



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
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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 $(P < .01)$] 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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August 3, 1970

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ON LIFETIME CALF PRODUCTION

by

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

of

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TABLE OF CONTENTS

	Page
VITA	ii
ACKNOWLEDGEMENTS	iii
INDEX OF TABLES	VII
INDEX OF APPENDIX TABLES	XI
ABSTRACT	XIV
INTRODUCTION	1
REVIEW OF LITERATURE	2
I. Factors Affecting Calf Production and Performance	2
Effect of year on weaning weight	2
Effect of cow line and breed on weaning weight	3
Effect of age at first calving on weaning weight	3
Effect of calf birth weight on weaning weight	4
Effect of sex of calf on weaning weight	7
Effect of age of dam on weaning weight	9
Effect of age of calf and pre-weaning growth rate on weaning weight	11
II. Relationship Between Calving Group and Performance	14

	Page
Effect of calving group on calf production and performance	15
Effect of date of dam's first calving on total lifetime calf production	18
III. Repeatability of Cow Performance	21
Repeatability and heritability of calving interval	21
Repeatability of weaning weight and pre-weaning growth rate	25
MATERIALS AND METHODS	28
Source of data	28
Analysis of data	29
RESULTS AND DISCUSSION	35
Initial calving group	35
Subsequent calving group	37
Calving interval	42
Lifetime calving groups	44
Repeatability of calving group and calving interval . .	46
Birth weight	48
Weaning weight	56
Weaning age	62
Average daily gain	64
Effect of initial calving group on lifetime production	66

	Page
Percent survival from birth to weaning	71
Cow weight at weaning	73
General discussion	77
SUMMARY	85
APPENDIX TABLES	88
LITERATURE CITED	97

INDEX OF TABLES

TABLE	Page
1. PERFORMANCE AVERAGES GROUPED BY DATE OF BIRTH OF CALF (Morrow and Brinks, 1968)	18
2. DESIGNATION OF INITIAL CALVING GROUP	31
3. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING INITIAL CALVING GROUP OF FIRST-CALF HEIFERS AT BOZEMAN	36
4. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING INITIAL CALVING GROUP OF FIRST-CALF HEIFERS AT HAVRE	36
5. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING CALVING INTERVAL AND SUBSEQUENT CALVING GROUP IN COWS AT BOZEMAN	39
6. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING CALVING INTERVAL AND SUBSEQUENT CALVING GROUP IN COWS AT HAVRE	39
7. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF INITIAL CALVING GROUP AND OTHER FACTORS ON SUBSEQUENT CALVING GROUP AT BOZEMAN	40
8. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF INITIAL CALVING GROUP AND OTHER FACTORS ON SUBSEQUENT CALVING GROUP AT HAVRE	40
9. EFFECT OF INITIAL CALVING GROUP ON SUBSEQUENT CALVING GROUP	41
10. EFFECT OF AGE OF COW ON CALVING INTERVAL	43
11. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING CALVING GROUP DURING THE LIFETIME OF COWS AT BOZEMAN	45

TABLE	Page
12. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING CALVING GROUP DURING THE LIFETIME OF COWS AT HAVRE	45
13. ANALYSIS OF VARIANCE WITH CONSTANT OF VARIATION FOR COMPONENTS FOR BOZEMAN CALVING GROUP AND CALVING INTERVAL REPEATABILITY ESTIMATES	47
14. ANALYSIS OF VARIANCE WITH CONSTANT OF VARIATION FOR COMPONENTS FOR HAVRE CALVING GROUP AND CALVING INTERVAL REPEATABILITY ESTIMATES	47
15. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON CALF BIRTH WEIGHT AT BOZEMAN	49
16. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON CALF BIRTH WEIGHT AT HAVRE	50
17. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF INITIAL CALVING GROUP AND OTHER FACTORS ON BIRTH WEIGHT OF CALVES BORN TO FIRST-CALF HEIFERS AND ALL SUBSEQUENT CALVES BORN TO COWS AT BOZEMAN	52
18. BIRTH WEIGHT OF ALL SUBSEQUENT CALVES BORN TO COWS AT BOZEMAN	53
19. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF INITIAL CALVING GROUP AND OTHER FACTORS ON BIRTH WEIGHT OF CALVES BORN TO FIRST-CALF HEIFERS AND ALL SUBSEQUENT CALVES BORN TO COWS AT HAVRE	54
20. BIRTH WEIGHT OF CALVES BORN TO FIRST-CALF HEIFERS AT HAVRE	55
21. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON CALF PERFORMANCE AT BOZEMAN	57
22. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON CALF PERFORMANCE AT HAVRE	58

TABLE	Page
23. CALF PERFORMANCE AVERAGES GROUPED BY DATE OF BIRTH OF CALF AT BOZEMAN	59
24. CALF PERFORMANCE AVERAGES GROUPED BY DATE OF BIRTH OF CALF AT HAVRE	60
25. EFFECT OF COW AGE ON CALF WEANING WEIGHT	62
26. EFFECT OF AGE OF COW ON CALF WEANING AGE AT BOZEMAN	63
27. EFFECT OF COW AGE ON AVERAGE DAILY GAIN OF CALVES	65
28. EFFECT OF INITIAL CALVING GROUP ON LIFETIME PRODUCTION OF COWS AT BOZEMAN	68
29. EFFECT OF INITIAL CALVING GROUP ON LIFETIME PRODUCTION OF COWS AT HAVRE	68
30. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF INITIAL CALVING GROUP AND OTHER FACTORS ON LIFETIME PRODUCTION OF COWS AT BOZEMAN	69
31. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF INITIAL CALVING GROUP AND OTHER FACTORS ON LIFETIME PRODUCTION OF COWS AT HAVRE	70
32. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON CALF SURVIVAL FROM BIRTH TO WEANING AT HAVRE	72
33. EFFECT OF CALVING GROUP ON PERCENT SURVIVAL FROM BIRTH TO WEANING	73
34. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING WEIGHT OF FIRST-CALF HEIFERS AT WEANING AT BOZEMAN	74
35. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON COW WEIGHT AT WEANING AT BOZEMAN	76

x

TABLE

Page

36. COW WEIGHT AT WEANING GROUPED BY DATE OF BIRTH OF CALF AT BOZEMAN	77
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INDEX OF APPENDIX TABLES

TABLE	Page
1. CALF BIRTH WEIGHT AVERAGES GROUPED BY DATE OF BIRTH OF CALF	89
2. EFFECT OF AGE OF COW ON CALF BIRTH WEIGHT	89
3. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON CALF SURVIVAL FROM BIRTH TO WEANING AT BOZEMAN	90
4. EFFECT OF INITIAL CALVING GROUP ON PERCENT SURVIVAL FROM BIRTH TO WEANING	90
5. WEIGHT OF FIRST-CALF HEIFERS AT WEANING GROUPED BY DATE OF BIRTH OF CALF AT BOZEMAN	91
6. EFFECT OF AGE ON COW WEIGHT AT WEANING	91
7. LEAST-SQUARES MEANS FOR EFFECT OF COW LINE X INITIAL CALVING GROUP INTERACTION ON SUBSEQUENT CALVING GROUPS AT HAVRE	92
8. LEAST-SQUARES MEANS FOR EFFECT OF COW LINE X CALVING GROUP INTERACTION ON BIRTH WEIGHTS OF ALL CALVES AT HAVRE	92
9. LEAST-SQUARES MEANS FOR EFFECT OF BREED X INITIAL CALVING GROUP INTERACTION ON AVERAGE BIRTH WEIGHTS OF SUBSEQUENT CALVES AT BOZEMAN	92
10. LEAST-SQUARES MEANS FOR EFFECT OF COW LINE X INITIAL CALVING GROUP INTERACTION ON AVERAGE BIRTH WEIGHTS OF CALVES FROM FIRST-CALF HEIFERS AT HAVRE	93
11. LEAST-SQUARES MEANS FOR EFFECT OF BREED X AGE AT FIRST CALVING INTERACTION ON AVERAGE WEANING WEIGHTS OF ALL CALVES AT BOZEMAN	93

TABLE	Page
12. LEAST-SQUARES MEANS FOR EFFECT OF BREED X CALVING GROUP INTERACTION ON AVERAGE WEANING WEIGHTS OF ALL CALVES AT BOZEMAN	93
13. LEAST-SQUARES MEANS FOR EFFECT OF BREED X CALVING GROUP INTERACTION ON AVERAGE WEANING AGES OF ALL CALVES AT BOZEMAN	94
14. LEAST-SQUARES MEANS FOR EFFECT OF COW LINE X AGE AT FIRST CALVING INTERACTION ON AVERAGE WEANING AGES OF ALL CALVES AT HAVRE	94
15. LEAST-SQUARES MEANS FOR EFFECT OF BREED X AGE AT FIRST CALVING INTERACTION ON LIFETIME AVERAGE WEANING WEIGHTS OF CALVES PRODUCED BY COWS AT BOZEMAN	94
16. LEAST-SQUARES MEANS FOR EFFECT OF BREED X AGE AT FIRST CALVING INTERACTION ON THE LIFETIME MEAN AVERAGE DAILY GAINS FROM BIRTH TO WEANING OF ALL CALVES PRODUCED BY COWS AT BOZEMAN	95
17. LEAST-SQUARES MEANS FOR EFFECT OF INITIAL CALVING GROUP X AGE AT FIRST CALVING INTER- ACTION ON LIFETIME AVERAGE WEANING WEIGHTS OF CALVES PRODUCED BY COWS AT BOZEMAN	95
18. LEAST-SQUARES MEANS FOR EFFECT OF COW LINE X AGE AT FIRST CALVING INTERACTION ON LIFETIME AVERAGE WEANING AGES OF ALL CALVES PRODUCED BY COWS AT HAVRE	95
19. LEAST-SQUARES MEANS FOR EFFECT OF COW LINE X INITIAL CALVING GROUP INTERACTION ON LIFETIME AVERAGE WEANING AGES OF ALL CALVES PRODUCED BY COWS AT HAVRE	96
20. LEAST-SQUARES MEANS FOR EFFECT OF SEX X CALVING GROUP INTERACTION ON SURVIVAL PERCENTAGE FROM BIRTH TO WEANING OF CALVES AT HAVRE	96

TABLE

Page

21. LEAST-SQUARES MEANS FOR EFFECT OF BREED X AGE .	
AT FIRST CALVING INTERACTION ON COW WEIGHTS	
AT WEANING THROUGHOUT THE LIFETIMES OF COWS	
AT BOZEMAN	96

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.

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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 $(P < .01)$] 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.

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),

Hafēz (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 ($P < .05$) 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

Urlick (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 Urlick (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. Urlick (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 ($P \leq .05$) 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 pre-weaning 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 ($P \leq .05$) 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 transmissible 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.

$$\begin{array}{lcl}
 \text{Calving} & & \\
 \text{group} & \text{Calf birth} & \Rightarrow \left[\text{Bull turn-in} + 283 \text{ day} \quad 365 \text{ days in} \right. \\
 \text{determinant} & = \text{day of year} & \left[\text{day of year} \quad \text{normal} \quad \text{a year (366} \right. \\
 & & \left. \text{gestation} = \text{if bred in a} \right. \\
 & & \left. \text{length} \quad \text{leap year)} \right] \\
 & & \hline
 & & 21 \text{ day normal estrous cycle length}
 \end{array}$$

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. Non-significant 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)

$$\frac{\sigma_c^2}{\sigma_c^2 + \sigma_e^2}$$

measured the tendency 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 :

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

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 misconstrued 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 Bozeman herd ($P < .05$). 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	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	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)

Subsequent calving group was significantly ($P \leq .05$) affected by initial calving group in both herds as shown in Tables 7 and 8. Thus, heifers calving in groups 1, 2 and 3 the first time tended to calve earlier throughout their productive lives than heifers calving in groups 3, 4, 5 or 6 the first time (Table 9). Burris and Priode (1958), Bergland (1964), Morrow (1968) and Roberts et al. (1970) reported similar observations. The mean initial calving group for the Bozeman and Havre herds was 2.8 and 2.7, respectively, as compared to 2.6 for the mean subsequent calving group in each herd.

TABLE 9. EFFECT OF INITIAL CALVING GROUP ON SUBSEQUENT CALVING GROUP

Bozeman		Havre	
Initial calving group	Subsequent calving group	Initial calving group	Subsequent calving group
1	2.4	1	2.2
2	2.5	2	2.4
3	2.5	3	2.6
4	2.8	4	2.7
5	2.7	5	3.1
6	2.7	--	---

There was a significant ($P \leq .01$) initial calving group x cow line interaction effect on subsequent calving groups at Havre (Appendix Table 7).

Calving interval

The calving interval between successive calvings by the same cow was significantly ($P < .01$) affected by the year of birth of the succeeding calf and the age of the cow as shown in Tables 5 and 6. The mean calving interval in the Bozeman herd was 363.8 days as compared to 365.6 days in the Havre herd. This average calving interval cannot be considered as a true indication of the fertility of the two herds in the study, however. As previously mentioned, only cow-years involving the actual birth of a calf were analyzed. Thus, a mean calving interval near 365.0 days is to be expected.

The mean calving interval ranged from 341.3 to 407.3 days during different years in the Bozeman herd and from 353.7 to 371.7 days in the Havre herd. These observations can be explained in several ways. Varying rainfall, grazing and temperature conditions affect reproductive activity during the breeding season (Guilbert, 1930 and Parr, 1930). Another factor which might result in a greatly extended calving interval for some cows is the length of the breeding season. As previously mentioned, some bulls remained with certain groups of cows at Bozeman for up to 113 days during the breeding season. This gave some cows an opportunity to settle which would not have settled during a shorter breeding season and would have been culled as open cows in the fall. Such cows would have long calving intervals and would contribute to the much wider range in calving interval found in the Bozeman herd as

compared to the Havre herd.

There does not appear to be any particular trend in calving interval with increasing or decreasing age (Table 10). A year x age interaction might have been found to be statistically significant if it had been tested. However, the computer capacity limited the least-squares program to 80 degrees of freedom and, thus, did not allow the testing of a year x age interaction.

The correlation between subsequent calving group and calving interval was 0.52 in the Bozeman herd and 0.63 in the Havre herd.

TABLE 10. EFFECT OF AGE OF COW ON CALVING INTERVAL

Age of cow (years)	Calving interval (days)	
	Bozeman	Havre
3	353.0	360.9
4	365.7	363.9
5	362.6	368.6
6	365.5	362.5
7	362.8	365.3
8	366.1	371.1
9	362.0	365.3
10 ^a	371.2	367.1
11 and older	365.3	---
Overall mean	363.8	365.6

a Includes cows 10 years old and older in the Havre herd.

Lifetime calving groups

Each calf produced by a cow was assigned to a particular calving group as previously discussed. Consequently, a cow could have calves born in any of the calving groups throughout her lifetime. A consideration of all of these calving groups for a particular cow has been termed lifetime calving groups. Tables 11 and 12 indicate the significance of factors which affected calving groups during the total lifetime of the cows. A significant difference ($P < .01$) in lifetime calving group was found between the breeds at Bozeman and the cow lines at Havre. The mean lifetime calving group for the Bozeman herd was 2.6 with the Angus mean 2.4 and the Hereford mean 2.8. The mean lifetime calving group for the Havre herd was also 2.6 with means of 2.3, 2.8, 2.6, 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 calving group throughout the lifetime of the cows in both herds. The mean lifetime calving group ranged from 2.0 to 3.2 in the Bozeman herd due to year effects. Here again, a narrower range in lifetime calving group was found in the Havre herd which ranged from 2.4 to 2.8.

The age of the cow at calving significantly ($P < .01$) affected calving group throughout the lifetime of cows at Havre but not at Bozeman. The age of the heifer at first calving significantly ($P < .05$) affected calving group throughout the lifetime of cows at Bozeman but not at Havre. The mean lifetime calving group for cows calving first

as two-year-olds at Bozeman was 2.7 as compared to 2.5 for cows calving first as three-year-olds. The sex of the calf significantly ($P < .05$) affected calving group throughout the lifetime of cows at Bozeman but not at Havre. The mean calving group for bull calves at Bozeman was 2.7 as compared to 2.5 for heifer calves.

TABLE 11. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING CALVING GROUP DURING THE LIFETIME OF COWS AT BOZEMAN

Source of variation	D.F.	Mean square
Breed	1	38.92**
Age at first calving	1	4.73*
Age of cow	9	1.35
Year	18	3.79**
Sex of calf	1	4.87*
Error	836	0.97
Total (corrected)	866	

** ($P < .01$)

* ($P < .05$)

TABLE 12. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING CALVING GROUP DURING THE LIFETIME OF COWS AT HAVRE

Source of variation	D.F.	Mean square
Cow line	4	5.34**
Age at first calving	1	0.35
Age of cow	8	2.22**
Year	14	1.79**
Sex of calf	1	1.38
Error	1140	0.61
Total (corrected)	1168	

** ($P < .01$)

Repeatability of calving group and calving interval

An estimate of the repeatability of the calving group throughout the lifetime of a cow was computed as an intra-class correlation among records by the same cow as previously described. Before the repeatability estimates were obtained, however, the calving group for each calf and cow-year was adjusted for significant sources of variation. The Bozeman records were adjusted for effects of years, breed, age at first calving and sex of calf. The Havre records were adjusted for effects of years, cow line and age of the cow. The repeatability estimates of 0.092 and 0.105 (Tables 13 and 14) for calving group among the Bozeman and Havre cows were very close to the repeatability of early calving of 0.14 reported by Harwin et al. (1969).

The repeatability of the calving interval was essentially zero due to the large negative value for σ_c^2 as shown in Table 13 and 14. The resulting negative repeatability estimates were not interpretable and were, therefore, assumed to be zero. This agrees with the observations of Schalles and Marlowe (1969) and Plasse et al. (1966) who reported calving interval repeatability estimates of 0.02 and 0.03, respectively. However, it does not agree with the estimates of 0.133 and 0.20 reported by Legates (1954) and Wheat et al. (1959), respectively.

TABLE 13. ANALYSIS OF VARIANCE WITH CONSTANT OF VARIATION FOR COMPONENTS FOR BOZEMAN
CALVING GROUP AND CALVING INTERVAL REPEATABILITY ESTIMATES

Source of variation	Calving group		Calving interval	
	D.F.	Mean square	D.F.	Mean square
Years	18	1.992**	17	322.411
Among cows within years	171	1.240**	116	296.102
Error (within cows)	677	0.856	487	619.487
Total	866		620	

Constant (k) = 4.412	Constant (k) = 4.437
$\sigma_c^2 = 0.087$	$\sigma_c^2 = -72.878$
$r_e = 0.092$	$r_e = \text{zero}$

** (P < .01)

TABLE 14. ANALYSIS OF VARIANCE WITH CONSTANT OF VARIATION FOR COMPONENTS FOR HAVRE
CALVING GROUP AND CALVING INTERVAL REPEATABILITY ESTIMATES

Source of variation	Calving group		Calving interval	
	D.F.	Mean square	D.F.	Mean square
Years	13	1.150**	12	122.201
Among cows within years	276	0.775**	172	125.637
Error (within cows)	879	0.529	587	398.781
Total	1168		771	

Constant (k) = 3.986	Constant (k) = 4.129
$\sigma_c^2 = 0.062$	$\sigma_c^2 = -66.160$
$r_e = 0.105$	$r_e = \text{zero}$

** (P < .01)

Birth weight

The sex of the calf significantly ($P < .01$) affected the birth weight of calves in both herds (Tables 15 and 16). The mean birth weight of Bozeman bull calves was 72.5 pounds as compared to 68.1 pounds for heifer calves. The mean birth weight of Havre bull calves was 78.2 pounds as compared to 74.0 pounds for heifer calves. The difference in birth weight between the sexes found here is in close agreement with that reported by many other workers (Knapp et al., 1940; Knapp et al., 1942; Dawson et al., 1947; Woolfolk and Knapp, 1949; Gregory et al., 1950; Burris and Blunn, 1952; Koch and Clark, 1955a, Clark et al., 1958; Foote et al., 1959; Koch et al., 1959; Tallis et al., 1959; and Flower et al., 1963).

Eckles (1919), Dawson et al. (1947), Burris and Blunn (1952), Herman et al. (1953) and Rice et al. (1954) have reported that bull calves are carried in gestation longer than heifer calves. This might explain the difference in birth weight found in succeeding calving groups in the Havre herd. However, the sex and calving group interaction was not statistically significant in the Havre herd and, thus, seems to rule out the probability of a dependent relationship between sex and calving group in affecting the birth weight of calves in this study.

Significant differences ($P < .01$) between breeds and cow lines were found. The Bozeman Angus calves weighed 65.5 pounds as compared

to 75.1 pounds for the Hereford calves. The mean birth weights of Havre calves were 72.7, 78.1, 69.3, 80.0 and 80.4 pounds for cow lines 1, 2, 3, 4 and 5, respectively. There was a significant ($P < .05$) cow line x calving group interaction effect on birth weight in the Havre herd (Appendix Table 8).

TABLE 15. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON CALF BIRTH WEIGHT AT BOZEMAN

Source of variation	D.F.	Mean square
Breed	1	16590.96**
Age at first calving	1	88.25
Calving group	5	124.91
Age of cow	9	597.01**
Sex of calf	1	3875.68**
Breed X age at first calving	--	n.s.
Breed X calving group	--	n.s.
Age at first calving X calving group	--	n.s.
Sex of calf X calving group	--	n.s.
Error	831	66.73
Within SS	848	

** ($P < .01$)

n.s. (non-significant interaction)

The age of the cow at calving significantly ($P < .01$) affected calf birth weight in both herds. Calf birth weight tended to increase with increasing cow age up to six or seven years and declined or became somewhat irregular until 10 years of age when birth weights began increasing again. The increase in average calf birth weight from cows 10 years old and older is probably due to the previous removal of less

productive cows from the herd. Such aged cows would have to have been good producers to remain in the herd as long as they did. Consequently, their calves would, quite likely, have a genotype for rapid growth and development which could be readily expressed in the limited environment of the pre-natal stages of life.

TABLE 16. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON CALF BIRTH WEIGHT AT HAVRE

Source of variation	D.F.	Mean square
Cow line	4	873.52**
Age at first calving	1	75.64
Calving group	4	703.60**
Age of cow	8	1769.57**
Sex of calf	1	4853.45**
Cow line X calving group	15	146.85*
Cow line X age at first calving	--	n.s.
Age at first calving X calving group	--	n.s.
Sex of calf X calving group	--	n.s.
Error	1121	80.82
Within SS	1154	

** ($P < .01$)

* ($P < .05$)

n.s. (non-significant interaction)

The initial calving group did not affect the birth weight of calves from first-calf heifers at Bozeman but did significantly affect ($P < .01$) the birth weight of subsequent calves (Table 17). No particular trend is evident from the data in Table 18. The correlations between calving group and birth weight of calves from Bozeman first-calf heifers and all calves were 0.02 and -0.02, respectively. There was a significant ($P < .01$) breed x initial calving group interaction effect on the birth weight of subsequent calves at Bozeman (Appendix Table 9). The relationship was reversed in the Havre herd where initial calving group significantly ($P < .01$) affected the birth weight of calves from first-calf heifers but not any of their subsequent calves as shown in Table 19. The correlations between calving group and birth weight of calves from Havre first-calf heifers and all calves were 0.08 and 0.18, respectively. The data in Table 20 indicate that the birth weight of calves from first-calf heifers increased with later calving groups. A cow line X calving group interaction significantly affected the birth weight of calves from Havre first-calf heifers (Appendix Table 10).

TABLE 17. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF INITIAL CALVING GROUP
AND OTHER FACTORS ON BIRTH WEIGHT OF CALVES BORN TO FIRST-CALF HEIFERS
AND ALL SUBSEQUENT CALVES BORN TO COWS AT BOZEMAN

Source of variation	First calves		Subsequent calves	
	D.F.	Mean square	D.F.	Mean square
Breed	1	3602.86**	1	10683.72**
Age at first calving	1	1.23	1	9.42
Initial calving group	5	113.16	5	181.47**
Age of cow	--	---	8	139.18*
Sex of calf	1	605.03**	1	3180.44**
Breed X age at first calving	--	n.s.	--	n.s.
Breed X initial calving group	--	n.s.	4	236.22**
Initial calving group X age at first calving	--	n.s.	--	n.s.
Initial calving group X sex of calf	--	n.s.	--	n.s.
Error	164	84.01	639	58.82
Within SS	172		659	

** (P $\leq$.01)

* (P $\leq$.05)

n.s. (non-significant interaction)

TABLE 18. BIRTH WEIGHT OF ALL SUBSEQUENT CALVES BORN TO COWS AT
BOZEMAN

	<u>No. calves</u>	<u>Avg. birth weight</u>
Total or average	677	71.6
<u>Initial calving group^a</u>		
1	64	71.4
2	217	71.5
3	212	69.8
4	117	72.5
5	54	69.5
6	13	74.9

^a Each group includes all subsequent calves produced by a cow
based on the cow's initial calving group.

TABLE 19. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF INITIAL CALVING GROUP AND OTHER FACTORS ON BIRTH WEIGHT OF CALVES BORN TO FIRST-CALF HEIFERS AND ALL SUBSEQUENT CALVES BORN TO COWS AT HAVRE

Source of variation	First calves		Subsequent calves	
	D.F.	Mean square	D.F.	Mean square
Cow line	4	766.90**	4	672.26**
Age at first calving	1	1229.83**	1	19.05
Initial calving group	4	274.72**	4	161.06
Age of cow	--	--	7	477.37**
Sex of calf	1	1081.08	1	4602.77**
Cow line X initial calving group	13	237.61**	--	n.s.
Cow line X age at first calving	--	n.s.	--	n.s.
Initial calving group X age at first calving	--	n.s.	--	n.s.
Initial calving group X sex of calf	--	n.s.	--	n.s.
Error	254	57.35	847	87.83
Within SS	277		864	

** ($P < .01$)

n.s. (non-significant interaction)

TABLE 20. BIRTH WEIGHT OF CALVES BORN TO FIRST-CALF HEIFERS AT
HAVRE

	No. calves	Avg. birth weight
Total or average	291	70.7
Calving group		
1	2	60.5
2	125	73.0
3	117	75.8
4	38	76.7
5	9	67.5

Weaning weight

Breed or cow line, calving group, age of cow and sex of calf significantly ($P < .01$) affected the weaning weights of calves in the Bozeman and Havre herds as shown in Tables 21 and 22. In addition, a breed x age at first calving and a breed x calving group interaction significantly ($P < .05$) affected the weaning weights of calves in the Bozeman herd (Appendix Tables 11 and 12).

The average calf weaning weight in the Bozeman herd was 413.7 pounds. The Angus calves averaged 432.8 pounds and the Herefords averaged 394.6 pounds. The average calf weaning weight in the Havre herd was 403.9 pounds with means of 375.9, 396.4, 378.7, 425.1 and 443.1 pounds for cow lines 1, 2, 3, 4 and 5, respectively.

Tables 23 and 24 indicate a continual decline in average weaning weight of calves born in progressively later calving groups. Morrow and Brinks (1968) reported similar observations from a herd in Colorado. They found that calves born in the first group had a less than normal gestation length and tended to weigh less at birth. Therefore, they would be expected to weigh less at weaning than calves born in the second group unless they were considerably older than the calves in the second group. Such is apparently the case in the Bozeman herd where the calves in Group 1 averaged two weeks older at weaning than the calves in Group 2. The increase in weaning weight of calves born in Group 6 relative to those born in Group 5 in the Bozeman herd

TABLE 21. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON CALF PERFORMANCE AT BOZEMAN

Source of variation	Avg. weaning weight		Avg. weaning age		Avg. daily gain	
	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.
Breed	1	36610.92**	1	48.83	1	7.12**
Age at first calving	1	1737.03	1	408.42*	1	0.05
Calving group	5	154968.19**	5	36660.47**	5	0.14*
Age of cow	9	24136.75**	9	871.99**	9	0.32**
Sex of calf	1	205532.25**	1	352.20	1	4.86**
Breed X age at first calving	1	12250.34*	--	n.s.	--	n.s.
Breed X calving group	5	6433.35*	5	277.01*	--	n.s.
Age at first calving X calving group	--	n.s.	--	n.s.	--	n.s.
Sex of calf X calving group	--	n.s.	--	n.s.	--	n.s.
Error	762	2349.40	763	101.77	768	0.05
Within SS	785		785		785	

** (P < .01)

* (P < .05)

n.s. (non-significant interaction)

TABLE 22. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON CALF PERFORMANCE AT HAVRE

Source of variation	Avg. weaning weight		Avg. weaning age		Avg. daily gain	
	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.
Cow line	4	79697.44**	4	539.82*	4	1.98**
Age at first calving	1	182.41	1	547.78	1	0.03
Calving group	4	189067.94**	4	43116.77**	4	0.36**
Age of cow	8	63987.80**	8	238.44	8	1.31**
Sex of calf	2	33613.53**	2	252.51	2	0.70**
Cow line X age at first calving	--	n.s.	4	714.02**	--	n.s.
Cow line X calving group	--	n.s.	--	n.s.	--	n.s.
Age at first calving X calving group	--	n.s.	--	n.s.	--	n.s.
Sex of calf X calving group	--	n.s.	--	n.s.	--	n.s.
Error	1059	2746.30	1055	196.73	1059	0.07
Within SS	1078		1078		1078	

** (P < .01)

* (P < .05)

n.s. (non-significant interaction)

TABLE 23. CALF PERFORMANCE AVERAGES GROUPED BY DATE OF BIRTH OF CALF AT BOZEMAN

	No. calves	Avg. weaning weight (lb)	Avg. weaning age (days)	Avg. daily gain (lb)
Total or average	804	413.7	199.6	1.72
<u>Calving group</u>				
1	64	487.9	241.1	1.76
2	375	462.5	227.4	1.75
3	224	430.0	210.2	1.74
4	91	379.4	190.0	1.67
5	37	351.7	175.5	1.65
6	13	370.6	153.4	1.75

TABLE 24. CALF PERFORMANCE AVERAGES GROUPED BY DATE OF BIRTH OF CALF AT HAVRE

	No. calves	Avg. weaning weight (lb)	Avg. weaning age (days)	Avg. daily gain (lb)
Total or average	1093	403.9	180.8	1.80
<u>Calving group</u>				
1	22	435.2	203.7	1.72
2	538	452.5	201.8	1.89
3	394	418.9	185.5	1.85
4	116	378.9	166.7	1.83
5	23	334.0	146.3	1.71

is more difficult to explain. The Group 6 subclass included four heifer and nine bull calves whereas the Group 5 subclass included 22 heifer and 15 bull calves. Since bull calves tended to weigh more than heifer calves at weaning, the subclass averages may have been influenced accordingly.

Table 25 shows the effect of cow age on calf weaning weights. Calf weaning weights tended to increase as cow age increased to seven years old and then became irregular thereafter. Knapp et al. (1942), Knox and Koger (1945), Sawyer et al. (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) have reported similar observations.

The average weaning weight of bull calves at Bozeman was 430.4 pounds as compared to 397.0 pounds or 33.4 pounds more than heifer calves. The average weaning weight of calves at Havre was 392.5, 405.0 and 414.2 pounds for heifers, steers and bulls, respectively. The steer calves weighed 12.5 pounds more than the heifer calves and 9.2 pounds less than the bull calves. The bull calves weighed 21.7 pounds more than the heifer calves at weaning. Similar results have been reported in the literature.

A correlation between birth weight and weaning weight of 0.31 and 0.40 was found for calves in the Bozeman and Havre herds,, respectively.

TABLE 25. EFFECT OF COW AGE ON CALF WEANING WEIGHT

Age of cow (years)	Avg. weaning weight (lb)	
	Bozeman	Havre
2	373.5	351.3
3	393.7	377.5
4	406.5	403.3
5	415.2	412.8
6	425.6	421.0
7	427.5	424.9
8	425.3	420.1
9	431.3	417.2
10 ^a	416.0	407.0
11 and older	422.4	--

a Includes cows 10 years old and older in the Havre herd

Weaning age

Since all calves within a given year were weaned on the same date, the weaning age is a direct function of the calving group. Consequently, the calving group significantly ($P < .01$) affected the weaning age of calves in both herds (Tables 21 and 22).

The age of a calf's dam at first calving significantly ($P < .05$) affected the weaning age of the calf in the Bozeman herd but not in the Havre herd. The average weaning age of calves from cows calving first as two-year-olds was 198.6 days as compared to 200.6 days for calves from cows calving first as three-year-olds. This merely substantiates the previously discussed fact that cows calving first as three-year-olds tended to calve earlier throughout their lifetime than cows calving first as two-year-olds.

A significant ($P < .01$) difference in the average weaning age of calves from cows of different ages was found in the Bozeman herd but not in the Havre herd. Table 26 indicates that the average weaning age of calves tended to increase as cow age increased up to seven years and decreased thereafter at Bozeman. Apparently, the cows remaining in the herd each successive year tended to calve earlier. However, the difference in calving date each year was not large enough to result in a significant effect of cow age on subsequent calving group as previously discussed.

TABLE 26. EFFECT OF AGE OF COW ON CALF WEANING AGE AT BOZEMAN

Age of cow (years)	Avg. weaning age (days)
2	191.2
3	200.8
4	199.9
5	200.0
6	200.5
7	201.8
8	200.8
9	200.8
10	200.0
11 and older	200.2

A breed x calving group interaction significantly ($P < .05$) affected calf weaning age throughout the lifetime of cows in the Bozeman herd (Appendix Table 13). Breed, sex and other interactions were not statistically significant in the Bozeman herd.

Table 22 indicates that cow line and its interaction with age at first calving significantly ($P \leq .01$) affected the average weaning age of calves throughout the lifetime of cows at Havre (Appendix Table 14). The average calf weaning age was 183.6, 180.7, 176.6, 180.9 and 182.2 days for cow lines 1, 2, 3, 4 and 5, respectively. No other interactions were statistically significant.

The correlations between the weaning weight and weaning age of calves from first-calf heifers and all calves were 0.33 and 0.29 for the Bozeman herd. The same types of correlations for the Havre herd gave values of 0.60 and 0.57, respectively.

Average daily gain

The average daily gain (ADG) of calves from birth to weaning was significantly ($P \leq .01$) affected by breed or cow line, age of the cow and sex of the calf in both herds as shown in Tables 21 and 22.

The mean ADG of the Bozeman calves was 1.72 pounds. The mean for the Angus calves was 1.82 pounds as compared to 1.62 pounds for the Hereford calves. The mean ADG for the Havre calves was 1.80 pounds with means of 1.66, 1.75, 1.69, 1.91 and 1.99 pounds for cow lines 1, 2, 3, 4 and 5, respectively.

Table 27 shows the effect of cow age on the ADG of calves. The ADG of calves in the Havre herd increased continually as cow age increased to seven years old and declined thereafter. The ADG of calves in the

Bozeman herd increased with cow age up to six years old and showed no consistent pattern thereafter.

TABLE 27. EFFECT OF COW AGE ON AVERAGE DAILY GAIN OF CALVES

Age of cow (years)	Avg. daily gain (lb)	
	Bozeman	Havre
2	1.61	1.57
3	1.62	1.68
4	1.68	1.79
5	1.73	1.84
6	1.77	1.88
7	1.76	1.90
8	1.76	1.87
9	1.81	1.86
10 ^a	1.71	1.81
11 and older	1.75	--

a Includes cows 10 years old and older in Havre herd.

The mean ADG of bull calves at Bozeman was 1.80 pounds as compared to 1.72 pounds for heifer calves. The mean ADG of calves at Havre was 1.75, 1.79 and 1.86 pounds for heifer, steer and bull calves, respectively.

Tables 23 and 24 indicate a continual decline in ADG of calves in each succeeding calving group except for Group 1 in the Havre herd and Group 6 in the Bozeman herd. The reasons for their inconsistency are the same as those for the weaning weights of calves in those groups as previously discussed. These results agree with those reported by Nelms and Bogart (1956), Marlowe et al. (1965) and Morrow and Brinks (1968).

The correlations between weaning age and ADG of calves from first-calf heifers and all calves were 0.14 and 0.08, respectively, for the Bozeman herd. The same types of correlations for the Havre herd were 0.46 and 0.43, respectively. The correlations between weaning weight and ADG of calves from first-calf heifers and all calves were 0.87 and 0.91, respectively, for the Bozeman herd. The same types of correlations for the Havre herd were 0.97 and 0.96, respectively.

Effect of initial calving group on lifetime production

Tables 28 and 29 show the effect of a cow's initial calving group on her total lifetime calf production. One of the most important findings of this study was the fact that cows calving early the first time had a higher total lifetime calf production than cows calving later the first time ($P < .01$). Morrow (1968), Morrow and Brinks (1968) and Roberts et al. (1970) have reported similar results. The importance of this fact for economic profit in a cow-calf operation cannot be overemphasized.

Tables 30 and 31 indicate a significant ($P < .01$) difference in lifetime calf production between breeds and cow lines. The averages reported here are based on the initial calving group of the cow. The average weaning weight of all calves produced during the lifetime of an Angus cow at Bozeman was 433.7 pounds as compared to 393.7 pounds for a Hereford cow. The average weaning weight of all calves produced during

the lifetime of a cow at Havre was 384.1, 390.5, 380.3, 425.5 and 439.1 pounds for cow lines 1, 2, 3, 4 and 5, respectively. A similar proportionality in differences in average weaning age ($P < .01$) and average daily gain from birth to weaning ($P < .01$) between breeds and cow lines was also found.

The age of a heifer at first calving did not significantly affect her total lifetime production with one exception. A significant ($P < .01$) difference in average weaning age of calves from two-year-old and three-year-old heifers was found in the Havre herd. The average weaning age of calves from cows calving first as two-year-olds at Havre was 184.5 days as compared to 177.1 days for calves from cows calving first as three-year-olds. Apparently, cows calving first as two-year-olds tended to calve earlier throughout their productive lifetime. However, this difference in average weaning age, apparently, was not large enough to make age at first calving significantly affect subsequent calving groups in the Havre herd as previously discussed.

The age of the cow and sex of the calf significantly affected the lifetime production of all cows in the same manner as previously discussed.

A breed x age at first calving interaction significantly ($P < .05$) affected the average weaning weight and average daily gain of calves from the Bozeman cows (Appendix Tables 15 and 16). An initial calving group x age at first calving interaction also significantly ($P < .05$)

affected the lifetime average weaning weight of calves from Bozeman cows (Appendix Table 17).

TABLE 28. EFFECT OF INITIAL CALVING GROUP ON LIFETIME PRODUCTION OF COWS AT BOZEMAN

	No. calves	Avg. weaning weight (lb)	Avg. weaning age (days)	Avg. daily gain (lb)
Total or avg.	804	413.7	199.6	1.72
<u>Initial calving group</u>				
1	77	443.3	210.8	1.76
2	264	432.8	206.4	1.75
3	244	416.1	201.1	1.78
4	138	409.5	194.7	1.77
5	65	405.2	194.8	1.67
6	16	375.3	189.8	1.59

TABLE 29. EFFECT OF INITIAL CALVING GROUP ON LIFETIME PRODUCTION OF COWS AT HAVRE

	No. calves	Avg. weaning weight (lb)	Avg. weaning age (days)	Avg. daily gain (lb)
Total or avg.	1093	403.9	180.8	1.80
<u>Initial calving group</u>				
1	9	406.9	191.8	1.76
2	465	416.1	188.2	1.82
3	453	406.9	182.3	1.81
4	131	396.3	174.7	1.80
5	35	393.3	167.0	1.81

TABLE 30. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF INITIAL CALVING GROUP AND OTHER FACTORS ON LIFETIME PRODUCTION OF COWS AT BOZEMAN

Source of variation	Avg. weaning weight		Avg. weaning age		Avg. daily gain	
	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.
Breed	1	135432.06**	1	12534.56**	1	3.82**
Age at first calving	1	2363.74	1	48.49	1	0.06
Initial calving group	5	20086.54**	5	4082.94**	5	0.16**
Age of cow	9	40248.65**	9	3107.37**	9	0.33**
Sex of calf	1	188731.38**	1	1827.68*	1	4.90**
Breed X age at first calving	1	15179.94*	--	n.s.	1	0.24*
Breed X initial calving group	--	n.s.	--	n.s.	--	n.s.
Initial calving group X age at first calving	5	11251.92*	--	n.s.	--	n.s.
Initial calving group X sex of calf	--	n.s.	--	n.s.	--	n.s.
Error	762	3327.97	768	362.33	767	0.05
Within SS	785		785		785	

** (P < .01)

* (P < .05)

n.s. (non-significant interaction)

TABLE 31. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF INITIAL CALVING GROUP AND OTHER FACTORS ON LIFETIME PRODUCTION OF COWS AT HAVRE

Source of variation	Avg. weaning weight		Avg. weaning age		Avg. daily gain	
	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.
Cow line	4	67893.13**	4	2039.73**	4	1.86**
Age at first calving	1	4550.32	1	4791.30**	1	0.04
Initial calving group	4	12814.34**	4	4125.54**	4	0.01
Age of cow	8	74608.69**	8	962.94**	8	1.33**
Sex of calf	2	25096.49**	2	508.95	2	0.69**
Cow line X age at first calving	--	n.s.	4	1063.38*	--	n.s.
Cow line X initial calving group	--	n.s.	13	681.46*	--	n.s.
Initial calving group X age at first calving	--	n.s.	--	n.s.	--	n.s.
Initial calving group X sex of calf	--	n.s.	--	n.s.	--	n.s.
Error	1059	3412.03	1042	340.31	1059	0.07
Within SS	1078		1078		1078	

** (P < .01)

* (P < .05)

n.s. (non-significant interaction)

A cow line x age at first calving and cow line x initial calving group interaction significantly ($P < .05$) affected the average weaning age of calves produced during the lifetime of cows at Havre (Appendix Tables 18 and 19).

Percent survival from birth to weaning

The initial calving group had no statistically significant effect on the percent of calves lost at birth or before weaning during the lifetime of cows in either herd.

Calving group significantly ($P < .01$) affected the percent of calves surviving from birth to weaning in the Havre herd (Table 32). Table 33 indicates a continual decline in percent survival for each 20 days later that calves were born during the calving season at Havre. Morrow and Brinks (1968) reported similar observations. Calves born in Group 1 had a gestation length of less than 283 days and might be expected to be weaker at birth than full term calves. The same trend of decreasing survival with later birth was not evident in the Bozeman herd.

The sex of the calf significantly ($P < .01$) affected the percent survival of calves at Havre with 91.6, 88.2 and 100.0 percent of the heifer, bull and steer calves, respectively, surviving from birth to weaning. A sex x calving group interaction significantly ($P < .05$) affected the survival percentage of calves at Havre (Appendix Table 20). The age of the cow significantly ($P < .05$) affected calf survival at

Havre. Calf survival increased from 87.6 percent to a peak of 96.7 percent as cows advanced from two to five years of age. After five years of age, the calf survival declined irregularly to 84.5 percent for cows 10 years old and older. Cow line and age at first calving had no statistically significant effect on calf survival. None of the above factors significantly affected calf survival in the Bozeman herd (Appendix Table 3).

TABLE 32. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON CALF SURVIVAL FROM BIRTH TO WEANING AT HAVRE

Source of variation	D.F.	Mean square
Cow line	4	0.06
Age at first calving	1	0.01
Age of cow	8	0.14*
Calving group	4	0.24**
Sex of calf	2	0.30**
Calving group X sex of calf	8	0.11*
Cow line X calving group	--	n.s.
Age of cow X calving group	--	n.s.
Age at first calving X calving group	--	n.s.
Error	1127	0.06
Within SS	1154	

** (P < .01)

* (P < .05)

n.s. (non-significant interaction)

TABLE 33. EFFECT OF CALVING GROUP ON PERCENT SURVIVAL FROM BIRTH TO WEANING

Calving group	Percent survival	
	Bozeman	Havre
1	86.7	92.6
2	93.3	99.6
3	94.1	99.2
4	93.1	92.9
5	87.6	83.2
6	100.0	--

The correlation between birth weight and percent survival was 0.06 for calves at Bozeman and 0.18 for calves at Havre. The correlation between calving group and percent survival was 0.02 for calves at Bozeman and -0.07 for calves at Havre.

Cow weight at weaning

Data concerning the weight of a cow at weaning was not on the production records used in this analysis for the Havre herd but was available for the Bozeman herd. Only breed and age differences significantly ($P < .01$) affected the weight of Bozeman first-calf heifers at weaning (Table 34). Only heifers actually weaning a calf were included in that analysis. Their mean weight at weaning was 1032.1 pounds. The Angus heifers averaged 1009.7 pounds and the Hereford heifers averaged 1054.5 pounds. Two-year-old heifers averaged 949.5 pounds as compared to 1114.7 pounds for three-year-old heifers. When heifers that did not wean a calf were included, the overall mean weight decreased to 1027.7

TABLE 34. LEAST-SQUARES ANALYSIS OF VARIANCE OF FACTORS AFFECTING WEIGHT OF
FIRST-CALF HEIFERS AT WEANING AT BOZEMAN

Source of variation	Heifers that weaned calves only		All heifers	
	D.F.	Mean square	D.F.	Mean square
Breed	1	63931.72**	1	137291.44**
Age at first calving	1	433588.75**	1	670406.31**
Calving group	5	4220.30	5	12157.20
Sex of calf	1	3044.48	1	3123.66
Breed X age at first calving	--	n.s.	--	n.s.
Breed X calving group	--	n.s.	--	n.s.
Calving group X age at first calving	--	n.s.	--	n.s.
Calving group X sex of calf	--	n.s.	--	n.s.
Error	142	6263.30	164	11860.28
Within SS	150		172	

** (P < .01)

n.s. (non-significant interaction)

pounds and breed and age differences were still the only significant ($P \leq .01$) factors affecting the weight of the first-calf heifers at weaning (Table 34). The mean weight of all Angus heifers at weaning time, whether or not they weaned a calf, was 997.5 pounds as compared to 1057.9 pounds for the Hereford heifers. Two-year-old heifers averaged 932.7 pounds as compared to 1122.7 pounds for three-year-old heifers. No relationship between calving group and weight of first-calf heifers at weaning was apparent.

Table 35 indicates that breed and age of the cow significantly ($P \leq .01$) affected cow weights at weaning throughout their lifetime along with a breed x age at first calving interaction ($P \leq .05$, Appendix Table 21). Only cow-years when a calf was actually weaned were included in this analysis. Calving group had no statistically significant effect on cow weight at weaning although a definite trend was evident as indicated by Table 36. Cow weight at weaning tended to increase up to six years of age and decline thereafter.

The correlation between the weights of first-calf heifers at weaning and the weaning weights of their calves was -0.05. This indicates that the heaviest calves at weaning were produced by the lightest first-calf heifers at weaning. This relationship apparently reverses itself as cow age and weight increase because the same correlation for all cows in the herd weaning calves was 0.10. However, neither of these correlations were statistically significant and, thus,

have little value as measures of future production and performance. The correlation of 0.10 is in agreement with that of Brinks et al. (1962) who reported a correlation between calf weaning weight and cow weight at weaning of 0.09 from 9797 cow-calf records collected at the U. S. Range Livestock Experiment Station, Miles City, Montana. Gregory et al. (1950) reported correlations for calf weaning weights and cow weights at weaning of 0.20 and -0.11, respectively, for two separate herds at the North Platte and Valentine, Nebraska experiment stations.

TABLE 35. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON COW WEIGHT AT WEANING AT BOZEMAN^a

Source of variation	D.F.	Mean square
Breed	1	985728.56**
Age at first calving	1	66266.25
Calving group	5	41239.47
Age of cow	9	669938.31**
Sex of calf	1	22620.52
Breed X age at first calving	1	111563.94*
Breed X calving group	--	n.s.
Age at first calving X calving group	--	n.s.
Sex of calf X calving group	--	n.s.
Error	767	26488.61
Within SS	785	

a Includes only cow-years when a calf was actually weaned.

** (P < .01)

* (P < .05)

n.s. (non-significant interaction)

TABLE 36. COW WEIGHT AT WEANING GROUPED BY DATE OF BIRTH OF CALF AT
BOZEMAN

	No. cows weaning calves	Avg. cow weight at weaning
Total or average	804	1147.2
<u>Calving group</u>		
1	64	1105.2
2	375	1133.5
3	224	1132.0
4	91	1169.7
5	37	1173.5
6	13	1169.3

General Discussion

The primary purposes of this study were to determine the effect of birth date on calf performance from birth to weaning and to determine the effect of the date of first calving in beef heifers on subsequent calving dates.

The calving group for a particular calf had a highly significant ($P < .01$) effect on its performance from birth to weaning. Tables 23 and 24 indicate how large the differences between groups were. Group 1 included calves that had a less than normal gestation length. Calves born in Group 1 had a higher death loss from birth to weaning than calves born in later groups. Consequently, the performance average for Group 1 calves might be expected to be lower than for the next group. Comparisons of Groups 2 through 5 are probably the most meaningful in

both herds.

Group 2 calves were born 51.9 and 55.5 days earlier than Group 5 calves in the Bozeman and Havre herds, respectively. They averaged 110.8 and 118.5 pounds heavier at weaning than Group 5 calves. Group 2 calves were born an average of 21.0 and 27.8 days earlier and weaned 48.8 and 48.6 pounds heavier than the overall Bozeman and Havre herd averages, respectively. Most of this advantage in weaning weights of Group 2 calves was due to their older age at weaning. However, calves born earlier in the normal calving season also grew faster from birth to weaning than later calves. Similar observations have been reported by Burgess et al. (1954), Nelms and Bogart (1956) and Morrow and Brinks (1968).

The correlations between weaning weight and weaning age for Bozeman and Havre calves were 0.29 and 0.57, respectively. This correlation tended to be higher for calves from first-calf heifers (0.33 and 0.60 for Bozeman and Havre calves, respectively) than for all calves. This indicates that calving dates have a greater effect on the weaning weights of calves from first-calf heifers than on calves from older cows. Breeding heifers to calve earlier than the average of the herd would then allow a higher degree of accuracy in selecting herd replacements on the basis of the first calf produced.

Older calves are probably able to utilize grass to greater advantage and consume greater quantities of milk produced by the dam as she

reaches peak milk production on the range. The capacity of the calf for milk consumption may be a limiting factor in range cow milk production (Gleddie and Berg, 1968). It seems reasonable to assume that at the time a cow reaches her peak milk production, she would maintain that high level of production for a longer time period while suckling an older calf with a larger capacity for milk consumption. As a result, the calf would grow at a faster rate and weigh more at weaning than its younger herd mates.

The correlations between weaning weight and average daily gain were 0.91 and 0.96 for Bozeman and Havre calves, respectively. The calves with the highest average daily gain were the heaviest at weaning.

The correlations between birth weight and weaning weight of 0.31 and 0.40 for the Bozeman and Havre herds, respectively, are in agreement with reports by Gregory et al. (1950) and Cartwright and Warwick (1955). The genotype for rapid and efficient growth apparently begins its phenotypic expression in the embryonic stages. Thus, selection for heavier weaning weights results in heavier birth weights. Wiltbank (1970) studied calving difficulty in 95 Hereford and 103 Angus two-year-old, first-calf heifers. The correlation between calving difficulty and birth weight was 0.54 ($P < .01$) and 0.48 ($P < .01$) for Hereford and Angus dams, respectively. The correlation between calving difficulty and pelvic area was -0.19 ($P < .10$) and -0.22 ($P < .05$) for Hereford and Angus dams, respectively. These correlations indicate

that as pelvic area increased, calving difficulty decreased. More emphasis should probably be placed on pelvic region measurements when selecting replacement heifers. This would allow the normal birth of larger calves throughout a cow's life and ultimately increase her lifetime calf production. Selection for high weaning weights from cows continually bred to bulls noted for progeny with low birth weights seems to be an example of diametrically opposed management practices commonly observed in the beef cattle industry. However, this does not preclude the possibility that some bulls do sire calves with lower birth weights and higher weaning weights than their contemporaries.

The initial calving group significantly ($P < .01$) affected the weaning weights of all of the calves produced by a cow. Tables 28 and 29 indicate that cows calving as heifers in Group 2 weaned calves weighing an average of 27.6 and 22.8 pounds heavier than cows calving as heifers in Group 5 at Bozeman and Havre, respectively. Table 14 indicates that an average of 3.986 calves were born to each cow in the Havre herd and Appendix Table 4 indicates the survival percentage for calves born to cows calving first in Group 2 was 94.4 percent as compared to 91.9 percent for calves born to cows calving first in Group 5. Thus, cows calving first in Group 2 weaned an average of 3.76 calves that weighed 416.1 pounds for a total lifetime calf production of 1564.5 pounds. Cows calving first in Group 5 weaned an average of 3.66 calves that weighed 393.3 pounds for a total lifetime calf

production of 1241.5 pounds. The difference in total lifetime calf production in favor of cows calving first in Group 2 was 323.0 pounds which, at 30 cents per pound, would be worth \$96.90 or \$25.77 per calf weaned. Similar calculations comparing cows calving first in Group 2 with the herd average of 3.73 calves that weighed 403.9 pounds results in a difference in total lifetime production in favor of Group 2 cows of 58.0 pounds which, at 30 cents per pound, would be worth \$17.40 or \$4.63 above the herd average per calf weaned.

The initial calving group significantly ($P \leq .05$) affected the subsequent calving groups of cows in both herds. Heifers calving in Groups 1, 2 and 3 the first time tended to calve 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. Harwin et al. (1969) reported a repeatability estimate for early calving of 0.14. These repeatability estimates indicate that significant progress might not be made by culling cows on the basis of calving dates during the normal calving season.

Dry cows and all of their subsequent calves were eliminated from consideration in this study for two reasons. One involved the requirement of the birth of a calf to meet the objectives of the study. The other involved the fact that dry cows should be eliminated from breeding herds as an actual management practice in a cow-calf operation. Heifers

which were bred and failed to calve as two-year-olds but did calve as three-year-olds were included in the analysis merely to increase the number of heifers calving first as three-year-olds. Such a practice cannot be recommended for an actual production operation. Table 31 indicates a significant difference ($P < .01$) between cows calving first as two-year-olds or as three-year-olds at Havre in the average weaning age of all of the calves they produced in their lifetime. As a result, one might expect the average weaning weight of calves from cows calving first as two-year-olds to be different than the average for calves from cows calving first as three-year-olds and, indeed, it was. Although the difference was not statistically significant (Table 31) the average weaning weight of all calves produced by cows calving first as two-year-olds was 406.8 pounds as compared to 401.0 pounds for calves from cows calving first as three-year-olds. When this annual lifetime advantage is combined with the opportunity of weaning one extra calf, cows calving first as two-year-olds have significantly higher total lifetime production.

There has been a consistent and statistically significant difference between the cow lines at Havre for all of the production traits analyzed in this study. The cow line designated as line 5 includes cows from lines 5, 6, 7 and 16. These cows were the progeny of crossline matings of Havre Hereford lines 1, 2, 3 and 4. The crossline cows consistently showed better performance than the straight line cows

analyzed in this study. The crossline cows had earlier initial calving groups than the straight line cows. Their calves had heavier birth weights, heavier weaning weights, older weaning ages and higher average daily gains than the straight line calves. The results of inbreeding depression and heterosis were plainly evident. Flower et al. (1963) reported similar conclusions from a study which involved many of the same cows used in this analysis.

The results of this study clearly indicate that certain cows tend to repeatedly calve early or late. However, the repeatability of calving group is not very high and the birth date of the first calf is not a permanent characteristic of the cow. The study substantiates the fact that heifers can be accurately measured and selected for their most probable lifetime producing ability on the basis of their first calf. Finally, it indicates the importance of managing first-calf heifers for early calving in the optimum season in herds where there is a limited breeding season and a definite time of weaning. A significantly larger number of heifers than needed should be bred for replacements for 45 days, pregnancy tested and culled at the end of the breeding season if they are open. The heifers that conceive and calve the earliest immediately indicate their greater reproductive efficiency and lifetime potential and should be given preference in selection for addition to the breeding herd. The proper application of basic genetic principles for rapid growth and early sexual maturity in yearling beef heifers and

an adequate nutritional regime to maximize that genetic potential are essential to a program of getting cows into the "habit" of calving early in the normal calving season throughout their productive lives. The result should be a significantly greater lifetime production per cow and a greater opportunity for economic profit.

SUMMARY

A study was conducted to determine the effect of the date of first calving in beef heifers on lifetime calf production. Lifetime production records of 85 Angus and 105 Hereford cows calving from 1950 to 1968 at the Montana Agricultural Experiment Station at Bozeman and 291 Hereford cows calving from 1952 to 1966 at the North Montana Branch Experiment Station at Havre, Montana were analyzed by the method of least-squares. The study involved 2036 calves 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 5 or 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.

The calving group for a particular calf had a highly significant ($P \leq .01$) effect on its performance from birth to weaning. Group 1

included calves that had a less than normal gestation length and a higher death loss from birth to weaning than calves born in later groups. Consequently, their performance was lower than that of the next group. More meaningful comparisons can be made with Groups 2 through 5. Group 2 calves were born an average of 21.0 and 27.8 days earlier and weaned 48.8 and 48.6 pounds heavier than the overall Bozeman and Havre herd averages, respectively. Most of this advantage in weaning weights of Group 2 calves was due to their older age at weaning. However, calves born earlier also grew significantly faster at Bozeman ($P \leq .05$) and at Havre ($P \leq .01$) from birth to weaning than later calves.

Older calves were probably able to utilize grass to greater advantage and consume greater quantities of milk produced by the dam as she reached peak milk production on the range. As a result, older calves grew faster and weighed more at weaning than their younger herd mates.

The initial calving group significantly ($P \leq .01$) affected the weaning weights of all calves produced by a cow. Cows calving as heifers in Group 2 weaned calves weighing an average of 27.6 and 22.8 pounds heavier than cows calving as heifers in Group 5 at Bozeman and Havre, respectively.

The initial calving group significantly ($P \leq .05$) affected the subsequent calving groups in both herds. Heifers calving in Groups

1, 2 and 3 the first time tended to calve 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, indicating that significant progress might not be made by culling cows on the basis of calving dates during the normal calving season.

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. This indicates that heifers that fail to calve should not be given a second chance to remain in a breeding herd.

The results of this study clearly indicate that certain cows tend to repeatedly calve early or late. However, the repeatability of calving group is not very high and the birth date of the first calf is not a permanent characteristic of the cow. The study substantiates the fact that heifers can be accurately measured and selected for their most probable lifetime producing ability on the basis of their first calf. Finally, it indicates the extreme 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 operation.

APPENDIX TABLES

APPENDIX TABLE 1. CALF BIRTH WEIGHT AVERAGES GROUPED BY DATE OF BIRTH OF CALF

	Bozeman		Havre	
	No. calves	Avg. birth weight	No. calves	Avg. birth weight
Total or average	867	70.3	1169	76.1
Calving group				
1	73	69.5	25	65.3
2	399	71.4	569	77.2
3	240	70.9	416	79.0
4	99	69.1	129	80.1
5	43	71.9	30	78.9
6	13	69.0	--	--

APPENDIX TABLE 2. EFFECT OF AGE OF COW ON CALF BIRTH WEIGHT

Age of cow (years)	Calf birth weight (lb)	
	Bozeman	Havre
2	63.9	67.6
3	67.6	73.2
4	70.1	76.7
5	70.9	78.3
6	71.1	79.2
7	71.9	76.5
8	70.5	78.9
9	71.2	77.1
10 ^a	72.4	77.4
11 and older	73.4	--
Overall mean	70.3	76.1

a Includes cows 10 years old and older in the Havre herd.

APPENDIX TABLE 3. LEAST-SQUARES ANALYSIS OF VARIANCE OF EFFECT OF CALVING GROUP AND OTHER FACTORS ON CALF SURVIVAL FROM BIRTH TO WEANING AT BOZEMAN

Source of variation	D.F.	Mean square
Breed	1	0.17
Age at first calving	1	0.10
Age of cow	9	0.09
Calving group	5	0.10
Sex of calf	1	0.00
Breed X calving group	--	n.s.
Age at first calving X calving group	--	n.s.
Age of cow X calving group	--	n.s.
Calving group X sex of calf	--	n.s.
Error	831	0.07
Within SS	848	

n.s. (non-significant interaction)

APPENDIX TABLE 4. EFFECT OF INITIAL CALVING GROUP ON PERCENT SURVIVAL FROM BIRTH TO WEANING

Initial calving group	Percent survival	
	Bozeman	Havre
1	90.3	92.0
2	90.5	94.4
3	90.4	95.3
4	91.3	93.9
5	93.1	91.9
6	100.0	--
Overall mean	92.7	93.5

APPENDIX TABLE 5. WEIGHT OF FIRST-CALF HEIFERS AT WEANING GROUPED BY DATE OF BIRTH OF CALF AT BOZEMAN^a

	No. heifers weaning calves	Avg. heifer weight at weaning
Total or average	168	1032.1
Calving group		
1	15	1042.0
2	64	1050.6
3	45	1043.7
4	27	1054.8
5	14	1034.0
6	3	967.5

a Includes only heifers that actually weaned a calf.

APPENDIX TABLE 6. EFFECT OF AGE ON COW WEIGHT AT WEANING

Age (years)	Weight at weaning (lb)
2	959.3
3	1062.0
4	1121.6
5	1201.0
6	1227.6
7	1211.6
8	1240.8
9	1222.7
10	1157.3
11 and older	1068.1

APPENDIX TABLE 7. LEAST-SQUARES MEANS FOR EFFECT OF COW LINE X INITIAL CALVING GROUP INTERACTION ON SUBSEQUENT CALVING GROUPS AT HAVRE

Initial calving group	Cow line				
	1	2	3	4	5
1	--	2.8	--	--	2.4
2	2.9	2.6	2.2	2.8	2.5
3	2.9	2.5	2.2	2.7	2.7
4	2.6	2.1	2.7	2.7	2.9
5	2.0	3.0	3.3	2.2	2.5

Overall mean = 2.6

APPENDIX TABLE 8. LEAST-SQUARES MEANS FOR EFFECT OF COW LINE X CALVING GROUP INTERACTION ON BIRTH WEIGHTS OF ALL CALVES AT HAVRE

Calving group	Cow line				
	1	2	3	4	5
1	75.1	71.9	--	80.2	77.2
2	76.3	74.8	80.4	73.6	75.4
3	77.9	76.1	79.1	72.9	74.5
4	75.8	73.1	78.9	74.0	78.7
5	75.4	84.6	66.0	79.8	74.7

Overall mean = 76.1 lb.

APPENDIX TABLE 9. LEAST-SQUARES MEANS FOR EFFECT OF BREED X INITIAL CALVING GROUP INTERACTION ON AVERAGE BIRTH WEIGHTS OF SUBSEQUENT CALVES AT BOZEMAN

Breed	Initial calving group					
	1	2	3	4	5	6
Angus	69.4	73.7	72.3	71.6	71.0	--
Hereford	73.8	69.5	70.9	71.6	72.2	71.6

Overall mean = 71.6 lb.

APPENDIX TABLE 10. LEAST-SQUARES MEANS FOR EFFECT OF COW LINE X INITIAL CALVING GROUP INTERACTION ON AVERAGE BIRTH WEIGHTS OF CALVES FROM FIRST-CALF HEIFERS AT HAVRE

Initial calving group	Cow line				
	1	2	3	4	5
1	--	70.3	--	--	71.1
2	66.2	68.9	78.7	69.4	70.3
3	68.8	68.4	80.9	67.1	68.3
4	69.8	60.8	83.2	68.0	71.7
5	78.0	85.1	40.0	78.3	72.1

Overall mean = 70.7 lb.

APPENDIX TABLE 11. LEAST-SQUARES MEANS FOR EFFECT OF BREED X AGE AT FIRST CALVING INTERACTION ON AVERAGE WEANING WEIGHTS OF ALL CALVES AT BOZEMAN

Breed	Age at first calving (years)	
	2	3
Angus	418.6	408.8
Hereford	408.8	418.6

Overall mean = 413.7 lb.

APPENDIX TABLE 12. LEAST-SQUARES MEANS FOR EFFECT OF BREED X CALVING GROUP INTERACTION ON AVERAGE WEANING WEIGHTS OF ALL CALVES AT BOZEMAN

Breed	Calving group					
	1	2	3	4	5	6
Angus	417.7	413.2	408.6	395.3	396.9	450.5
Hereford	409.7	414.2	418.8	432.1	430.5	376.9

Overall mean = 413.7 lb.

APPENDIX TABLE 13. LEAST-SQUARES MEANS FOR EFFECT OF BREED X CALVING GROUP INTERACTION ON AVERAGE WEANING AGES OF ALL CALVES AT BOZEMAN

Breed	Calving group					
	1	2	3	4	5	6
Angus	201.8	201.1	200.0	196.6	199.0	199.1
Hereford	197.4	198.1	199.2	202.6	200.6	200.1
Overall mean = 199.6 days						

APPENDIX TABLE 14. LEAST-SQUARES MEANS FOR EFFECT OF COW LINE X AGE AT FIRST CALVING INTERACTION ON AVERAGE WEANING AGES OF ALL CALVES AT HAVRE

Age at first calving (years)	Cow line				
	1	2	3	4	5
2	182.9	181.6	176.9	183.3	179.3
3	178.7	180.0	184.7	178.3	182.3
Overall mean = 180.8 days					

APPENDIX TABLE 15. LEAST-SQUARES MEANS FOR EFFECT OF BREED X AGE AT FIRST CALVING INTERACTION ON LIFETIME AVERAGE WEANING WEIGHTS OF CALVES PRODUCED BY COWS AT BOZEMAN

Breed	Age at first calving (years)	
	2	3
Angus	420.3	407.1
Hereford	407.1	420.3
Overall mean = 413.7 lb.		

APPENDIX TABLE 16. LEAST-SQUARES MEANS FOR EFFECT OF BREED X AGE AT FIRST CALVING INTERACTION ON THE LIFETIME MEAN AVERAGE DAILY GAINS FROM BIRTH TO WEANING OF ALL CALVES PRODUCED BY COWS AT BOZEMAN

Breed	Age at first calving (years)	
	2	3
Angus	1.74	1.70
Hereford	1.70	1.74
Overall mean = 1.72 lb. per day		

APPENDIX TABLE 17. LEAST-SQUARES MEANS FOR EFFECT OF INITIAL CALVING GROUP X AGE AT FIRST CALVING INTERACTION ON LIFETIME AVERAGE WEANING WEIGHTS OF CALVES PRODUCED BY COWS AT BOZEMAN

Age at first calving (years)	Initial calving group					
	1	2	3	4	5	6
2	425.3	411.0	429.8	423.8	407.1	385.2
3	402.1	416.4	397.6	403.6	442.2	420.3

Overall mean = 413.7 lb.

APPENDIX TABLE 18. LEAST-SQUARES MEANS FOR EFFECT OF COW LINE X AGE AT FIRST CALVING INTERACTION ON LIFETIME AVERAGE WEANING AGES OF ALL CALVES PRODUCED BY COWS AT HAVRE

Age at first calving (years)	Cow line				
	1	2	3	4	5
2	179.5	179.2	183.4	176.5	185.4
3	182.1	182.4	178.2	185.1	176.2

Overall mean = 180.8 days

APPENDIX TABLE 19. LEAST-SQUARES MEANS FOR EFFECT OF COW LINE X INITIAL CALVING GROUP INTERACTION ON LIFETIME AVERAGE WEANING AGES OF ALL CALVES PRODUCED BY COWS AT HAVRE

Initial calving group	Cow line				
	1	2	3	4	5
1	--	171.8	--	--	189.8
2	176.3	183.2	183.1	175.3	186.1
3	175.6	183.7	188.8	175.4	180.5
4	179.2	187.6	185.8	180.6	170.8
5	192.1	177.7	165.5	191.9	176.8

Overall mean = 180.8 days

APPENDIX TABLE 20. LEAST-SQUARES MEANS FOR EFFECT OF SEX X CALVING GROUP INTERACTION ON SURVIVAL PERCENTAGE FROM BIRTH TO WEANING OF CALVES AT HAVRE

Sex of calf	Calving group				
	1	2	3	4	5
Heifer	92.2	96.6	97.9	97.2	83.6
Bull	106.7 ^a	94.7	92.3	87.4	86.4
Steer	81.6	89.2	90.3	95.9	110.5 ^a

Overall mean = 93.5 percent

^a Means above 100 percent due to least-squares adjustment for independent variables.

APPENDIX TABLE 21. LEAST-SQUARES MEANS FOR EFFECT OF BREED X AGE AT FIRST CALVING INTERACTION ON COW WEIGHTS AT WEANING THROUGHOUT THE LIFETIMES OF COWS AT BOZEMAN

Breed	Age at first calving (years)	
	2	3
Angus	1161.8	1132.6
Hereford	1132.6	1161.8

Overall mean = 1147.2 lb.

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