Effect of date of first calving in beef heifers on lifetime calf production
by John Leo Lesmeister

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Animal Science
Montana State University

Abstract:
Records on 2036 calves born to 85 Angus and 396 Hereford cows from 1950 to 1968 at the Bozeman and Havre, Montana Agricultural Experiment Stations were analyzed by the method of least-squares to determine the effect of birth date on calf performance from birth to weaning and the effect of the date of first calving in beef heifers on subsequent calving dates. All calves were born in the spring and weaned at the same time in October or November of each year.

An initial calving group was determined for each heifer based on the birth date of her first calf relative to the turn-in date of the calf's sire at the previous breeding season. The expected calving season was divided into 21-day periods. Group 1 consisted of all cows that calved as heifers in the first 21 days of the expected calving season. Groups 2 through 6 consisted of cows calving first in subsequent 21-day intervals during the calving season.

A subsequent calving group was assigned to each additional calf from the same cow based on the calf's birth date relative to the breeding season as previously described. Consequently, a cow would be in one initial, calving group all of her life based on the birth date of her first calf and would have additional calves in any subsequent calving group.

Calving group significantly ($P<.01$) affected calf weaning weight with a continual decline in average weaning weights for calves born in subsequent later calving groups, Calves born earlier also grew significantly faster [($P<.05$) at Bozeman and ($P<.0l$)] at Havre from birth to weaning than later calves. The initial calving group significantly ($P<.01$) affected the weaning weights of all calves produced by a cow. Earlier calving first-calf heifers weaned heavier calves throughout their lifetimes than later calving first-calf heifers. The initial calving group significantly ($P<.05$) affected the subsequent calving groups. Heifers calving in Groups 1, 2 and 3 the first time calved earlier throughout their productive lives than heifers calving in Groups 4, 5 or 6 the first time. The repeatability estimates for calving group among the Bozeman and Havre cows were 0.092 and 0.105, respectively. Cows calving first as two-year-olds had higher average annual production as well as higher total lifetime production than cows calving first as three-year-olds.

The study indicates the importance of managing and breeding heifers to calve early and to maintain the "habit" of calving early in the normal calving season throughout their productive lives for maximum economic profit to the cow-calf operator.

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Date August 3, 1970

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by

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A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE

in

Animal Science

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Bozeman, Montana

August, 1970

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. Peter J. Burfening for his advice, assistance and guidance throughout his graduate program. Appreciation is also extended to Dr. Robert L. Blackwell and Dr. Edward L. Moody for their advice and encouragement throughout his graduate program.

The author extends his thanks to Dr. William J. Dorgan, Dr. Samuel J. Rogers, Dr. Ervin P. Smith, Professor A. E. Flower, Roger V. Stewart and Donald C. Anderson for their assistance during the course of this study.

A sincere thank you is expressed to Frankie Larson for her help in typing the manuscript.

The author expresses his grateful and sincere appreciation to his wife, Carol, for her assistance in preparing this manuscript. Without her help, understanding, and encouragement, this thesis would have been much more difficult.

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ABSTRACT

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The study indicates the importance of managing and breeding heifers to calve early and to maintain the "habit" of calving early in the normal calving season throughout their productive lives for maximum economic profit to the cow-calf operator.

INTRODUCTION

The relentless economic pressure to increase performance and production efficiency in the beef cattle industry necessitates more information on the relative importance of environmental and management factors that cause differences in the total lifetime production from each cow.

Calves from a range cow-calf operation are usually sold in a group at a specific time, rather than at a specific individual weight. Therefore, the calves born later in the calving season are usually lighter weight when sold. To assure a profit, the rancher must sell the largest weight of calf per cow bred that is economically feasible. Hence, the question arises whether there is any tendency for certain cows to repeatedly produce either early or late calves and, ultimately, have a higher or lower total lifetime calf production. If so, can these cows be detected at an early age and to what extent is the birth date of the first calf a permanent characteristic of the cow? How much culling can accurately be done on the basis of the first calf produced?

With these questions in mind, a study was conducted to determine the effect of the date of first calving in beef heifers on subsequent calving dates and to determine the effect of birth date on calf performance from birth to weaning. The resulting information provides evidence from which conclusions may be drawn concerning the above questions and other questions directly associated with them.

REVIEW OF LITERATURE

I. Factors Affecting Calf Production and Performance

The managerial ability of a commercial cow-calf operator is ultimately expressed each year in the pounds of calf weaned per cow bred.

Many factors influence calf weaning weights and other aspects of calf production and performance. For the most part, it appears that sex of calf, age of dam, age of calf at weaning and pre-weaning growth rate have the greatest influence on calf weight at weaning. Year of calf birth, cow line or breed, age of the heifer at first calving and birth weight of the calf may also affect weaning weight.

Effect of year on weaning weight

Years appear to show an effect on production as significant as any other factor reviewed. The year calves were born had a significant influence on their weaning weights in studies made by Shelby, Clark and Woodward (1955). Marchello (1960), using 26 years of data from the North Montana Branch Experiment Station, found a significant year effect on birth and weaning weights. Pahnish *et al*. (1964) found that year significantly affected ($P < .01$) weaning weight but not birth weight. The effect of year on calf growth rate and weaning weight appears to be greatly influenced by rainfall and grazing conditions, according to Guilbert (1930), Lush *et al*. (1930), Parr (1930), Woolfolk and Knapp (1949), Baker *et al*. (1953), Botkin and Whatley (1953), Bellows (1966), Hafez (1968) and Bosman and Harwin (1969).

Effect of cow line and breed on weaning weight

Flower *et al*. (1963), using North Montana Branch Experiment Station data, reported that line effects were highly significant for birth weights and weaning weights in heifer calves where both crosslines and inbred lines were included. Stonaker (1958) also found considerable variation in the performance of different inbred lines and their crosses. Nelms and Bogart (1956) reported a significant difference ($P \leq .05$) in pre-weaning growth rate between purebred Angus and Hereford calves but not among the three lines represented in the Hereford breed.

Effect of age at first calving on weaning weight

Urick (1958) found no significant difference in the subsequent annual performance of cows calving first as two-year-olds versus those calving first as three-year-olds in a study of 20 years of data at the North Montana Branch Experiment Station. Withycombe, Potter and Edwards (1930) reported similar results from six years of data collected at the Oregon Agricultural Experiment Station. Chapman and Dickerson (1936) studied calving and production records of 253 Holstein cows from 40 herds in Wisconsin and found no significant differences in monthly milk production over five lactations between cows calving first at 24 months or 36 months of age.

Effect of calf birth weight on weaning weight

Most studies have shown that, within a breed, there is a tendency for calves that are heavier at birth to be heavier at weaning. Factors that influence the birth weight of calves include breed or cow line, sex of calf, age of dam and length of gestation. The tendency for a positive correlation between the birth and weaning weights of calves is to be expected, since birth weight is a component of weaning weight and both traits are affected in the same direction by the sex of the calf and the age of the dam.

Calf birth weights differ among lines within a breed as well as among breeds. Brinks, Clark and Kieffer (1965) found a marked depression in calf birth and weaning weights due to inbreeding of the calf and dam. Likewise, the inbreeding of the calf had a more pronounced effect on females than on males. Nelson and Lush (1950) reported a decrease of 0.125 pound in birth weight of Holstein-Friesian calves for each one percent increase in inbreeding. Sutherland and Lush (1962) reported a decrease of 0.2 pound in birth weight for each one percent increase in inbreeding from data on 25 years of mild inbreeding of Holstein-Friesian cattle. Foote, Tyler and Casida (1959) studied 536 gestations of 258 Holstein cows with the average inbreeding of their calves being 24.9 percent. They concluded that the inbreeding of the calf significantly affected birth weight but not gestation length.

Conversely, Alexander and Bogart (1959, 1961) studied the relative effects of selection and inbreeding on 280 beef calves in four inbred lines and found no effect of inbreeding on birth weight. Anderson (1966) reported that the inbreeding of the calf had no significant effect on the birth weight of the calf in a study of 14 years of data from three closed lines of Hereford cattle at the North Montana Branch Experiment Station. Bovard, Priode and Harvey (1963) reported similar observations in beef calves.

Bull calves tend to be heavier at birth than heifer calves, within a breed. Bull calves averaged approximately 5 pounds heavier at birth than heifer calves in studies by Knapp, Lambert and Black (1940); Knapp et al. (1942); Dawson, Phillips and Black (1947); Woolfolk and Knapp (1949); Gregory, Blunn and Baker (1950); Burris and Blunn (1952); Koch and Clark (1955a); Clark et al. (1958); Foote et al. (1959); Koch et al. (1959); Tallis, Klosterman and Cahill (1959); and Flower et al. (1963).

According to Nelms and Bogart (1956), the difference in pre-weaning gains exhibited by the two sexes is largely due to a difference in birth weight. The males are heavier at birth and carry that advantage through the suckling period. Also, the larger calves at birth gain more rapidly during the suckling period. Their study showed a regression coefficient for pre-weaning rate of gain on birth weight to be 0.0115. This indicates that for each 10 pound increment in birth weight there is an associated difference in rate of gain of 0.115 pounds per day from birth to weaning. Thus, bull and heifer calves of the same birth weight gain at approximately the same rate from birth to weaning. These results are in agreement with those reported by Stanley (1938); Knapp, Baker and Quesenberry (1942); and Neville (1962). Gregory et al. (1950) reported highly significant correlations of 0.27 and 0.60 for weaning weight with birth weight of Hereford calves in two herds. They also found correlations of 0.07 and 0.44 for pre-weaning gain with birth weight. Cartwright and Warwick (1955) reported a correlation coefficient of 0.31 between the birth and weaning weights of beef calves. Flock, Carter and Priode (1962) reported correlations of 0.30, 0.24 and 0.15 for average daily gain from birth to weaning with birth weight in Angus, Hereford and Shorthorn calves, respectively. All of the data were adjusted for age of dam, year, month of birth and sex of calf. None of the calves in the studies described above were creep fed.

Dawson et al. (1947) found birth weight increased 0.2 pound for each month increase in age of dam up to six years of age, after which age of dam had no effect on birth weight. Calf birth weights continually increased from cows up to four years of age in a study by Knapp et al. (1942); up to five years of age in studies by Botkin and Whatley (1953) and Clark et al. (1958); and up to six years of age in a study by Koch and Clark (1955a). Cows from six to eight years of age usually produce calves with the heaviest birth weights according to Vinke and Dickson (1933); Knapp et al. (1942); Dawson et al. (1947); Woodward, Clark and Cummings (1947); and Braude and Walker (1949).

According to Burris and Blunn (1952), the average gestation length for Angus and Hereford cattle is 281.7 and 286.1 days, respectively. These differences were highly significant statistically as were the mean birth weights of calves from those cows. Differences in gestation length accounted for 7.9 percent of the variation in calf birth weight. About 10 percent of the sex difference in birth weight was attributable to the difference in gestation length between the two sexes. The gestation period for bull calves is one to five days longer than for heifer calves. Similar relationships between sex, gestation length and birth weight have been reported by Eckles (1919); Dawson et al. (1947); Herman, Spalding and Bower (1953); and Rice, Kelley and Lasley (1954).

Knapp et al. (1940) found a significant tendency ($P \leq .01$) for individual cows to have a characteristic gestation length which was not significantly influenced by sex of the calf. Birth weight increased with increasing gestation length.

Effect of sex of calf on weaning weight

Sex has had a significant influence on weaning weight in most studies. Bulls are usually heaviest at weaning with steers and heifers following in that order. Bull calves were 68 pounds heavier than heifer calves at 240 days of age in a study by Rollins and Guilbert (1954) and 44 pounds heavier than heifer calves at 176 days of age in a study by Koch (1954). Bull calves were found to be 20 to 30 pounds heavier than heifer calves at weaning by Botkin and Whatley (1953); Burgess, Landblom and Stonaker (1954); Rice, et al. (1954); Evans et al. (1955); Koch and Clark (1955a); Marlowe and Gaines (1958); and Flower et al. (1963). Bull calves were found to be 30 to 50 pounds heavier than heifer calves at weaning by Koch (1951), Southwell and Warwick (1956), Clark et al. (1958), and Pahnish et al. (1961).

Bull calves were 5, 20 and 36 pounds heavier than steer calves at weaning in studies reported by Evans et al. (1955), Burgess et al. (1954), and Clark et al. (1968), respectively.

Koger and Knox (1945) found that steer calves averaged 32 pounds more than heifer calves when weaning weights were adjusted to 210 days of age. Steer calves were found to be 10 to 30 pounds heavier than heifer calves at weaning by Knapp et al. (1942), Koger and Knox (1947), Koch (1951), Botkin and Whatley (1953), McCleery and Blackwell (1954), Evans et al. (1955), Clark et al. (1958), and Urick (1958).

Sex was found to have no significant influence on weaning weights when corrections were made for birth weight differences in a report by Nelms and Bogart (1956).

The extent of the effect of sex on weaning weight varies greatly with year and location of the animals being studied.

Effect of age of dam on weaning weight

Numerous studies have verified that age of dam has a highly significant influence on the weaning weight of a calf. Cows wean their heaviest calves at six to eight years of age (Knapp et al., 1942; Knox and Koger, 1945; Sawyer, Bogart and Oloufa, 1948; Knox et al., 1951; Burgess et al., 1954; Rollins and Guilbert, 1954; Clark et al., 1958; Swiger et al., 1962; Flower et al., 1963 and Kumazaki and Matsuo, 1969). Calf weaning weights increased continually from two-year-old cows up to six- to nine-year-old cows and declined thereafter in studies by Chambers et al. (1953); Koch and Clark (1955a); Blackwell, Knox and Hurt (1958) and Urick (1958). Warren, Thrift and Carmon (1965) studied performance records on 28,493 Hereford, Angus and Santa Gertrudis calves from the Georgia Beef Cattle Improvement Association. They found that the average weaning weight of calves increased as cow age increased to eight years. Calves from 8- to 11-year-old cows were of comparable weight and declined as cow age increased beyond 11 years.

Studies by Botkin and Whatley (1953) and Marlowe and Gaines (1958) showed age of dam to be the largest source of variation in the pre-weaning gains of beef calves. Calves from five- to seven-year-old cows had the highest average daily gain from birth to weaning in a study reported by Woodward et al. (1947). Marlowe, Mast and Schalles (1965) reported that cow age significantly ($P < .01$) influenced calf gains from birth to weaning. Calves from cows under seven years of age and over 11 years grew slower than calves from 7-through 11-year-old cows. There were no significant differences among calves from the 7-through 11-year-old cows.

The variation in growth rate and weaning weight associated with the age of the dam is largely due to differences in milk production of the dams associated with their age as shown by Bonsma (1943) and Gleddie and Berg (1968) with milk production and consumption measurement studies. Sixty-six percent of the variation in eight-months weight was due to differences in milk consumption in a study reported by Neville (1962). The most rapid and efficient weight gains were made from birth to four months of age. This is an agreement with observations reported by Gifford (1949). He found the correlation between daily milk production of Hereford cows and the daily weight gain of their calves to be 0.60, 0.71, 0.52 and 0.35 for the first, second, third and fourth month of lactation, respectively. The correlation for the following four months was not significant. Differences in milk consumption accounted for 75, 77 and 60 percent of the variability in calf daily gains up to one, three and six months of age, respectively, (Drewry, Brown and

Honea, 1959).

The weaning weights of bull calves were influenced to a significantly greater degree by age of dam effects than were the weaning weights of heifer calves (Pahnish *et al*. 1958b).

Effect of age of calf and pre-weaning growth rate on weaning weight

Most studies have shown the effect of age of calf on weaning weight to be nearly linear. The growth of range calves was nearly linear up to 155 days of age and then continued at a decreasing rate (Johnson and Dinkel, 1951). Their study involved 297 calves from 155 to 225 days of age which were raised under South Dakota range conditions. Pahnish *et al*. (1958a) found the weight-age relationship to be essentially linear between the ages of 121 and 323 days. Urick (1958) reported a linear growth curve for calves from 140 to 220 days of age at the North Montana Branch Experiment Station. Calves weighed 2.03 pounds more at weaning for each day increase in age. Brody *et al*. (1926) reported a linear growth curve for calves from 2 to 10 months of age. Koch (1951) studied data on 745 calves from 180 cows having two or more calves born on the range between April and May at the U. S. Range Livestock Experiment Station, Miles City, Montana during the period 1938 to 1948. The calves were weaned about October 20 at an average age of 176 days and an average weight of 393 pounds. The regression of calf weight on age at weaning was 2.27 pounds per day.

Gottlieb et al. (1962) reported a regression of weaning weight on weaning age of 1.79 and 1.21 pounds in two lines of Shorthorn cattle. Sawyer et al. (1948) reported the regression of weaning weight on age to be 1.28 pounds per day. Between the ages of 175 and 245 days, calves grew at practically a constant rate of 1.28 pounds per head daily. Evans et al. (1955) reported the regression of weaning weight on age of calf to be significantly different ($P < .05$) between purebred and grade Hereford calves. The regression coefficients for the 1737 calves were 0.908 for the purebreds and 1.080 for the grade calves. Minyard and Dinkel (1965a) reported a linear regression of weaning weight on age of calf within ranch-year-month of birth subclasses of 1.20 pounds with 2351 Hereford and Angus range calves. Cooper et al. (1965) reported a highly significant regression of weaning weight on age of calf and average daily gain on age of calf at weaning with 6147 Hereford calves from Colorado Beef Cattle Improvement Association records. Koger and Knox (1945), Burgess et al. (1954), and McCleery and Blackwell (1954) reported regressions of weaning weight on age at 205 days of 1.33, 1.67 and 1.17 pounds, respectively. Botkin and Whatley (1953) reported a regression of weight on age of 1.46 pounds at 210 days of age.

The research results described above indicate that calf preweaning growth rate is essentially linear and thus, older calves weigh more at a constant weaning time due to an age differential. However, several workers have shown that older calves also grow faster from birth to weaning than their younger herd mates. Brody (1921) reported that the monthly gain of calves increases from birth to five months of age, when the gain is the most rapid in the life of the animal, and then decreases to weaning. Burgess et al. (1954) in a three-year study of 546 range calves found that the older half of the calves averaged 1.76 pounds daily gain from birth to weaning compared to 1.60 pounds for the other half of the calves that averaged 28 days younger. Nelms and Bogart (1956) studied 103 Hereford and Angus calves born from 1953 to 1954. The breeding season was for 90 days and the first calving date was about March 15 each year. The calving season was broken down, arbitrarily, into 20-day periods beginning with March 1. The average daily gain (ADG) from birth to weaning for all calves was 1.63 pounds. The ADG of calves by period of birth (20-day increments) was 1.67, 1.83, 1.69, 1.58, 1.56 and 1.45 pounds for calves born in periods one through six, respectively. Morrow and Brinks (1968) studied data from 2411 calves born to 546 Hereford cows from 1948 through 1967 at Colorado's San Juan Branch Experiment Station. The breeding season began about June 1 each year and lasted approximately 90 days with calves being born from March through early June the following year. All calves were weaned at the same time in late October or early November. The expected calving season was broken down into 20-day periods beginning with March 1 each year. The ADG from birth to weaning for all calves was 1.60 pounds. The ADG by period of birth (20-day increments) was 1.66, 1.59, 1.51, 1.43 and 1.38 pounds for calves born in periods one through five, respectively. Average weaning weights showed a similar decline from 436 pounds in group 1 to 274 pounds in group 5.

Rice (1956) observed that range calves dropped in June averaged 27 pounds lighter at 205 days of age than calves dropped in April. Sewell _et al_. (1963) studied the influence of month of birth on the 180-day adjusted weaning weights of Hereford calves born from 1951 to 1961 in Missouri. Calves born in February and March were 20, 36 and 65 pounds heavier than calves born in April, May and June, respectively.

II. Relationship Between Calving Group and Performance

Many studies of range calf pre-weaning growth rates and weaning weights assume that calves born early or late in the calving season grow at the same rate at the same ages. However, calves born early in the normal calving season may actually grow at a faster rate than those born later. As a result, early calves would weigh more at weaning not only due to their older age but also to their more rapid growth rate from birth to weaning.

Effect of calving group on calf production and performance

Morrow and Brinks (1968) studied data from 2411 calves born to 546 Hereford cows from 1948 through 1967 at Colorado's San Juan Branch Experiment Station. The data were separated into five groups based on the date of birth of each calf. Group 1 consisted of calves born in the first 20 days of the expected calving season plus calves born as much as 15 days early due to natural variation in gestation lengths. Groups 2 through 5 consisted of subsequent 20-day intervals during the calving period. In addition, early and late categories were designated for calves born outside the 115-day calving period of March through June. Table 1 shows the overall herd averages and averages for calves born in each of the time interval groups. The weaning weights of calves born in earlier groups were considerably heavier than those born in subsequent later groups. Calves born in Group 1 weighed 39 pounds more than the overall herd average. This is expected since calves born early in the calving season are older at weaning time. The earlier calves also had a higher rate of gain from birth to weaning than later calves and for each 20 days later, there was a definite decline in average daily gain. They also observed that the percent of calves lost at birth or before weaning was lowest for calves born in the early part of the normal calving season and increased as the season progressed. Nelms and Bogart (1956) conducted a similar study and reported calf average daily gains from birth to weaning of 1.67, 1.83, 1.69, 1.58, 1.56 and 1.45

pounds for Groups 1 through 6, respectively. Their data involved 103 Hereford and Angus range calves born during two, 90-day calving seasons beginning about March 1 each year.

Sewell et al. (1963) reported a continual decline in the average 180-day adjusted weaning weight of 566 Hereford calves as the calving season progressed. The average weaning weights were 431, 431, 411, 395 and 366 pounds for calves born in February, March, April, May and June, respectively. Marlowe et al. (1965) studied the performance of 5163 Angus and 3165 Hereford calves relative to their month of birth. The average daily gain from birth to weaning was 1.70, 1.65, 1.63 and 1.60 pounds for Angus calves born in March, April, May and June, respectively. The average daily gain of Hereford calves born during the same months was 1.63, 1.65, 1.63 and 1.60 pounds, respectively. Cundiff, Willham and Pratt (1965) studied the 205-day adjusted weaning weights of 13,937 Hereford and Angus calves recorded by the Oklahoma Beef Cattle Improvement Association from 1959 through 1962. They found an average weaning weight of 444.4 pounds for calves born from February through April and 418.4 pounds for calves born from May through July. Brown (1961) has also reported similar observations of calf growth and weaning weights.

Pherigo et al. (1969) reported a significant ($P \leqslant .05$) association between birth date and the 205-day adjusted weaning weights of 1373 Hereford and Angus calves in some years but not in all years.

The calves were born between January 1 and June 30 from 1951 through 1965 at the Fort Reno Livestock Research Station in Oklahoma.

According to Rollins, Guilbert and Gregory (1952), the growth mechanism and the genetic factors affecting the calf from birth to four months of age are significantly different from and independent of the mechanism and genetic factors affecting the calf from four months of age to weaning. They contend that the principal variation in genotype for growth rate from birth to four months is primarily concerned with the calf's vigor and adaptability to the postnatal environment, while genotypic differences for ultimate size and rate of maturity are the principal source of genetic variation in growth rate from four months to weaning.

Gleddie and Berg (1968) contend that the capacity of the calf for milk consumption during the early stages of lactation may be a limiting factor in milk production of range cows. The maximum production is determined by the calf's capacity and if milk production is in excess, it declines to the level of the calf's appetite. Thus, some cows with inherent abilities for high production cannot express such abilities. Consequently, younger calves grow slower because their dams are on poorer quality forage near the normal period of greatest milk production and consumption. Also, the relatively lower previous milk consumption capacity of their calves has limited their productive capabilities during the entire suckling period.

TABLE 1. PERFORMANCE AVERAGES GROUPED BY DATE OF BIRTH OF CALF (Morrow and Brinks, 1968)

Calving group	No. calves	Avg. day of birth	Avg. daily gain (lb)	Avg. weaning weight (lb)	Percent lost
1[a]	1138	26	1.66	436	13.0
2	652	44	1.59	390	13.5
3	372	64	1.51	346	14.1
4	198	85	1.43	304	19.8
5[a]	51	103	1.38	274	10.5
Total or avg.	2411	43	1.60	397	13.9

a Early and late categories combined with groups 1 and 5, respectively.

Effect of date of dam's first calving on total lifetime calf production

Very little information is available in the literature concerning this aspect of beef cattle production.

Morrow (1968) studied the effect of calving date on calf weaning weights and cow production with data from 2411 calves born to 546 Hereford cows from 1948 through 1967 at Colorado's San Juan Branch Experiment Station. The breeding season began about June 1 each year and lasted approximately 90 days with calves being born from March through early June the following year. The data were separated into five groups based on the date of the dam's first calving. Group 1 consisted of all calves ever born to cows that calved as heifers in the first 20 days of the expected calving season plus as much as 15 days early due to natural variation in gestation lengths. Groups 2 through 5 consisted of subsequent 20-day intervals during the calving period.

In addition, early and late categories were designated for cows calving for the first time outside the 115-day calving period of March through June. Each cow was assigned to a group determined by the birth date of her first calf and her subsequent calf data remained in that classification throughout her lifetime.

Weaning weights of calves from cows calving first in Group 1 were the heaviest, being 20 pounds heavier than the herd average. There was a steady decline in average weaning weights by group, thereafter. Weaning weights of calves from cows calving first in Group 5 were 20 pounds lighter than the herd average. The average daily gain from birth to weaning showed a similar pattern of decline as the date of first calving advanced farther into the calving season. The data indicate that cows calving early their first time tend to calve early thereafter and that early calving appears to be nearer the optimum for maximum daily gain of calves--probably because of the right combination of milk production by the dams and milk consumption potential of the calves. Thus, calves from cows calving early the first time weigh considerably more at weaning because they are older and also have gained faster.

Regression analyses based on 4.7 calves per cow were performed. The regression of average day of birth of all calves on day of birth of the first calf was 0.42 days, indicating that for every 20 days earlier a cow calved the first time, she would be expected to average 8.4 days earlier on all calves. The regression of average weaning weight of all calves on date of birth of the first calf was -.64 pounds, indicating that heifers calving 20 days earlier the first time should wean calves averaging 12.8 pounds heavier throughout their productive lives.

Morrow (1968) concluded that an important way of increasing lifetime production is to manage to breed yearling heifers so they will calve early in a short, optimum calving season the first time.

Roberts, LeFever and Wiltbank (1970) designed an experiment to test the effectiveness of a management system for increasing the reproductive efficiency of a cow herd by dividing 139 yearling Angus heifers into two groups according to weight, source and whether they were cycling or not. One group was designated New Management and the other was a control group. In the New Management group, 85 heifers or 170 percent more heifers than needed as replacements were bred beginning April 22 the first year and May 12 the second year. The breeding season was limited to 45 days and estrus synchronization was used. In the control group, 54 heifers or approximately the same number of heifers as needed for replacements were bred beginning May 12 both years for a 90-day breeding season. All animals were bred artificially to one sire and the nutritional regime was the same for both groups. For the first 4, 21 and 45 days of the first breeding season, the percent of New Management heifers bred was 61, 73 and 80, respectively, versus 7, 70 and 83 percent of the heifers in the control group. The percent pregnant was 33, 51 and 66 for the New Management group and 2, 48 and 59 percent for the control group by days 4, 21 and 45, respectively, of the first breeding season. The average weaning weight of the first calves was 409.7 pounds for the New Management group and 339.2 pounds for the control group ($P < .01$). The number of days from calving to first estrus was 76 for the New Management group and 68 for the controls. In the second breeding season, the percent of heifers bred in the first 4, 21 and 45 days of the breeding season was 66, 92 and 100 for the New Management group and 16, 63 and 82 for the control group. The percent pregnant was 30, 46 and 74 for the New Management group and 12, 41 and 53 for the controls. They concluded that selecting replacement heifers for early pregnancy improves reproductive performance in subsequent years and improves the weaning weight of calves.

III. Repeatability of Cow Performance

Lush (1945) has termed the repeatability of a characteristic as the degree of likeness of repeated records. It includes all variations due to permanent differences between cows and thus, measures the accuracy of predicting future production on the basis of past production. It contains both genetic and environmental components of variation.

Repeatability and heritability of calving interval

The previously described work of Morrow (1968) tends to indicate that the date of birth of a cow's first calf could be used as a measure of that cow's expected lifetime calf production. If this is a true measure of expected lifetime performance, one would expect the repeatability and heritability of the length of the calving interval to be relatively high.

However, that is not the case. The repeatability and heritability of the calving interval appears to be quite low. Schalles and Marlowe (1969) reported a repeatability estimate of 0.02 and heritability estimate of 0.03 on 3989 calvings from 769 Angus cows. Plasse, Koger and Warnick (1966) found a calving interval repeatability of 0.03 for 2346 calvings from 566 Brahman cows. Wheat, Riggs and Shrode (1959) estimated the repeatability of the calving interval to be 0.20 from 282 Angus calvings. Legates (1954) found the repeatability of calving interval length to be 0.133 with a heritability estimate of zero from 2419 calvings by 1016 cows. Harwin, Lamb and Bisschop (1959) reported the repeatability of early calving to be 0.14 among 1341 Sussex and 1515 Africander matings. Dunbar and Henderson (1950) reported a heritability value of zero for calving interval length in dairy cattle. Such low heritability values suggest that any significant repeatability values are not due to transmissable hereditary differences. Relating this to continued early calving results in the conclusion that environmental factors are extremely important in getting a heifer to calve early and to maintain the "habit" of calving early all of her productive life.

Bergland (1964) studied the relationship between the first calving date of Hereford heifers and their subsequent calving dates in 222 heifers calving at two years of age from 1952 to 1958 at the North Montana Branch Experiment Station. A total of 316 calf births were used in the analysis. He found that heifers calving early their first time tended to be about 11 days later in the year at their second calving and then remained at about the same date through their eighth pregnancy. Heifers calving late their first time tended to gain about 11 days at their second calving and remained in much the same range of calving date throughout their life. Late calving heifers were more variable as a group during succeeding calvings, however.

Burris and Priode (1958) studied records from Angus, Hereford and Shorthorn cattle which calved at the Virginia experiment station from 1950 to 1957. The spring calving season was restricted by a limited breeding season of 90 days. They reported a regression of the percentage of cows failing to calve on previous calving date of 6.1 percent per 20-day period during the normal calving season. In other words, for each delay of 20 days in the previous calving date, 6.1 percent more cows did not calve the following year. Cows which calved late one year tended to calve late the next year if they calved at all. They concluded that selection of early calving cows would result in an earlier calf crop with a higher percent of the cows calving in the following year.

Most studies of the repeatability of calving intervals are conducted with herds that have a controlled breeding season. This may cause some bias in the data because early calvers cannot get any earlier, but only remain the same or get later, and late calvers can only remain the same or get earlier. This bias might be overcome if year-around breeding were practiced. However, Brown et al. (1954) studied calving intervals from 927 calvings in a New Mexico range herd on a year-around breeding basis and found no repeatability.

Roubicek, Clark and Stratton (1956) reported that the highest level of fertility in range cattle occurred in the spring and early summer, with lowest fertility in the hot summer and fall. Consequently, cows which calved late would have a decreased chance of being bred and fertilized for the next calving.

Pou, Henderson and Asdell (1953) studied dairy herds at Beltsville to estimate fertility on the basis of number of services required for conception, the number of days from first service to conception and the regularity of the occurrence of estrus. They found that the regularity of occurrence of estrus had a repeatability of 0.18; number of services required for conception, 0.12; and the number of days from first service to conception, 0.11. Dunbar and Henderson (1953) reported a repeatability and heritability of non-return to first service of 0.027 and 0.004, respectively. Carman (1954) studied several aspects of breeding efficiency in dairy cattle and reported a repeatability of zero to 0.27

for the time to first estrus following parturition; a repeatability of zero to 0.08 for the time from first breeding to conception; and a repeatability of zero to 0.08 for the number of services for conception.

Warnick (1953) studied post-partum estrus in Angus and Hereford cows with a controlled breeding season from June 20 to September 20. He found the post-partum interval to be 46.9 days for the Angus cows and 52.4 days for the Herefords. The age of the cow had no effect on the interval. There was a significant effect of date of calving on the post-partum interval, however. A cow had a 4.6 day shorter interval for each 10 days later that she calved in the season. The length of the interval did not affect the conception rate. He concluded that late-calving cows tend to come into heat earlier than early-calving cows. He reported no significant repeatability of the post-partum interval.

Repeatability of weaning weight and pre-weaning growth rate

Since a cow, possibly, cannot be accurately selected for continual early calving on the basis of the birth date of her first calf, selection for another performance trait might indirectly result in selection for early calving. Selection for high weaning weights and calf gains from birth to weaning might be such a performance trait. Implicit in this idea is the assumption that early calves grow faster and weigh more at weaning than later calves.

The repeatability of weaning weight and pre-weaning gain is relatively high as reported by many workers. Koch (1951) found the difference between cows accounted for 52 percent of the variation in the corrected weaning weights of range calves. He concluded that the repeatability was high enough to permit reasonably accurate selection of cows for high lifetime production on the basis of the first calf weaned. Similar values for the repeatability of weaning weight have been reported by Koger and Knox (1947), Gregory et al. (1950), Botkin and Whatley (1953), Chambers et al. (1953), Rollins and Guilbert (1954), Rollins and Wagnon (1956), Stonaker (1958), Sewell et al. (1963), Minyard and Dinkel (1965b) and Kilkenny (1968).

Rollins, Guilbert and Gregory (1952), using variance and covariance analyses, found the repeatability of growth rate from birth to four months of age to be 37 percent in purebred Hereford calves at the University of California. The repeatability of growth rate from four months of age to eight months was 26 percent. Koch and Clark (1955b) found a repeatability of 34 percent for weaning weight and pre-weaning gain in a study of 4553 calves at the U. S. Range Livestock Experiment Station, Miles City, Montana. Schalles and Marlowe (1969) reported a repeatability of 18 percent for pre-weaning daily gain in 2638 calves raised by 769 Angus cows. Estimates of repeatability of pre-weaning daily gain from 30 to 40 percent have been reported by Botkin and Whatley (1953), Rollins and Guilbert (1954) and Taylor et al. (1960).

Koger and Knox (1947) found the average correlation of the weaning weight of adjacent calves to be 0.49 for range cows that had produced five consecutive calves. The correlation of the weight of the first calf with that of the second calf was 0.66. When the weight of the first calf was compared with various combinations of subsequent records, the correlation varied from 0.51 to 0.53. When the average of the first two calves was compared with the weaning weights of various subsequent calves, the coefficients varied from 0.54 to 0.59, being only slightly higher than when the first calf weight was used in the comparison. Botkin and Whatley (1953) reported a correlation between the weaning weight and pre-weaning gain of first and second calves of 0.66 and 0.69, respectively. Gregory _et al_. (1950) reported correlations for the weaning weight of first with second, first with third, and second with third calves of 0.50, 0.35 and 0.37, respectively. The same comparisons made for pre-weaning gain resulted in correlations of 0.50, 0.38 and 0.43, respectively. Rollins and Guilbert (1954) found a correlation of 0.48 between the rate of growth from birth to four months of a cow's first calf and the average 240-day weaning weight of her second and third calves. These data indicate that potentially low-producing cows can be culled with a high degree of accuracy on the basis of the performance of their first calf.

MATERIALS AND METHODS

Source of data

The data for this study were obtained from records collected at the Montana Agricultural Experiment Station at Bozeman and the North Montana Branch Experiment Station at Havre, Montana. Records on 386 calves born to 85 Angus cows and 481 calves born to 105 Hereford cows from 1950 to 1968 at Bozeman and 1169 calves born to 291 Hereford cows from 1952 to 1966 at Havre were used in the analysis.

The Havre cows were from eight different Hereford breeding lines and crosslines which included lines 1, 2, 3, 4, 5, 6, 7 and 16. For this study, all records from cows in lines 5, 6, 7 and 16 were combined into one classification and designated as line 5. These cows were the progeny of crossline matings of Havre Hereford lines 1, 2, 3 and 4.

Until 1953, all Bozeman heifers were bred to calve first as three-year-olds. From 1953 on, all heifers were bred to calve first as two-year-olds unless intentionally held open for research purposes. All Havre heifers were bred to calve first as three-year-olds until 1952 and were bred to calve first as two-year-olds from then on. All calves were born in the spring and weaned at the same time in October or November of each year.

The cattle breeding records at the Bozeman station are from a herd representing a fairly typical registered cattle operation in a sub-irrigated mountain valley. The records at the Havre station are from a herd representing a fairly typical commercial range cattle operation.

The bull turn-in and take-out dates during the breeding season for each group of females were known exactly for all sires involved in this study. The breeding season length for individual bulls ranged from 10 to 113 days over the 19-year period studied at Bozeman. The breeding season at Havre began on June 15th of each year for 60 days for all sires involved in the study. A total of 48 different bulls sired calves in the Bozeman study and 86 bulls sired calves in the Havre study.

The number of production years per cow ranged from 2 to 14 in the Bozeman data and from 2 to 11 in the Havre data. The cows ranged in age from 2 to 15 years in the Bozeman data and from 2 to 13 years in the Havre data. All records from cows 11 years of age and older in the Bozeman data and 10 years of age and older in the Havre data were combined into one age classification as 11 or 10 years of age, respectively.

Analysis of data

A separate computer data card was prepared for every cow each year they were in the herd. Each card, thus, represented one cow-year. These cards contained all of the production and performance information necessary for the study.

To facilitate the analysis, certain cows were eliminated from consideration in the study for the following reasons:

1. The sire of the cow's first calf was unknown.
2. The cow's first calf was aborted, abnormal or premature. Consequently, the cow could not be assigned to the proper initial calving group based on the birth of a normal calf.

Certain calves and cow-years were eliminated from consideration in the study for the following reasons:

1. All calves born to an unknown sire and all subsequent calves from that same cow whether the sire was known or not.
2. All aborted, abnormal and premature calves and all subsequent calves from the same cow whether the calves were normal or not.
3. All cow-years when the cow was dry and all subsequent calves from that same cow. An exception to this was a dry, two-year-old heifer which was then considered as calving first as a three-year-old.

The expected calving season was divided into 21-day increments based on the normal 21-day estrous cycle length of the cow. Thus, all cows would have had an opportunity to be bred and conceive at least once during the first 21 days of the breeding season.

An initial calving group was determined for each heifer based on the birth date of her first calf relative to the turn-in date of the calf's sire at the previous breeding season. The following formula was used to determine the initial calving group for each heifer.

$$\text{Calving group determinant} = \frac{\text{Calf birth day of year} - \left[\text{Bull turn-in day of year} + \text{283 day normal gestation length} - \text{365 days in a year (366 if bred in a leap year)}\right]}{\text{21 day normal estrous cycle length}}$$

The mathematical solution to the above formula determined what the initial calving group was to be for each heifer as shown in Table 2.

TABLE 2. DESIGNATION OF INITIAL CALVING GROUP

Calving group determinant	Initial calving group	Biological significance
> 0.00	1	Less than 283 days gestation
0.00-> 1.00	2	First 21 days of expected calving season
1.00-> 2.00	3	Second 21 days of expected calving season
2.00-> 3.00	4	Third 21 days of expected calving season
3.00-> 4.00	5	Fourth 21 days of expected calving season
< 4.00	6	After 84th day of expected calving season

The following example may help to clarify the method of determining the initial calving group. A bull was turned into a breeding pasture on June 10 (161st day of the year) and bred a heifer sometime during the breeding season. The heifer calved on April 16 (106th day of the following year). Inserting the appropriate values in the formula, $\frac{106 - [161 + 283 - 365]}{21}$, gives a value of 1.29 and a designation of 3 for the initial calving group.

A subsequent calving group was assigned to each additional calf from the same cow based on the calf's birth date relative to the breeding season as previously described. Consequently, a cow would be in one initial calving group all of her life based on the birth date of her first calf and would have additional calves in any subsequent calving group.

The Bozeman cows fell into six initial and subsequent calving groups. Due to a shorter breeding season, the Havre cows fell into five initial and subsequent calving groups.

The calving interval was determined as the exact number of days between successive calvings by the same cow.

Due to disproportionate subclass frequencies, the least-squares method of analysis described by Harvey (1960) was used to analyze these data. The independent variables used in the analysis were years, breed or cow line, age of cow, age of heifer at first calving, initial calving group, subsequent calving group, sex of calf, and appropriate and meaningful interactions among the independent variables. Nonsignificant interactions were deleted from the model for the final analysis in order to obtain a more accurate estimate of the significance of all other effects. The dependent variables studied were initial calving group, subsequent calving group, calving interval, birth weight, weaning age, weaning weight, average daily gain, percent survival from birth to weaning and cow weight at weaning. The limitations of the least-squares computer program and the large number of sires involved in the study required the exclusion of sires as an independent variable in the analysis of variance. This must be kept in mind since sires have significantly affected the average birth weights and weaning weights of calves in previous studies (Knapp _et al_., 1942; Knapp and Phillips, 1942; and Pahnish _et al_., 1961). Bergland (1964) found a variation in the birth date of the first calf born by respective sires within years. Phenotypic within subclass correlations among the dependent variables were also obtained in this study.

Due to the small number of observations in several subclasses and the limitations of the least-squares computer program, the effect of years was absorbed in all of the analyses unless indicated otherwise. As a result, the data were adjusted for year effects and the number of degrees of freedom in the analysis was reduced by the number of classes absorbed. When year effects were not absorbed, the total number of degrees of freedom in the analysis was reduced by one for the least-squares overall mean. The totals reported in these tables have been corrected for the least-squares overall mean by subtraction of one degree of freedom and indicated as such.

The subclass means reported in the tables were obtained by adjusting the overall mean for that particular dependent variable with the least-squares constant estimates. The constant estimates were assumed to sum to zero.

The repeatability of calving group and calving interval was computed as an intraclass correlation among records by the same cow. The intraclass correlation or repeatability (r_e) $\dfrac{\sigma_c^2}{\sigma_c^2 + \sigma_e^2}$

measured the tendencey for observations on the same cow to be more alike than observations on different cows. The σ_c^2 was the variance of cow effects on a particular production trait and σ_e^2 was the error or variance among calves from the same cow. The estimate of σ_e^2 was obtained directly from the analysis of variance. The expected value of the mean square among cows was $\sigma_e^2 + k\ \sigma_c^2$. The k was the effective number of calves in each cow subclass (Steel and Torrie, 1960). The following equation results in the determination of σ_c^2:

$$\sigma_c^2 = \frac{\left(\sigma_e^2 + k\ \sigma_c^2\right) - \sigma_e^2}{k}$$

The calving group and calving interval for each calf and cow-year were adjusted for the effects of breed or cow line, age at first calving, age of the cow, year and sex of the calf as significant sources of variation before the repeatability estimates were obtained from the constant estimates provided by least-squares analysis of the effect of the above variables on the calving group and calving interval.

RESULTS AND DISCUSSION

Initial calving group

There was a significant difference ($P < .05$) in initial calving group between the breeds at Bozeman (Table 3) and the cow lines at Havre (Table 4). The mean initial calving group for the Bozeman herd was 2.8 with the Angus mean 2.6 and the Hereford mean 3.0. The mean initial calving group for the Havre herd was 2.7 with means of 2.5, 2.9, 2.8, 2.7 and 2.6 for cow lines 1, 2, 3, 4 and 5, respectively.

The year of birth of the calf significantly ($P < .01$) affected the initial calving group in both herds (Tables 3 and 4). The mean initial calving group ranged from 2.0 to 4.3 during different years in the Bozeman herd. Although significant ($P < .01$) such a wide range in effect of year on initial calving group was not evident in the Havre herd where the mean initial calving group ranged from 2.2 to 3.3 during different years.

The age of the heifer at first calving did not significantly affect initial calving group in the Bozeman herd (Table 3) but did in the Havre herd ($P < .01$) as shown in Table 4. The mean initial calving groups for two-year-old heifers at Havre was 2.9 as compared to 2.5 for three-year-old heifers. Such an observation is expected since the heifers calving first as three-year-olds have a much longer opportunity to begin cycling before exposure to a bull for breeding for the first time. As previously mentioned, heifers bred to calve as two-year-olds that failed to calve due to failure to conceive or embryonic mortality were included in the classification of heifers calving first as three-year-olds. Such heifers would also be expected to come in estrus and conceive early in the next breeding season and calve early the following year.

TABLE 3. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING INITIAL CALVING GROUP OF FIRST-CALF HEIFERS AT BOZEMAN

Source of variation	D.F.	Mean square
Breed	1	5.63*
Age at first calving	1	2.02
Year	17	4.48**
Sex of calf	1	0.00
Error	169	1.02
Total (corrected)	189	

* (P < .05)
** (P < .01)

TABLE 4. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING INITIAL CALVING GROUP OF FIRST-CALF HEIFERS AT HAVRE

Source of variation	D.F.	Mean square
Cow line	4	1.39*
Age at first calving	1	6.20**
Year	13	6.15**
Sex of calf	1	0.06
Error	271	0.56
Total (corrected)	290	

* (P < .05)
** (P < .01)

Neither the sex of the calf nor any meaningful interactions tested significantly affected the initial calving group in either herd (Tables 3 and 4).

Subsequent calving group

Tables 5 and 6 indicate the factors which affected the subsequent calving group and calving interval. A significant difference ($P < .01$) in calving group was found between the breeds at Bozeman and the cow lines at Havre. The mean subsequent calving group for the Bozeman herd was 2.6 with the Angus mean 2.4 and the Hereford mean 2.8. The mean subsequent calving group for the Havre herd was also 2.6 with means of 2.3, 2.9, 2.5, 2.6 and 2.7 for cow lines 1, 2, 3, 4, and 5, respectively. The year of birth of the calf significantly ($P < .01$) affected the subsequent calving group in both herds. The mean subsequent calving group ranged from 2.1 to 3.4 during different years in the Bozeman herd and from 2.3 to 2.9 in the Havre herd.

Neither age of the cow nor any meaningful interactions tested significantly affected the subsequent calving group.

The cow's age at first calving did not significantly affect subsequent calving group in the Havre herd but did in the Bozeman herd ($P < .05$). The mean subsequent calving group for two-year-old heifers at Bozeman was 2.7 as compared to 2.5 for three-year-old heifers. This observation is expected since heifers calving first as two-year-olds must meet nutritional requirements for body growth in addition to maintenance, production and reproduction during their first lactation. Such demands on the heifer tend to result in decreased reproductive efficiency. Three-year-old heifers would not have to meet requirements for body growth during their first lactation since they would, quite likely, have attained their mature body size. This is not to be miscontrued with the attainment of mature body weight. (Knox and Koger, 1945 and Brinks et al., 1962).

The sex of the calf did not significantly affect subsequent calving group in the Havre herd but did in the Bozemanherd ($P < .05$). The mean subsequent calving group for bull calves at Bozeman was 2.7 as compared to 2.5 for heifer calves. This might be due to an increased gestation length for bull calves relative to heifer calves as reported by Eckles (1919), Dawson et al. (1947), Burris and Blunn (1952), Herman et al. (1953) and Rice et al. (1954). However, such a conclusion could not be definitely derived from these data since the exact date of conception was unknown.

TABLE 5. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING CALVING INTERVAL AND SUBSEQUENT CALVING GROUP IN COWS AT BOZEMAN

Source of variation	D.F.	Mean squares: Calving interval	Mean squares: Subsequent calving group
Breed	1	293.26	36.34**
Age at first calving	1	193.85	3.66*
Year	17	4211.45**	2.77**
Age of cow	8	1887.99**	0.99
Sex of calf	1	639.43	5.27*
Error	648	586.61	0.89
Total (corrected)	676		

** ($P < .01$)
* ($P < .05$)

TABLE 6. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING CALVING INTERVAL AND SUBSEQUENT CALVING GROUP IN COWS AT HAVRE

Source of variation	D.F.	Mean squares: Calving interval	Mean squares: Subsequent calving group
Cow line	4	105.41	4.62**
Age at first calving	1	532.86	1.85
Year	13	1456.28**	1.65**
Age of cow	7	1033.61**	1.20
Sex of calf	1	755.58	1.70
Error	851	353.04	0.60
Total (corrected)	877		

** ($P < .01$)

TABLE 7. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF INITIAL CALVING GROUP AND OTHER FACTORS ON SUBSEQUENT CALVING GROUP AT BOZEMAN

Source of variation	D.F.	Mean square
Breed	1	29.02**
Age at first calving	1	0.64
Initial calving group	5	2.22*
Age of cow	8	1.17
Sex of calf	1	4.22
Initial calving group X breed	--	n.s.
Initial calving group X age at first calving	--	n.s.
Error	643	0.88
Within SS	659	

** (P < .01)
* (P < .05)
n.s. (non-significant interaction)

TABLE 8. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF INITIAL CALVING GROUP AND OTHER FACTORS ON SUBSEQUENT CALVING GROUP AT HAVRE

Source of variation	D.F.	Mean square
Cow line	4	4.07**
Age at first calving	1	2.39*
Initial calving group	4	1.62*
Age of cow	7	1.46*
Sex of calf	1	1.78
Initial calving group X cow line	13	1.33**
Initial calving group X age at first calving	--	n.s.
Error	834	0.59
Within SS	864	

** (P < .01)
* (P < .05)
n.s. (non-significant interaction)