately April 6 to May 9, June 6 to July 9, and August 6 to September 9 (exact dates vary by year), resulting in seasons of calving occurring in late January to late February (**Feb** calving), mid-March to mid-April (**Apr** calving), and mid-May to mid-June (**Jun** calving). Because calving seasons had not yet completely shifted to those designed for the study, 1998 performance data were not included in the analysis. Age structure and cow numbers for treatments throughout the study are presented in Table 1.

Each calving herd was managed separately throughout the year with inputs appropriate for the specific calving season, resulting in different calving systems. Cows were managed in a total of 45 pastures, varying in size from approximately 46 to 1,869 ha. Cattle movements among pastures were based on forage availability and management needs. Quantity and quality of hay and supplements were provided based on forage and weather conditions, physiological state of the cows, and available harvested feed resources within a year. Our goal was to feed to achieve a BCS of 5 (scale of 1 to 9; Herd and Sprott, 1986) at calving, but we were not always successful. Cows were maintained primarily on native rangeland, except for calving periods for the Feb and Apr calving herds. At calving, the Feb calving herd was housed in drylots and fed corn silage or corn silage and hay through calving. The Apr calving herd calved in small pastures with inadequate forage to support the herd, so hay was fed during the calving period. The Jun calving herd calved in native rangeland pastures. During the calving period, the Feb calving herd was checked approximately twice per hour over the 24-h period for signs of dystocia, and calves were moved inside for warming as needed. The Apr cows were checked slightly less frequently because of the need to patrol a larger area (76 ha). The Jun cows calved in a

167-ha pasture of native rangeland and were checked throughout the day but not at night. Individual cow-calf pairs were moved to pasture for grazing within 1 wk after parturition in all systems.

Bull calves were castrated at approximately 6 to 8 wk of age, and all calves received a seven-way clostridial vaccination at this time. Weaning occurred at approximately 190 and 240 d of age for the Feb and Apr calves and at 140 and 190 d of age for the Jun calves. Calendar dates for weaning were approximately August 15 (Feb, 190 d), October 19 (Feb, 240 d; Apr, 190 d; Jun, 140 d), and December 9 (Apr, 240 d; Jun, 190 d). Weaning dates were assigned randomly to calves within each year. Calves received a seven-way clostridial vaccine and vaccination against *Haemophilus somnus*, bovine respiratory syncytial virus, infectious bovine rhinotracheitis, bovine viral diarrhea, and parainfluenza 3 approximately 3 wk before weaning and at weaning. Calves also received a pour-on treatment for internal parasites at weaning. No implants were used in calves during the preweaning period.

After weaning, calves were housed in drylots for approximately 3 wk, after which time they were sorted into postweaning treatments. Steers were placed on one of two diets at LARRL or were shipped to the USDA-ARS Grazingland Research Laboratory (El Reno, OK). Heifers were placed either in a drylot and fed a diet of 60% corn silage, 39% hay, and 1% protein and mineral supplement (as-fed basis) or were placed on pasture for grazing with hay fed as needed (Grings et al., 2002).

Yearling heifers were added to cow herds at the beginning of the breeding season. Heifers remained in the calving systems in which they were born. These heifers had been raised under various management strategies from birth to weaning as described above and as described in Grings et al. (2002). At the end of the postweaning treatment period, some heifers were chosen randomly to provide a suitable number of replacements. Heifers that had been raised in drylots were moved to pasture at least 1 wk before the beginning of the breeding season. Heifers then remained with the cow herds throughout the year and were not separated during the winter feeding period. Heifers were placed in separate pens or pastures at calving to allow for increased monitoring for calving assistance as needed.

Animal Data Collection

Cows were weighed approximately 3 wk before the start of the calving season (average = 26 d pre calving), within 48 h after calving, at the beginning of the breeding season (average = 64 d after calving), and at each weaning time. Condition scores were assigned (scale of 1 to 9; Herd and Sprott, 1986) at each weighing by palpation over the back and ribs by two technicians. Calves were weighed at birth, during the breeding season (average = 69 d of age), and at each weaning time. Weight at the second weaning time for calves weaned at 190 d (Feb or Apr) or 140 d (Jun) included data from calves that had been placed into varied post-weaning management programs.

The number of cows ≥2 yr of age that exhibited a functional corpus luteum (**CL**) at the beginning of the breeding season was determined from blood progesterone concentrations. Blood samples were collected by tail vessel venipuncture on d −7 and 0 relative to the beginning of the breeding season. Serum was collected from blood after centrifugation (3,000 × g for 30 min), frozen, and subsequently analyzed for progesterone by radioimmunoassay (Kit TKPGX; DPC, Los Angeles, CA). A cow was assumed to have a functioning CL if at least one serum sample had a progesterone concentration >1 ng/mL. Pregnancy was determined by transrectal ultrasonography in October.

Harvested feed inputs were measured by daily recording of the feed supplied to each calving herd. Silage was measured by a scale on the feed truck at time of delivery. Hay inputs were recorded by the number of bales supplied. Representative bales were weighed to obtain estimates of the actual weight of hay supplied. Hay bales were cored after harvest each year for estimates of quality. Supplement (1.9-cm pellet) delivery was estimated by the calibration of a range cake feeder mounted on a truck. Hay, silage, and supplement samples were sent to a commercial laboratory for analysis of DM, ash, CP, and ADF (AOAC, 1990).

Diet Quality

Diet quality during grazing periods was estimated from esophageal extrusa. Diet samples were collected monthly, and sampling times were scheduled to provide estimates of diet quality at calving, breeding, and weaning, with other months sampled as appropriate. A total of 41 time-points were sampled between April 1998 and December 2001. Diet samples were not collected in January and November 2000 or in January and February 2001 when snow cover prevented grazing. Extrusa samples were collected using three to six adult esophageally cannulated cows in each pasture. Cows were allowed approximately 4 d to adapt to each pasture, and different cows were used in each pasture. Before each diet sample collection, cows were penned overnight with access to water. Two 45-min collection periods were conducted within 1 wk on nonconsecutive days for each calving system. Extrusa samples were lyophilized, ground to pass a 1-mm screen, and stored until analysis for DM, OM (both AOAC, 1990), CP, and in vitro OM digestibility (**IVOMD**).

Samples for CP determinations were placed in a roller grinder for 12 h (Mortenson, 2003). Nitrogen was determined by combustion techniques in a C-N analyzer (CE Elantech, Inc., Lakewood, NJ). Nitrogen was multiplied by 6.25 to obtain CP, and these values were expressed on an OM basis. The IVOMD was determined by the method of Tilley and Terry (1963).

Forage Quantity and Quality, Standing Crop, and Grazing Pressure

Forage quantity and quality data were collected to describe the study environment. Stocking rate and grazing pressure were calculated to ensure that effects attributable to calving systems were not affected by differences in grazing management, other than those directly related to altered season of calving. The total of 41 forage sample dates occurred approximately monthly during the period from April 1998 through December 2001 during the same week as diet sampling.

Triplicate herbage sample sites were subjectively located in each sample pasture on each of three topographic positions (Upland, Hillside, and Bottomland). Before clipping, the three dominant plant species at each site were recorded as a plant community descriptive metric. Thereafter, the herbage in fifteen 0.1-m^2 randomly located quadrats was harvested by herbage type (grass or forb) to ground level, dried at 60°C, for 48 h or until dry, and weighed. Forage from the 15 quadrats was composited and ground for analysis of DM and CP as described for diet quality samples, with CP expressed as percentage of DM.

Monthly stocking rates (animal unit month [**AUM**]/ha) were calculated by proportionally adjusting for temporal movements of herds among varying sized pastures within months. No adjustments were made to animal units (**AU**) for varying class and size of animals, as proportions of various size and class of animals were similar among calving systems. Thus, dry cows, cow-calf pairs, yearling heifers, and bulls were all considered 1.0 AU. Instantaneous grazing pressures (AU/kg of available herbage) were calculated for each herd on each of the 41 herbage sample dates by dividing number of AU by whole pasture herbage availability estimates.

Statistical Analyses

Diet quality data were analyzed using the MIXED procedure of SAS (SAS Inst., Cary, NC). To aid in describing and interpreting the dynamic nature of the interface between the nutritional environment and cow physiological state, each sample date was assigned to the appropriate month after calving for each of the three calving systems (Figure 2). The model evaluating dietary CP and IVOMD included calving system and month from calving within calving system as fixed effects. Year, the interaction of year and calving system, and the esophageal cow used within calving system × month after calving for the calving system × year interaction were random effects. The effect of month after calving within calving system was tested using the mean square for esophageal cow within calving system × month after calving for the calving system × year term. Data from 1998 were included in the diet quality analysis as this provided an estimate of the pre-calving environment for performance in 1999.

Calf data were analyzed using the MIXED procedure in SAS. After an initial analysis indicated that calving distribution did not differ among calving systems, weaning weights were adjusted for actual days to respective weaning (i.e., 140, 190, or 240 d). This was done to account for differences in actual weaning dates among years and calving systems. Average daily gains were estimated from birth to the breeding season (approximately 69 d of age) and from birth to first or second weaning. The model used for calf data included fixed effects of weaning age within calving system, calf sex, and cow age. Year and interactions of year with fixed effects were included as random effects. Nonorthogonal contrasts were used to evaluate treatment effects. For calf data collected between birth and weaning, contrasts were 1) Feb vs. Apr calving systems and 2) Jun calving system vs. the average of the Feb and Apr calving systems. For data analyzed according to different weaning ages, contrasts were 1) Feb vs. Apr calving system, 2) Jun vs. the average of the Feb and Apr calving systems for 190-d weaning age only, 3) 190- vs. 240-d weaning age for Feb and Apr calving systems, and 4) 140- vs. 190-d weaning age for Jun only.

Statistical analyses of cow BW and BCS data were conducted using the MIXED procedure in SAS. Weigh dates were assigned values of 1 to 5, with 1 = precalving, 2 = calving, 3 = prebreeding, 4 = first weaning, and 5 = second weaning. Cow BW and BCS data were analyzed in a repeated measures model that included weaning age nested within calving system, weigh date, their interaction, and cow age. Year and the year × weaning age within calving system interaction were considered random. The subject for repeated measures was cow within weaning age × calving system × year. An unstructured covariance structure was used.

The effect of previous year's weaning (including 1998) time on cow BW and BCS was tested using the MIXED procedure of SAS on data for multiparous cows. Fixed effects included previous year's weaning assignment nested within calving system, cow age, and their interaction. Random effects included year, the interaction of year × previous year's weaning assignment within calving system, and year × cow age. Contrasts were used to compare weaning at 190 vs. 240 d after calving for the Feb and Apr systems and 140 vs. 190 d after calving for the Jun calving system (Wean 1 vs. Wean 2).

Proportions of cows exhibiting luteal activity by the beginning of the breeding season and pregnant in the fall were analyzed by the CATMOD procedure in SAS. The model included year, calving system, cow age, and the calving system × cow age interaction. The effect of previous year's weaning strategy on current year pregnancy status was tested using a CATMOD model that included cow age, weaning age within calving system, year, and the interaction of cow age × previous weaning age within calving system.

Standing crop data were analyzed using SAS GLM procedures. Main effects for assessing the effects of topographic position on quantity and quality of available forage were location, year, and sample date within year. Total herbage standing crops were estimated for sam-

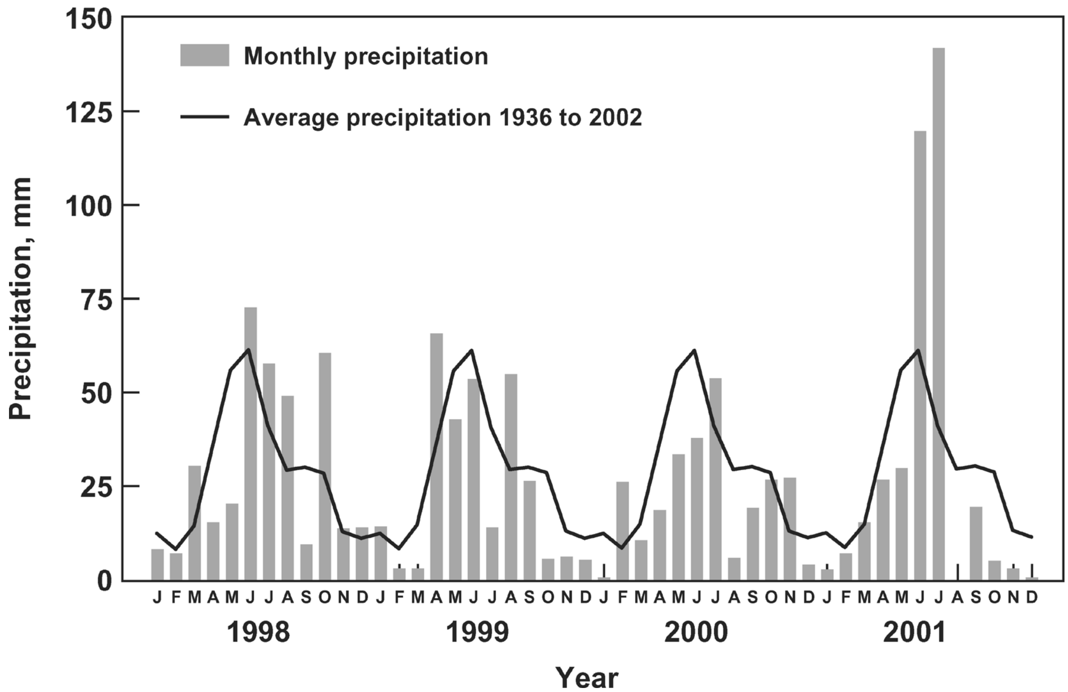

Figure 1. Actual monthly precipitation (bars) from January 1998 to December 2001 at Miles City, MT (NOAA, 1998 to 2001) and long-term average (line) precipitation. Months of the year are abbreviated sequentially by their first letter.

pled pastures by proportionally multiplying estimated topographic site standing crop estimates by topographic composition of pasture (Table A1). These data were ultimately combined with the stocking rate data to estimate a pasture level grazing pressure index (forage demand per unit of forage available). Stocking rate and grazing pressure estimates were analyzed using the MIXED procedures in SAS; calving system was considered a fixed effect, and year and treatment × year interaction were random effects. Mean separation procedures follow Tukey Q procedures, with statistical significance set at P< 0.05.

Results and Discussion

Environmental Conditions

Temperature and precipitation varied among years, thereby altering forage quantity and quality along with winter feed needs. Total precipitation was 18 and 29 mm above the 66-yr average in 1998 and 2001, and 46 and 78 mm below average in 1999 and 2000 (Figure 1).

Figures A1 and A2 provide an indication of the forage conditions under which this study was conducted. Averaged across sample dates, average standing crops were 782, 647, and 1,155 kg/ha for the Upland, Hillside, and Bottomland sites, respectively. Averaged across pastures and sample dates, average CP (DM basis) was 7.7, 6.2, and 7.5% for the Upland, Hillside, and Bottomland sites, respectively. Variations among years and sample dates (Figures A1 and A2) were the result of varying annual patterns of herbage growth and senescence, arising largely from variations in annual patterns of precipitation (Figure 1). These yearly patterns generally agree with previous findings from this location (Heitschmidt et al., 1995, 1999) and across the Northern Great Plains in general (Singh et al., 1983).

Statistical analyses of stocking rates revealed no significant main effects for calving system or year; however, the interaction effects of calving system and year were significant ($P < 0.001$), largely because of differences in the kinds and amounts of harvested feedstuffs used and differing sizes of pastures. An example is presented in Table A1 for April 2001 when stocking rates averaged 0.97, 1.52, and 0.22 AUM/ha for the Feb, Apr, and Jun calving systems, respectively. This was because 1) the Feb calving herd rotated through several pastures and received supplement (2.7 kg·cow^{-1}·d^{-1}) and some alfalfa hay (5.6 kg·cow^{-1}·d^{-1}) from April 1 to April 22, 2) the Apr calving herd was in two medium-sized (<56 ha) crested wheatgrass pastures while being fed alfalfa hay and supplement (22.3 and 2.9 kg·cow^{-1}·d^{-1}, respectively) for the entire month, and 3) the Jun calving herd was receiving no supplementation while grazing native rangeland.

Analyses of the instantaneous grazing pressure estimates derived on the herbage sample dates showed no significant effects including no calving system × year interaction. The data were quite variable, however, for the same reasons outlined above for the stocking rate data.

Finally, although there were no significant main calving system effects for stocking rate or grazing pressure, relative differences in average stocking rates were indicative of the management tactics required to maintain these treatments. For example, for the entire length of the study, the heaviest stocking rate was 0.66 AUM/ha for the Jun calving system, and the lightest was 0.31 AUM/ha for the Feb calving system, with an intermediate stocking rate of 0.40 AUM/ha for the Apr calving system. These differences were largely because of differences among herds in amount of time spent in a nongrazing environment (i.e., under full-feeding conditions). In such instances, stocking rates were considered zero, and thus, average annual stocking rates were lowered. Differences among systems in total quantities of harvested feeds provided show that annual stocking rates will have to be greater for Jun calving systems than for either the Feb or Apr calving system if equal numbers of animals are to be maintained on equivalent areas of rangeland.

We conclude that the three calving herds were managed such that only minor differences in animal performance and productivity can be attributed to differing grazing tactics. This conclusion is reflected by the general absence of any calving system effects relative to stocking rates and grazing pressures.

Diet quality, estimated by CP and IVOMD, was quite variable throughout the year and followed patterns typical of the Northern Great Plains (Adams and Short, 1988), with a peak in June followed by a rapid decrease throughout the growing season as temperatures increased and precipitation decreased. The nutritional environment of beef cows in the late pre- and early post-calving periods is considered critical to efficient reproductive performance (Houghton et al., 1990). Cows from the three calving systems experienced very different nutritional patterns relative to their physiological state, especially during the first 3 to 4 mo after calving, a period that included the breeding season (Figure 2, A and B). Additionally, Jun cows experienced greater forage quality 2 to 3 mo before calving compared with Feb and Apr cows. The data in Figure 2 include nutrient levels from range forage only and do not account for any supplementary or hay feeding that may occur during the winter months. Supplemental feed would effectively increase dietary nutrient concentrations before calving for approximately 3 mo for cows calving in April and for 1 mo for cows calving in Feb. On average, diets were of similar quality between Wean 1 and 2 for the Feb calving herd because of fall precipitation, whereas diet quality decreased between Wean 1 and 2 for the Apr and Jun herds.

Calf Performance

Calving system × year and weaning age within calving system × year interactions were significant ($P < 0.001$) for all calf traits. These yearly variations in calf BW and gain are expected as both cow milk production and quality of forage consumed by calves are affected by precipitation pattern and its effect on quantity and quality of available forage. Year effects and all interactions that included year were considered random effects in this study. Choice of calving season is a long-term decision that does not allow for adjustments associated with yearly variation. Weaning age, however, can be used to adjust production to yearly changes in the environment. This study was conducted over 3 yr that fell within 78 mm of the 338-mm long-term precipitation average and is thereby representative of expected responses for a majority of years.

Calf birth weight averaged 36 kg and did not differ among calving systems (Table 2). Our results tend to disagree with reports that birth weights of summer and fall calves are less than those of winter and spring calves (Donald et al., 1962). As the reported lighter birth weights of summer calves might be related to warmer temperatures, this seasonal effect may have been minimized for the Jun calves, which were born before temperatures became hot and while forage was close to its greatest quality. Calf mortality averaged 3.5% for the Feb calving system compared with 1.5% for both the Apr and Jun calving systems; these data were not analyzed statistically.

Average daily gain by calves from birth to the beginning of the breeding season (approximately 69 d of age) was affected by calving system ($P = 0.02$); Feb calves gained approximately 0.12 kg/d less during this period than Apr or Jun calves (Table 2). However, once diet quality from rangeland improved (Figure 2), gains by these calves increased, as evidenced by the increased rate of gain from 69 d of age until the first weaning. Overall rate of gain from birth to weaning was greater for earlier than for later weaned calves for all calving systems ($P = 0.03$). Differences in the timing and amount of preweaning growth may have minimal effects on mature BW of cows (Holloway and Totusek, 1973) or carcass quality of steers (Morgan, 1972; Patterson et al., 1995) but could potentially affect subsequent milk production in heifers (Johnsson and Obst, 1984).

Calf weaning weight differed by weaning age within calving system ($P < 0.001$; Table 2); younger calves were lighter than calves 50 d older at weaning. When weaned at 190 d of age, calves from the Jun calving system tended ($P = 0.06$) to be lighter than calves from the Feb or Apr calving systems. Average daily gain from 69 d of age to first weaning was not decreased for Jun calves compared with those from Feb and Apr calving systems, indicating that the decreased weaning weight in October for Jun calves is primarily an age effect (i.e., 140 d), whereas the decreased weaning weight observed in December (i.e., 190 d) is a seasonal effect. Declining forage quality resulted in decreases in calf gains with advancing season and was presumably related to both a decrease in milk intake and a decline in quality of forage consumed by the calf (Grings et al., 1996).

Adams et al. (2001) reported decreased weaning weights for June vs. March born-calves raised on Nebraska sandhills rangeland, and similar results were

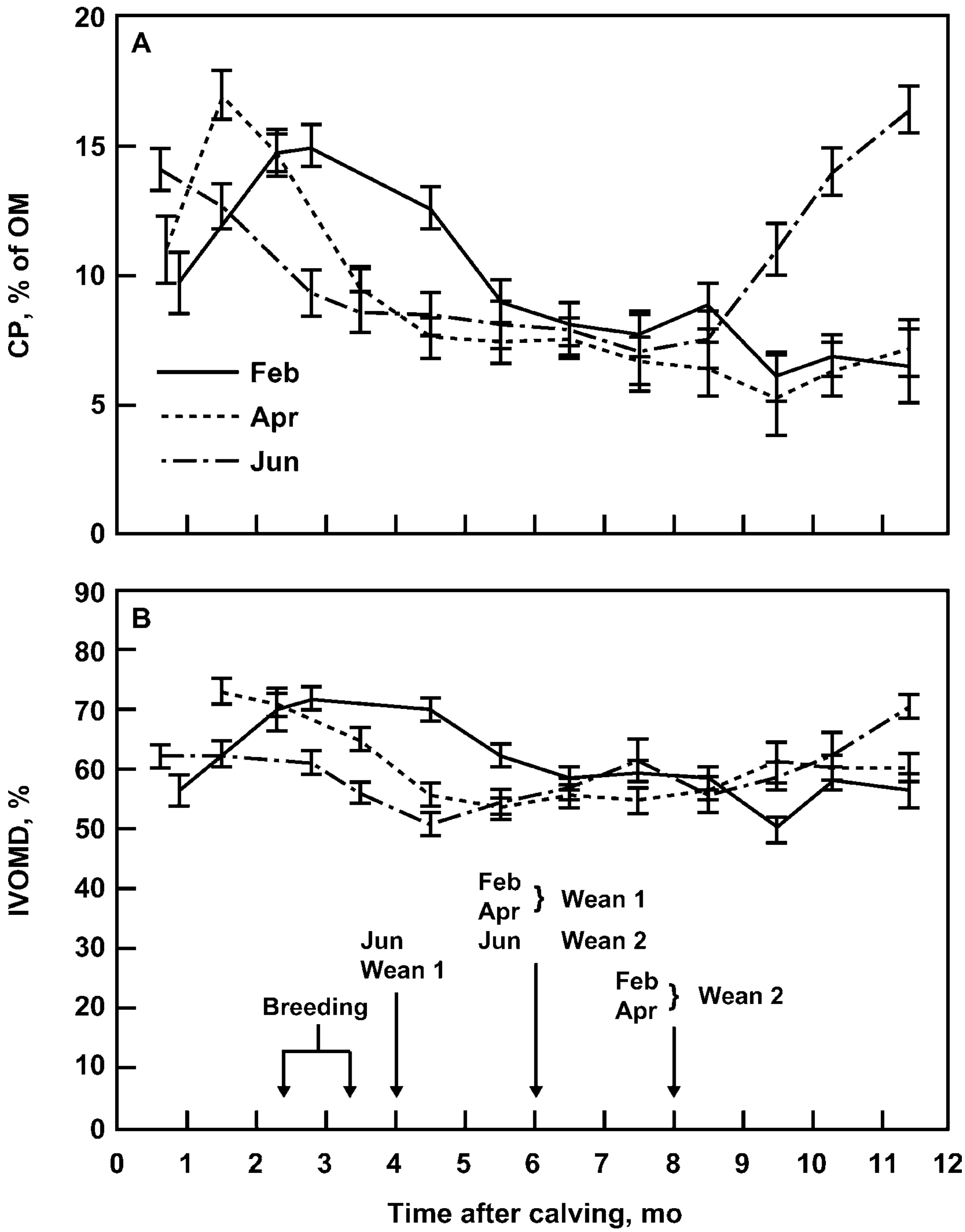

Figure 2. Crude protein (% of OM; Panel A) and in vitro OM disappearance (IVOMD, %; Panel B) of esophageal extrusa samples collected from cows grazing pastures in which Feb, Apr, and Jun calving herds (late winter, early spring, and late spring calving systems, respectively) grazed during April 1998 through December 2001. The graphs illustrate the physiological state of cows in the three calving systems relative to diet quality. Timing of specific management activities is noted along the x-axis.

observed by Smith et al. (2001) for early vs. late spring-born calves on the short-grass prairie of southern Wyoming. Pang et al. (1998) reported decreased preweaning ADG by calves with an average birth date of April 14 compared with May 27 when grazing rangeland in east-central Alberta. The decrease in weaning weights for later-born calves is related to declines in forage quality and different environmental conditions (Figure 1; NOAA, 1998–2001) than those for calves born earlier in the year. Temperature and snow cover also may play a role in decreased weaning weights for calves born and weaned later in the year. For example, in our study there were 26 d of snow cover >2.54 cm in November 2000, which would affect forage availability to December-weaned calves. Average temperature across the 3 yr decreased from 24.3°C in August (Wean 1 for Feb

Table 2. Least squares means of birth weight, preweaning ADG, and weaning weight of calves born in three calving systems and weaned at one of two ages[a]

Item	Calving system[b] Feb		Apr		Jun		Average SE
Birth weight, kg	35		36		38		1.1
ADG from birth to 69 d, kg/d[c]	0.84		0.97		0.95		0.02
ADG from 69 d to first weaning, kg/d	1.03		0.92		0.99		0.07
	Feb		Apr		Jun		
Age at weaning:	190 d	240 d	190 d	240 d	140 d	190 d	
ADG from birth to weaning, kg/d[de]	0.97	0.91	0.94	0.83	0.97	0.85	0.06
Weaning weight, kg[f]	220	265	214	245	173	199	11.0
ADG from first to second weaning, kg/d[g]	0.71	0.75	0.52	0.48	0.42	0.57	0.11

[a]Number of observations and *P*-values for fixed effects: birth weight (n = 1,600): calving system = 0.16, calf sex = 0.001, and cow age = 0.001; ADG from birth to 69 d of age (n = 1573): calving system = 0.02, calf sex = 0.001, and cow age = 0.001; ADG from 69 to first weaning (n = 759): calving system = 0.31, calf sex = 0.001, cow age = 0.001; ADG from birth to weaning (n = 1,507): weaning age within calving system = 0.03, calf sex = 0.01, cow age = 0.001; weaning weight (n = 1,507): weaning age within calving system = 0.001, calf sex = 0.001, and cow age = 0.001; ADG from first to second weaning (n = 1,472): weaning age within calving system = 0.18, calf sex = 0.001, and cow age = 0.36.

[b]Calving systems were late winter (Feb), early spring (Apr), and late spring (Jun).

[c]Contrasts for significant calving system effect: Feb vs. Apr, $P = 0.01$; Jun vs. the average of the Feb and Apr, $P = 0.15$.

[d]Data from calves weaned at 190 d only.

[e]Contrasts for significant weaning age within calving system effect: Feb vs. Apr, $P = 0.11$; Jun vs. the average of Feb and Apr for 190-d weaning age only, $P = 0.02$; 190- vs. 240-d weaning age for Feb and Apr, $P = 0.02$; 140- vs. 190-d weaning age for Jun, $P = 0.01$.

[f]Contrasts for significant weaning age within calving system effect: Feb vs. Apr, $P = 0.11$; Jun vs. the average of Feb and Apr for 190-d weaning age only, $P = 0.06$; 190- vs. 240-d weaning age for Feb and Apr, $P = 0.001$; 140- vs. 190-d weaning age for Jun, $P = 0.03$.

[g]Steer and heifer calves were fed differing diets after weaning, and there were several treatments assigned to each sex for the calves weaned early. Treatments were consistent across calving systems.

calves) to 9.3°C for the October weanings, to –5.2°C in December (Wean 2 for the Apr and Jun calves).

No weaning age within calving system effects for calf ADG between Wean 1 and 2 were observed (Table 2), although ADG ranged from 0.41 to 0.75 kg/d for the various calving and weaning systems. Basarab et al. (1986) reported a substantial decrease in calf BW gain for 1 mo following weaning at approximately 150 to 160 d of age compared with calves kept with their dams on Northern Great Plains native rangeland during this period. The effect was much less in our study, which may be related to a longer period (50 d) between early and late weaning that allowed early weaned calves to recover from the stress of weaning.

Cow Performance

Cow BW change dynamics were affected by calving system. Cow BW exhibited a calving system × cow age × weigh day interaction ($P < 0.001$), as shown in Figure 3. The pattern of BW change was similar by calving system for 3-yr-old cows and those ≥4 yr of age. The Feb cows lost BW ($P < 0.001$) between calving and the beginning of the breeding season, whereas Apr cows were able to take advantage of high-quality forage in late spring to gain BW ($P < 0.001$) between calving and breeding. Two-year-old cows showed less difference in BW relative to calving system than older cows, and there was a notable difference in the BW response around calving for Jun cows of different ages. Older Jun cows exhibited a limited BW change throughout the year, whereas 2-yr-old cows lost BW ($P = 0.006$) between the precalving and calving BW measures and weighed less ($P = 0.04$) than Apr 2-yr-old cows at breeding. In contrast, older Jun and Apr cows were similar in BW and heavier ($P < 0.001$) than Feb cows at breeding.

Deutscher et al. (1991) compared a March 1 to April 1 calving date for range cows in the Sandhills of Nebraska and found equivalent cow productivity when calves were weaned at equivalent ages. They reported that April-calving cows lost less BW between precalving and prebreeding than did March-calving cows, and that the April-calving cows were heavier at prebreeding, which would be consistent with the BW relationships we observed for Feb and Apr cows between precalving and prebreeding. Bellido et al. (1981) reported greater fluctuations in cow BW for early calving (comparable with the Feb and Apr cows calving early in the season in our study) than late-calving cows (comparable with Apr cows calving late in the season and Jun calving cows in our study) grazing New Mexico rangeland.

Body condition score followed the same trend as BW for cows in the three calving systems (Figure 3). Calving system × cow age × date interactions ($P < 0.001$) occurred, as were observed with BW (Figure 3). For older cows, BCS before (Feb, $P < 0.001$; Apr, $P = 0.056$) and

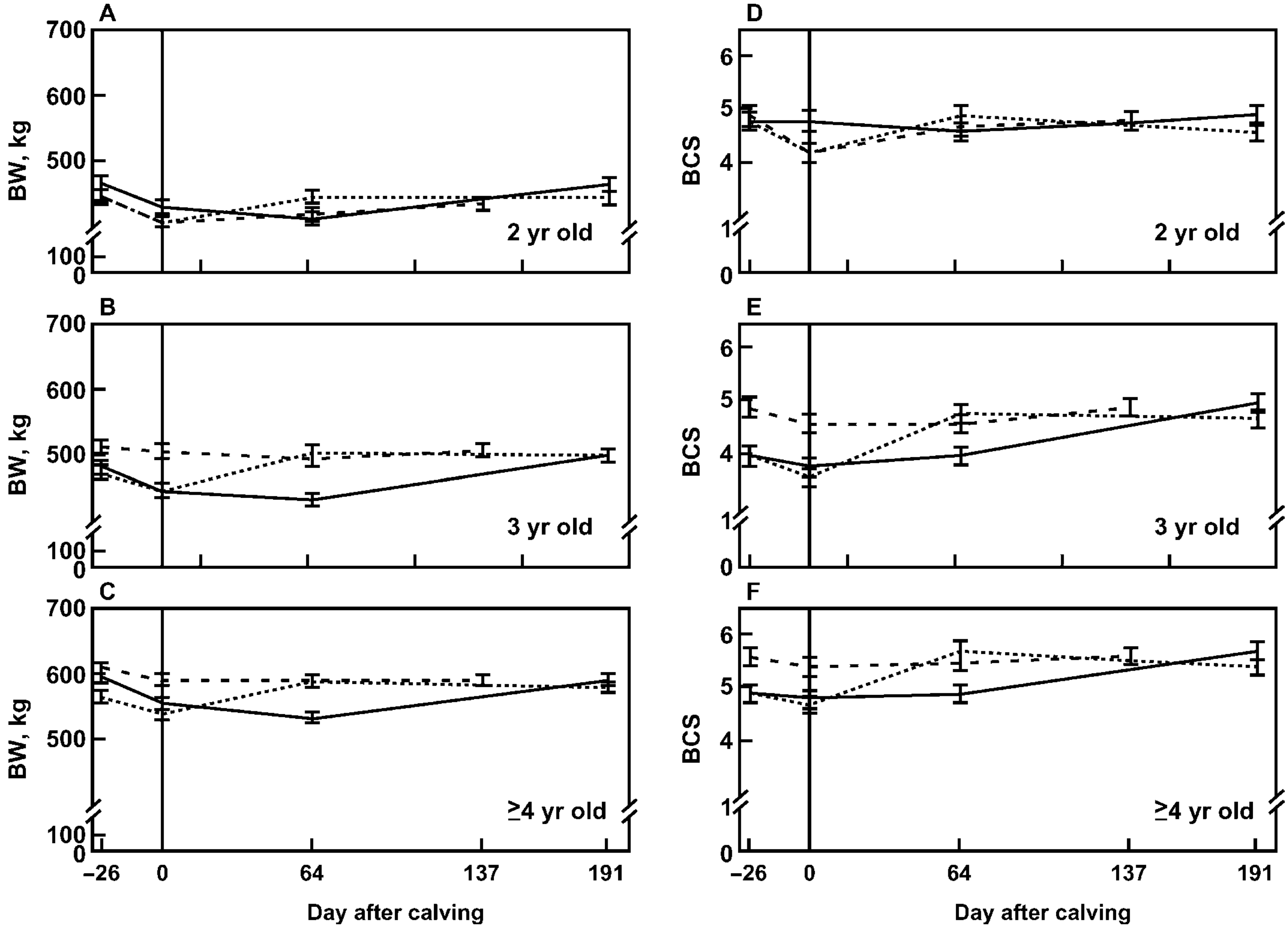

Figure 3. Body weight (±SE; Panels A, B, and C) dynamics of 2- (Panels A and D), 3- (Panels B and E), and ≥4-yr-olds (Panels C and F) and BCS (scale 1 = emaciated to 9 = obese; Panels D, E, and F) of beef cows managed for calving in late winter (Feb; solid line, ——), early spring (Apr; long dashed line, — — —, or late spring (Jun; short dashed line, – – – –, to weaning at 190 (Feb, Apr) or 140 d after calving (Jun). The BW and BCS data were taken approximately 26 d before calving, within 48 h after calving, at 65 d after calving, and at either 140 or 190 d after calving.

at calving (Feb and Apr; both $P < 0.001$) were lower for the Feb and Apr cows than at the previous fall's weaning (Figure 3; Table 3), whereas Jun cows had similar BCS at calving and at previous weaning. This finding indicates the increased resiliency of older cows in early gestation to winter conditions in the Northern Great Plains compared with cows in late- (Feb) and mid-gestation (Apr). Two-yr-old Jun cows, however, lost more ($P < 0.001$) condition than older cows between the precalving and calving condition scorings, which is consistent with their BW change patterns. Our intent was to have all cows at a condition score of approximately 5 at calving to compare the feed inputs required to carry cows through the winter on an equal condition basis; however, we underestimated this point for the Feb and Apr cows, primarily in response to rapid changes in BCS associated with severe winter storms. Older Jun cows were able to withstand winter conditions with less variation in BW and body condition.

Cows suckled for an additional 60 d weighed less ($P < 0.001$) and either gained less or lost more BW ($P < 0.001$) than cows weaned earlier (Table 3). Condition score showed a similar tendency ($P = 0.08$). Effects on condition score were moderated by the relatively short (50 d) period between the two weaning times. Decreasing temperatures, along with declining diet quality, affected the BW and BCS responses to weaning by cows from the different calving systems. Additionally, Jun cows were in an earlier stage of lactation under similar environmental conditions than the Apr suckled cows, resulting in greater BW loss.

The proportion of cows with a functional CL by the beginning of the breeding season differed ($P < 0.001$) by calving system, with a greater proportion of cows in the Jun calving system exhibiting luteal activity early in the breeding season. The proportion of cows exhibiting luteal activity by the beginning of the breeding season from the three calving systems was Feb, 0.68 ±

Table 3. Least squares means for cow BW and BCS and changes in relation to the current year's weaning strategy (n = 1,458 for all measures)[a]

	Calving system[b]						
	Feb		Apr		Jun		
	190 d[c]	240 d	190 d	240 d	140 d	190 d	SE
Cow BW, kg							
At Wean 2[d]	546	523	512	496	514	484	21
Change from Wean 1 to Wean 2	23	4	2	−13	−3	−30	12
Cow BCS							
At Wean 2	5.2	4.8	4.9	4.4	5.0	4.4	0.3
Change from Wean 1 to Wean 2	0.1	−0.3	−0.2	−0.5	−0.4	−0.6	0.3

[a]*P*-values for fixed effects: cow BW: weaning age within calving system = 0.001, cow age = 0.001, and cow age × weaning age within calving system = 0.36; cow BW change: weaning age within calving system = 0.001, cow age = 0.09, and cow age × weaning age within calving system = 0.001; cow BCS: weaning age within calving system = 0.08, cow age = 0.005, and cow age × weaning age within calving system = 0.63; and cow BCS change: weaning age within calving system = 0.28, cow age = 0.14, and cow age × weaning age within calving system = 0.41.
[b]Calving systems were late winter (Feb), early spring (Apr), and late spring (Jun).
[c]Row data indicate calf age at weaning.
[d]Wean 1 = 190 d after calving for Feb and Apr and 140 d after calving for Jun; Wean 2 = 240 d after calving for Feb and Apr and 190 d after calving for Jun.

0.02; Apr, 0.72 ± 0.20; and Jun, 0.86 ± 0.02. Additionally, an effect of cow age was observed ($P < 0.001$), with a greater proportion of cows ≥4 yr of age having functional CL by the beginning of the breeding season (0.82 ± 0.01) than 2- (0.79 ± 0.03) or 3-yr-old (0.60 ± 0.02) cows. No interaction between calving system and cow age occurred for this response.

Date of birth within a season did not differ among calving systems, indicating that although there were more cows exhibiting luteal activity at the beginning of the breeding season, this was not associated with more cows becoming pregnant early in the season. This result may be because of the response to injection of prostaglandin at 7 d into the breeding season.

The proportion of cows pregnant in the fall averaged 0.86 and did not differ among calving systems. A tendency ($P = 0.09$) for a calving system × cow age interaction was observed (Table 4), which was primarily related to an increased proportion of 3-yr-old cows in the Jun calving system being pregnant compared with the Feb and Apr calving systems. Bellido et al. (1981) also observed no effect of calving season on pregnancy rates in New Mexico, except in a drought year, when late-calving cows had higher pregnancy rates than early calving cows.

Bellows and Short (1978) suggested that, for cows calving earlier in the year, feed levels before and after calving are inadequate for short postpartum, anestral periods. Our cow BW change data support this suggestion, in that Feb cows were at their lightest BW at breeding, whereas Apr and Jun cows were able to utilize high-quality, late-spring forage for BW gain and were heavier than Feb cows at breeding. Photoperiod and temperature effects also may influence the length of the postpartum interval; these effects are more evident under conditions of limited nutrition (Montgomery et al., 1985). Although the cow BW data support the theory that feed levels may be less than optimum when calving early in the year in the Northern Great Plains, pregnancy rates did not differ for the Feb cows compared with those in other calving systems. Precalving nutrient intake was modified by use of harvested feedstuffs such as hay and pelleted supplements, so that total available nutrients for Feb and Apr cows were greater than indicated by the extrusa quality graph. Increased reliance on harvested feedstuffs can increase total cost of production. Because of the short-term nature of the experiment, the location's farming system was not adjusted to fit a particular calving system. With the change of an entire operation to a specific calving sea-

Table 4. Proportion of cows pregnant at fall palpation for 2-, 3- and ≥4-yr-old cows from three calving systems (±SE)

Calving system[a]	Cow age, yr 2	3	≥4
Feb	0.776 ± 0.043	0.802 ± 0.042	0.880 ± 0.019
Apr	0.760 ± 0.043	0.792 ± 0.040	0.931 ± 0.015
Jun	0.805 ± 0.044	0.882 ± 0 039	0.877 ± 0.017

[a]Calving systems were late winter (Feb), early spring (Apr), and late spring (Jun). *P*-value for calving system × cow age interaction = 0.09.

Table 5. Approximate harvested feed inputs (kg of DM per cow) and chemical composition of feeds used in three rangeland-based calving systems for beef cows in the Northern Great Plains averaged over 3 yr

Item	Protein supplement	Grain supplement	Alfalfa pellets	Hay: Sudan	Hay: Oat	Hay: Grass	Hay: Alfalfa	Corn silage	Rolled barley
Calving system[a]	(kg of DM·cow^{-1}·yr^{-1})								
Feb	44	97	9	57	11	17	681	211	14
Apr	56	70	38	189	127	119	554	47	0
Jun	19	19	42	222	96	42	111	0	0
Chemical composition	(% of DM)								
CP	35.1	15.9	20.8	8.1	10.6	9.3	18.4	7.2	14.1
ADF	22.1	9.8	33.1	38.7	36.8	38.8	36.2	26.1	8.1

[a]Calving systems were late winter (Feb), early spring (Apr), and late spring (Jun).

son, alterations in harvested feed management could be made to make greater changes in the feeding strategies for each system than we used in this experiment.

Previous year's weaning status had minimal effects on cow performance. Significant differences caused by previous year's weaning within calving system for cow BCS through weaning were due to differences across calving systems but not within (data not shown). The proportion of cows pregnant in the fall also was unaffected by previous year's weaning status and the interaction of cow age with previous weaning status within calving system.

Estimated feed inputs were less for Jun cows than for Feb and Apr cows (Table 5). In addition to a lesser quantity of feed, a different quality of feed was provided to these cows because of different nutritional demands during the winter feeding period. Both the quantity and type of feeds can affect feed costs. There was more variation in the amount of harvested feeds provided to Jun cows among years than for other herds. The winter of 1999 to 2000 was relatively mild, and rangeland was free of snow much of the winter. Additionally, fall precipitation stimulated growth of some of the annual and cool-season grasses, such that winter forage quality was increased, and no supplemental feed was provided to the Jun cows throughout the entire winter (Figure 4). The following winter, however, rangeland was covered in snow by November, and it remained so until April, resulting in a need to provide harvested feeds to the Jun cows throughout the entire winter. These results indicate some risk with the Jun cows, in that a full winter of feed should be planned for, yet may not be required.

Feed costs should be weighed against calf prices and marketing strategies to determine optimum calving time. The effects of trading harvested feed for grazing of native forage need to be considered in determining the herd size for a fixed forage base for each calving season strategy. Other management scenarios may be appropriate and will depend on the resource availability

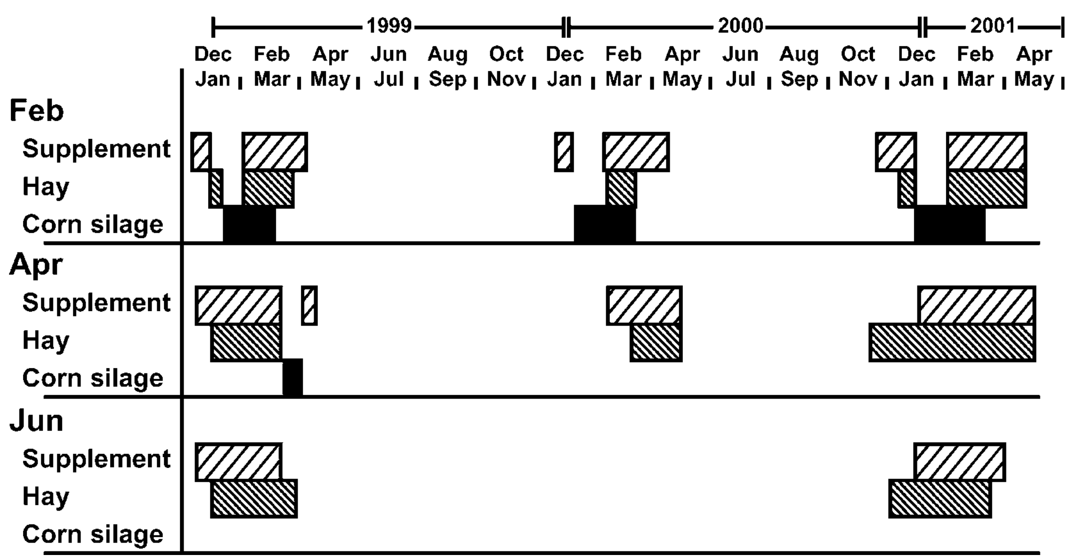

Figure 4. Timing of harvested feed inputs to Feb, Apr, and Jun calving systems (late winter, early spring, and late spring systems, respectively) in the Northern Great Plains from December 1998 through May 2001. No additional harvested feeds were provided between May 2001 and the termination of the study in December 2001.

of an operation. The choice of management strategy affects all aspects of a particular operation, including labor needs, farming goals, and marketing objectives.

Literature Cited

Adams, D., D. Clark, R. Sandberg, G. Carriker, T. Klopfenstein, and T. Milton. 2001. June vs. March calving for the Nebraska sandhills: Production traits. Pages 8–9 in 2001 Nebraska Beef Report, Agric. Res. Div., Univ. of Nebraska Coop. Ext., Inst. Agric. Nat. Res. Univ. of Nebraska, Lincoln.

Adams, D. C., and R. E. Short. 1988. The role of animal nutrition on productivity in a range environment. Pages 37–45 in Achieving Efficient Use of Rangeland Resources. R. S. White and R. E. Short, eds. Fort Keogh Res. Symp, Miles City, MT.

AOAC. 1990. Official Methods of Analysis, 15th ed. Assoc. Off. Anal. Chem., Arlington, VA.

Basarab, J. A., F. S. Novak, and D. B. Karren. 1986. Effects of early weaning on calf gain and cow performance and influence of breed, age of dam and sex of calf. Can. J. Anim. Sci. 66:349–360.

Bellido, M. M., J. D. Wallace, E. E. Parker, and M. D. Finkner. 1981. Influence of breed, calving season, supplementation and year on productivity of range cows. J. Anim. Sci. 52:455–462.

Bellows, R. A., and R. E. Short. 1978. Effects of precalving feed level on birth weight, calving difficulty and subsequent fertility. J. Anim. Sci. 46:1522–1528.

Deutscher, G. H., J. A. Stotts, and M. K. Nielsen. 1991. Effects of breeding season length and calving season on range beef cow productivity. J. Anim. Sci. 69:3453–3460.

Donald, H. P., W. S. Russell, and C. S. Taylor. 1962. Birth weights of reciprocally cross-bred calves. J. Agric. Sci. (Camb.) 58:405.

Grings, E. E., R. E. Short, T. W. Geary, and M. D. MacNeil. 2002. Heifer development within three seasons of calving. Proc. West. Sec. Am. Soc. Anim. Sci. 53:261–264.

Grings, E. E., R. E. Short, M. D. MacNeil, M. R. Haferkamp, and D. C. Adams. 1996. Efficiency of production in cattle of two growth potentials on Northern Great Plains rangelands during spring-summer grazing. J. Anim. Sci. 74:2317–2326.

Heitschmidt, R. K., E. E. Grings, M. R. Haferkamp, and M. G. Karl. 1995. Herbage dynamics on two Northern Plains range sites. J. Range Manage. 48:211–217.

Heitschmidt, R. K., M. R. Haferkamp, M. G. Karl, and A. L. Hild. 1999. Drought and grazing: I. Effects on quantity of forage produced. J. Range Manage. 52:440–446.

Herd, D. B., and L. R. Sprott. 1986. Body condition, nutrition and reproduction of beef cows. Texas A&M Univ. Ext. Bull. 1526, College Station.

Holloway, J. W., and R. Totusek. 1973. Relationship between preweaning nutritional management and the growth and development of Angus and Hereford females. J. Anim. Sci. 37:800–806.

Houghton, P. L., R. P. Lemenager, L. A. Horstman, K. S. Hendrix, and G. E. Moss. 1990. Effects of body condition, pre- and postpartum energy level and early weaning on reproductive performance of beef cows and preweaning calf gain. J. Anim. Sci. 68:1438–1446.

Johnsson, I. D., and J. M. Obst. 1984. The effects of level of nutrition before and after 8 months of age on subsequent milk and calf production of beef heifers over three lactations. Anim. Prod. 38:57–68.

Julien, D. J., and M. W. Tess. 2002. Effects of breeding date, weaning date, and grazing season length on profitability of cow-calf production systems in southeastern Montana. J. Anim. Sci. 80:1462–1469.

Kuchler, A. W. 1964. Potential natural vegetation of the coterminous United States. Am. Geogr. Soc. Spec. Pub. 36, New York, NY.

Montgomery, G. W., I. C. Scott, and N. Hudson. 1985. An interaction between season of calving and nutrition on the resumption of ovarian cycles in post-partum beef cattle. J. Reprod. Fertil. 73:45–50.

Morgan, J. H. L. 1972. Effect of plane of nutrition in early life on subsequent live-weight gain, carcass and muscle characteristics and eating quality of meat. J. Agric. Sci. (Camb.) 78:417–423.

Mortenson, M. C. 2003. Effects of interseeded alfalfa (*Medicago sativa* ssp. *falcata*) on forage production, forage quality, and carbon sequestration on a mixed-grass rangeland. M.S. Thesis, Univ. Wyoming, Laramie.

NOAA. 1998–2001. Climatological data, Montana. 101–104(01–12). National Oceanic and Atmospheric Administration, Natl. Climatol. Data Ctr. Asheville, NC.

Pang, H., M. Makarechian, L. A. Goonewardene, and R. T. Berg. 1998. Effects of early versus late spring calving on beef cow-calf productivity. Can J. Anim. Sci. 78:249–255.

Patterson, D. C., R. W. J. Steen, and D. J. Kilpatrick. 1995. Growth and development in beef cattle. 1. Direct and residual effects of plane of nutrition during early life on components of gain and food efficiency. J. Agric. Sci. (Camb.) 124:91–100.

Reisenauer, V. L., M. W. Tess, D. A. Griffith, and J. A. Paterson. 2001. Evaluation of calving seasons and marketing strategies in Northern Great Plains cow-calf enterprises. Proc. West. Sec. Am. Soc. Anim. Sci. 52:50–54.

Singh, J. S., W. K. Laurenroth, R. K. Heitschmidt, and J. L. Dodd. 1983. Structural and functional attributes of the vegetation of northern mixed prairie of North America. Bot. Rev. 49:117–149.

Smith, M. A., J. W. Waggoner, D. M. Perry, R. H. Hart, and G. Younglove. 2001. Late spring calving lowers cow wintering costs with minimal impact to calf performance. Proc. West. Sec. Am. Soc. Anim. Sci. 52:231–233.

Tilley, J. M. A., and R. A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Br. Grassl. Soc. 18:104-111.

APPENDIX

Table A1. Estimated hectares, herbage standing crop, percent of % CP by site (Upland, Hillside, Bottomland), and estimated whole pasture average standing crop, herbage CP, and estimated dietary CP (DM basis)

	Site											
	Upland			Hillside			Bottomland			Whole pasture		
Calving system[a]	Area, ha	Quantity, kg/ha	% CP	Area, ha	Quantity, kg/ha	% CP	Area, ha	Quantity, kg/ha	% CP	Quantity, kg/ha	% CP	Diet, % CP
Feb	269	451	11.8	140	265	9.8	56	818	9.9	439	11.0	21.7
Apr	54	704	14.3	0	0	0	1	NS[b]	NS	704	14.3	NS
Jun	492	428	14.0	202	681	6.6	85	652	11.2	518	11.1	12.5

[a]Calving systems were late winter (Feb), early spring (Apr), and late spring (Jun).
[b]NS = no sample.

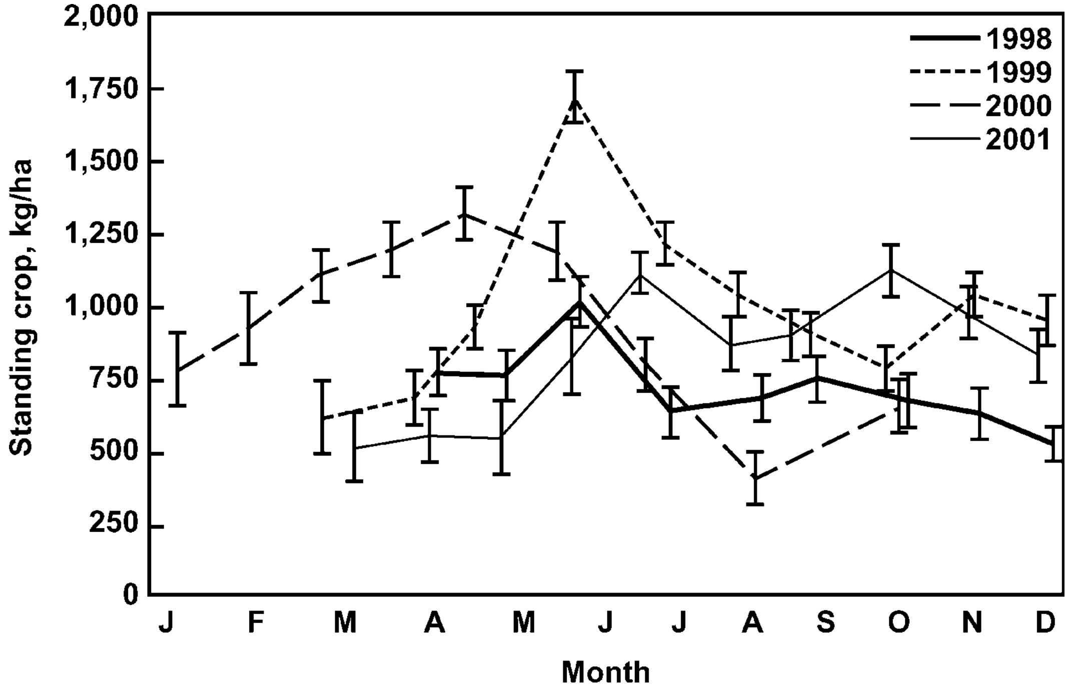

Figure A1. Average (±SE) herbage DM standing crop (kg/ha) for 41 sample dates across 4 yr. The average is for triplicate Upland, Hillside, and Bottomland sites in pastures used in Feb, Apr, and Jun calving systems (late winter, early spring, and late spring systems, respectively). Months of the year are abbreviated sequentially by their first letter.

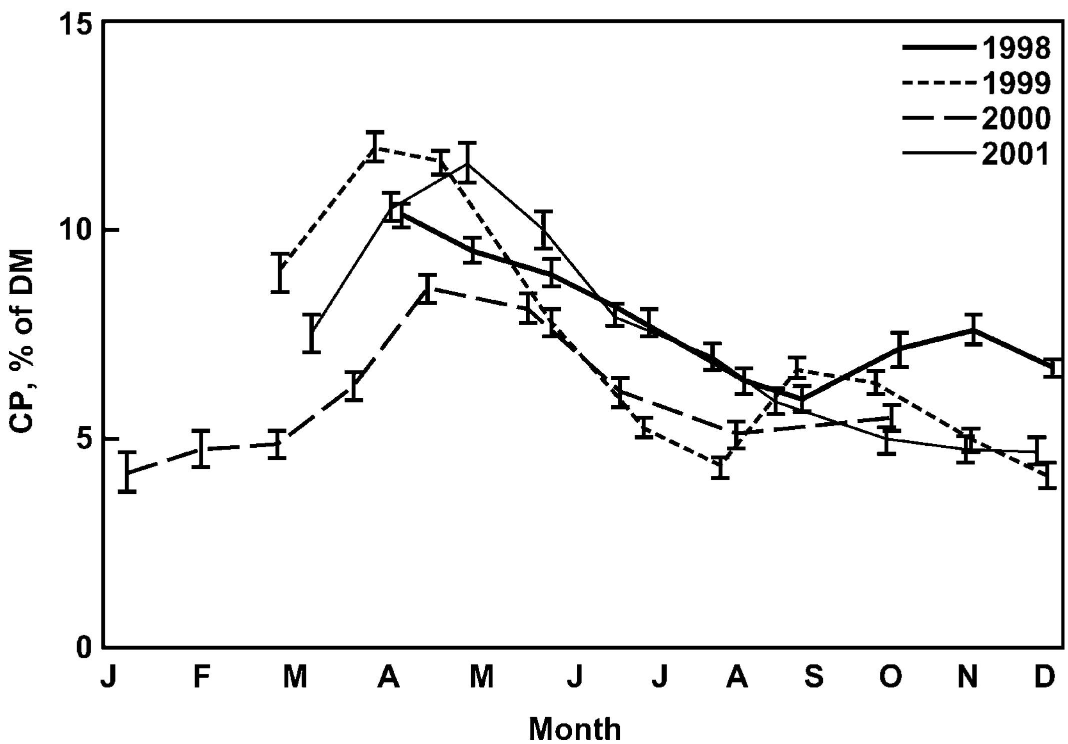

Figure A2. Average (±SE) herbage CP (%, DM basis) for 41 sample dates across 4 yr. The average is for triplicate Upland, Hillside, and Bottomland sites in pastures used in Feb, Apr, and Jun calving systems (late winter, early spring, and late spring systems, respectively). Months of the year are abbreviated sequentially by their first letter.