FACTORS AFFECTING CALVING DIFFICULTY
AND THE INFLUENCE OF PELVIC SIZE
ON CALVING DIFFICULTY IN
PERCENTAGE LIMOUSIN
HEIFERS

By

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Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1975

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1979

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ACKNOWLEDGMENTS

I would like to express my deepest appreciation to Dr. Richard R. Frahm for his guidance, counsel and friendship while serving as my major adviser during the course of this study and the preparation of this final manuscript.

I also wish to thank Dr. Robert P. Wetteman and Dr. Keith S. Lusby for their aid and concern while serving on my guidance committee.

Gratitude is extended to Dr. Larry Rice, DVM, for aid and thoughts dealing with the context of this study and Dr. Ronald W. McNew for his help with the statistical analysis of the data.

Much thanks is also owed to Mr. Bill Dameron of Dameron Land and Cattle Company, his secretary and entire staff of cattlemen for collecting and recording this information and cooperating in making it available for analysis. I believe more cooperation of this type could be used to aid in the research of livestock populations.

Utmost is the appreciation of my parents, Jim and Caroline Belcher, and my wife, Carla, whose unending love, support and understanding has resulted in my attaining this ambition and making it meaningful.

Finally, I would like to dedicate this manuscript to the Bill G. Follis family of Miami, Oklahoma, for their patience, understanding and guidance in the development of my early background in animal husbandry practices.

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CHAPTER I

INTRODUCTION

In recent years increased competition from foreign markets, lower profit margins and generally higher costs of production have caused livestock producers to direct more attention towards total productive efficiency.

To increase production efficiency in cattle populations it is necessary to maximize lifetime productive output from each cow in the herd. This involves calving a heifer at the youngest practical age and maintaining her reproductive performance throughout her herd life. Research has shown that weaning weights of first calves from two-year-old heifers are lighter than weaning weights of first calves from three-year-old heifers. Subsequent to first calving cows of the same age perform similarly regardless of age at first calving. Thus, heifers calving first as two-year-olds are expected to have a higher lifetime productivity. Two-year-old heifers are still in a rapid growth stage and are not only physically smaller but have not yet reached physiological maturity, consequently, more calving difficulties are expected. In addition, the use of large bulls as terminal sires and selection for increased size in our cattle populations has increased the rate of calving difficulties and magnified associated problems.

Research has also shown that calf losses at or near birth are a major contributing factor to reducing the number of calves weaned and that the most common cause of calf mortality near birth is injury due to difficult or prolonged parturition (Wiltbank et al., 1961). It has further been demonstrated that heifers with difficult parturitions have poorer reproductive performance the following breeding season indicated by lower conception rates and a reduction of calf crop weaned the following year (Brinks et al., 1973; Laster et al., 1973).

The economic gain that could be realized through a reduction of difficult births is apparent. Extensive research has been conducted to identify variables associated with calving difficulty and to utilize these variables to predict the possibility of a particular heifer experiencing difficulty during parturition. However, the variables identified have failed to explain a large portion of the variation in calving difficulty. Further research to identify other sources of variation in calving difficulty and increase the accuracy of prediction from known variables is necessary to aid in developing a method to identify potentially difficult calving heifers and to reduce losses due to dystocia.

The objectives of this study were: (1) to evaluate the relationship between heifers pelvic size measured prior to breeding and subsequent calving performance, (2) to identify factors most highly associated with dystocia and (3) to develope a prediction equation that could be used to estimate dystocia in young heifers and effectively cull heifers likely to have difficulty calving.

CHAPTER II

REVIEW OF LITERATURE

This review of literature will cover: (1) calf losses associated with dystocia, (2) factors affecting dystocia and (3) the relationship of pelvic measurements to dystocia and other traits.

Calf Losses Associated with Dystocia

The primary reduction in potential calf crop of 1344 Angus, Hereford, Shorthorn and Zebu cows was found to be the failure of cows to conceive during breeding or early embryonic death loss and death of the calf at or shortly after birth (Wiltbank et al., 1961b). Calf losses near birth appear to be higher at first calving than at subsequent births (Woodward and Clark, 1959; Walser, 1977). Anderson and Bellows (1967) found that 124 calves were lost at birth out of 3,049 parturitions and concluded the most common cause of death was injury due to difficult or prolonged parturition. Autopsies of dead calves revealed that 79% were anatomically normal and 30% exhibited functional lungs suggesting these calves had breathed sometime during or shortly after birth and could probably have been saved if management had been available to minimize dystocia.

Laster and Gregory (1973) in a study involving 5,064 parturitions of 18 breed groups revealed that cows with dystocia suffered four times greater calf losses than those with no dystocia (20.4% vs. 5.0%). In a subsequent study involving 2,368 parturitions from the same breed groups, Smith et al. (1976) found that calf death losses were 3.7 times higher in calves experiencing dystocia at birth (11.5% vs. 3.1%). Young (1968) in a study with 1,429 beef heifers found that dystocia was the major cause of calf losses following pregnancy diagnosis with 14.2% loss averaged over two years.

Lowered reproductive performance of cows following a difficult birth results in further reduction of net calf crop and increased economic losses to producers. Wiltbank et al. (1961) found the interval from calving to first estrus was longer in young cows suckling calves than older cows with calves and that young cows had a higher incidence of dystocia. However, this could be due to greater nutritional demands on young, growing cows as well as a higher rate of dystocia. A study by Brinks et al. (1973) involving 2,733 parturitions of Hereford cows revealed that heifers experiencing calving difficulty as two-year-olds weaned 11% fewer calves the first year and 14% fewer calves the second year compared to those without difficult births. Three-year-old cows that experienced calving difficulty at two years of age calved 13 days later than cows that did not have calving difficulty. In a similar study, Laster et al. (1973) found that dystocia level significantly influenced the percent of cows detected in estrus during a 45 day artificial insemination (AI) period, and also had a significant effect on conception to AI and total conception rate. Fourteen percent fewer cows that experienced dystocia were detected in estrus compared to those with no dystocia. Dystocia resulted in 15.6% lower conception to AI (53.6% vs. 69.2%) and 15.9% lower conception overall (69.4% vs. 85.3%). Dystocia had no significant effect on services per conception, interval from calving to breeding or interval from calving to conception. Phillipson (1976) also found that calving difficulty and stillbirths resulted in a fewer number of heifers cycling and poorer conception rates in Swedish Fresian heifers.

Factors Affecting Dystocia

Of the factors commonly found to be associated with dystocia, birth weight has invariably been the most important. Monteiro (1969) reported a direct relationship between mean birth weight of the calves and the frequency of calving difficulties in a study of purebred and crossbred progeny from Friesian, Ayrshire and Jersey dams. Many studies have reported birth weight to be a significant factor influencing calving difficulty (Smith et al., 1976; Pollack and Freeman, 1976; Nelson and Huber, 1971; and Laster et al., 1973) and that birth weight was often the most important factor associated with dystocia (Bellows et al., 1971; Short et al., 1977; Laster, 1974; Price and Wiltbank, 1978; and Rice, 1969). Webster et al. (1977) in a study involving calvings of 928 heifers found that mean birth weight and size score of calves was significant ($P<.05$) greater in heifers requiring assistance than those not requiring assistance. Rice and Wiltbank (1970) reported that mean birth weight of calves causing dystocia was 4.4 pounds (lb) heavier than the mean herd birth weight.

Nelson and Huber (1971) found a significant effect of birth weight on dystocia and reported that Hereford cows with calves weighing more than 80 lb at birth suffered 36% calving difficulty while cows having calves weighing less than 60 lb had only eight percent dystocia when bred to Angus, Hereford, Brown Swiss and Charolais bulls. Young (1970), in a study involving 93 Angus heifers calving at two years of age, also reported that calves from heifers suffering dystocia had significantly ($P<.01$) heavier birth weights than calves from non-dystocia heifers (60.3 vs. 53.3 lb).

Studies at the United States Meat Animal Research Center (USMARC) have disclosed similar results in the beef cattle germ plasm evaluation studies. Laster et al. (1973), studying records of 1,889 calvings from Hereford and Angus cows bred to Hereford, Angus, Jersey, South Devon, Limousin, Simmental and Charlais bulls, found by regression analysis that birth weight was a significant ($P<.005$) source of variation in calving difficulty and that percent calving difficulty increased 1.05% for each pound increase in birth weight. Smith et al. (1976) found, from a study of 2,368 records of the same breed groups, that birth weight significantly ($P<.01$) influenced calving difficulty and that dystocia level increased linearly with birth weight both across and within breed groups. Dystocia over all dam ages increased by .74% for each pound increase in birth weight.

In a study involving 1,000 primiparous Angus, Charolais and Angus cross Hereford heifers, birth weight forced first into a stepwise regression model was found to account for 19% of the variation in dystocia (Price and Wiltbank, 1978).

In most studies correlations between birth weight and dystocia have been moderate to high. Rice and Wiltbank (1972) found a correlation between calf birth weight and dystocia of .43 which is in agreement with the correlation of .46 reported by Ward (1971). However, Sagebiel et al. (1969), from a study involving 461 calvings of purebred Angus, Charolais, Hereford and all possible two-breed crosses, found a correlation between birth weight and dystocia score of only .11 over all breed combinations. The correlation within each breed of dam was .36 for Angus, .24 for Hereford and .16 for Charolais indicating that birth weight may have a greater effect on dystocia in dams of smaller breeds. Correlations between the ratio of birth weight to cow weight and dystocia score were .41 for Angus, .30 for Hereford and .24 for Charolais indicating that a larger calf in relation to the cow has more dystocia and this is more evident in cows of smaller breeds.

Calf sex has also been found to significantly effect dystocia in most studies (Cadle and Ruttle, 1976; Laster and Gregory, 1973; Brinks et al., 1973; and Smith et al., 1976). Anderson and Bellows (1967) reported that of 3,049 parturitions more male calves required assistance at birth than female calves ($P<.05$). Seventy-five (2.5%) male calves were lost at birth compared to 49 (1.6%) females. Birth weight of male and female calves that died at birth averaged 75.7 and 58.3 lb, respectively, indicating the effect of sex may be due to heavier birth weights of male calves. Short et al. (1977) found that a small increase in the variation in calving difficulty could be accounted for by adding calf sex to a regression model. Price and Wiltbank (1978) found calf sex significantly correlated to dystocia ($r=.27$) with male calves requiring the most assistance ($P<.01$). Bellows et al. (1971) also found that male calves required more assistance than females ($P<.05$) and had higher average calving scores.

As previously mentioned the effect of calf sex on dystocia may be due to differences in birth weight of male and female calves. Tyler et al. (1947) found male calves to be 5.4 lb heavier than females from 794 calvings and also noted that sex accounted for seven percent of the variation in birth weight. Other studies lend support to this hypothesis with differences in birth weight of male and female calves ranging from 2.0 lb to 6.2 lb (Moore, 1956; Sagebiel et al., 1969 and McCormick et al., 1956). Laster et al. (1973) found male calves were significantly (P<.005) heavier and experienced more dystocia than female calves (77.3 lb, 28.4% dystocia vs. 70.6 lb, 17% dystocia). This was in agreement with studies by Nelson and Huber (1971) who found male calves were heavier and required more assistance (69.5 lb, 30% assistance) than female calves (64.5 lb, 15% assistance).

Reports on the relationship between length of gestation and dystocia have been contradictory. Price and Wiltbank (1978) found a correlation between gestation length and dystocia score of .19 with male calves requiring a longer gestation, indicating the effect of gestation length may be due to heavier birth weights of male calves. However, Sagebiel et al. (1969) found correlations between gestation length and dystocia score were generally low and nonsignigicant (r=.09).

Other factors commonly found to be associated with dystocia have been sire breed, sire sithin breed, dam breed, dam age, dam condition score or nutritional level and dam's pelvic dimensions.

Koger et al. (1967) reported that the most important factor influencing survival from 3,408 calvings over a five year period was breed while Webster (1977) found that breed of sire and breed of dam significantly influenced calf birth weight from 928 heifers studied. Laster et al. (1973) summarizing data from 1,889 calvings from matings of Hereford and Angus cows to sires of seven different breeds found that sire breed, dam breed and dam age were significant (P<.005) sources of variation in calving difficulty, birth weight not included. However, when birth weight was held constant, dam age was the only main effect significantly ($P<.005$) associated with percent dystocia, suggesting the effect of dam and sire breed on dystocia was due to their effect on birth weight. Smith et al. (1976) found similar results. However, Sagebiel et al. (1969) found a significant ($P<.05$) effect of sire and dam breed on dystocia score in purebred and all possible reciprocal two-breed crosses of Angus, Charolais and Hereford cattle. Laster and Gregory (1973) reported significant ($P<.01$) effects of cow age and breed group on dystocia from 5,064 parturitions involving 18 breed groups.

Some variation in amount of dystocia has been due to sire's among breeds. Moore (1956) classified Hereford bulls as small, medium or large by visual appraisal and found significantly reduced birth weight of calves and calving difficulty of two-year-old Hereford heifers with small or medium sized bulls as compared to large bulls. Phillipson (1976a), studying calving difficulties in Swedish cattle breeds, found significant differences between sires for dystocia in agreement with Brown and Galvez (1969) who found that sire effects accounted for 20% and 9.5% of the variation in calf birth weight from 789 Hereford and 932 Angus records, respectively. However, Price and Wiltbank (1978) from measures on approximately 1,000 primiparous Angus, Charolais and Hereford x Angus heifers bred to 12 Angus, six Hereford and two Charolais bulls found significant breed of sire differences but only small differences between bulls of the same breed. Young (1970) also failed to find a significant sire effect on dystocia of 93 Angus heifers, but sires were all from the same sire and were inbred.

The effect of age of dam on frequency of calving difficulty has been well documented. Generally, first calf primiparous heifers have more dystocia than multiparous cows and two-year-old heifers have higher dystocia rates than three-year-old heifers and older cows (Brinks et al., 1973; Laster et al., 1973; and Smith et al., 1976).

The effect of dam weight on dystocia score is somewhat questionable. Singleton et al. (1973) studying 74 crossbred heifers mated to Angus and Charolais bulls found that dam weight was an important factor influencing dystocia score and from regression analysis determined that for each 99.9 lb increase in dam weight, dystocia score increased by .68 on a scoring system ranging from one for no assistance with live calf to six for calf puller, dead calf. Monteiro (1969) studied 458 calvings from Friesian, Ayrshire and Jersey dams and reported heavier breeds of dams as having a higher frequency of difficult calvings. However, Cadle and Ruttle (1976) reported from a study of 55 heifers, a significant ($P<.05$) negative correlation between dam body weight and dystocia, indicating that as dam body weight increased, dystocia decreased. Pollak and Freeman (1976) found size of dam was not a significant source of variation in dystocia from 17,077 Holstein parturitions and Young (1968) found incidence of dystocia showed no relationship to dam's weight at breeding.

Dam's nutritional level during pregnancy or condition score at calving have been found in most studies to not be significantly associated with dystocia (Nelson and Huber,1971; Joandet et al.,1973 and Young,1970).

It is important to note that although generalizations can be drawn from the above data, there are significant yearly effects on the level of dystocia and many of the traits associated with calving difficulty

(Brinks et al., 1973; Laster et al., 1976 and Wiltbank, 1961).

Relationship of Pelvic Measurements to Dystocia and Other Traits

Use of Measurements on Young Heifers

A measurement or number of measurements taken on a heifer early in her life to be used to predict the possibility of her having calving difficulty could be useful to producers in identifying and removing high risk heifers from their herds at a young age.

Krahmer and Jahn (1971) reported from a study of German cattle that pelvic measurements made on young females could be used to predict the possibility of a heifer having calving difficulties. Fitzhugh et al. (1972) took monthly pelvic measurements on 65 heifers of five breeds from weaning (six to seven months old) until primiparity (22 to 25 months old). He reported that breed groups ranked similarly for growth of horizontal and vertical pelvic measurements and body weight and that peripubertal pelvic measurements appeared useful in predicting size and shape of pelvic inlet at primiparity.

Webster (1977) from a study involving 928 heifers, found breed, wither height and weight of heifer as large sources of variation associated with pelvic area and the correlation between wither height and pelvic area was highest at one year of age. He also found, in 170 nulliparous heifers, that pelvic area grew in a linear manner with estimated daily growth rates of .27, .36 and .38 square cm for non-pregnant Angus, pregnant Angus and pregnant exotic heifers, respectively. Price and Wiltbank (1978) measured size of the pelvis in 1000 Angus, Charolais and Angus x Hereford heifers at 35 days after breeding, approximately five months of gestation and again one month to two weeks prior to calving. They reported linear growth rate of the pelvis to be similar for all breed groups at .275, .254 and .250 square cm per day for the Angus, Angus x Hereford and Charolais heifers, respectively. They also reported pelvic area near calving was most highly correlated to dystocia in the Hereford x Angus and Charolais dams (-.34 and -.47, respectively), but pelvic area near breeding was highest correlated to dystocia in Angus (-.42). This difference suggests that pelvic measurements on young heifers may be better estimates of dystocia in early maturing breeds.

Singleton et al. (1973) studied 74 crossbred heifers measured at 413, 579 and 702 days of age and found most correlations between pelvic measurements and dystocia were negative and nonsignificant, however, of the measurements taken, he found anterior pelvic height at 413 days had the highest relationship to dystocia score.

The previous studies suggest that measurements on young heifers could be used to measure representative differences in calving ability. However, Cadle and Ruttle (1976) from a study of 55 primiparous heifers whose pelvises were measured three times at equal intervals during gestation, found that only the latter two measurements were significantly ($P<.01$) correlated to dystocia and concluded prediction of dystocia was more reliable when measurements were taken closer to parturition. This is in agreement with results on Hereford x Angus and Charolais heifers previously mentioned (Price and Wiltbank, 1978).

Rice and Wiltbank (1972) reported, from a study of 93 two-year-old Angus dams measured at breeding, 6 to 7 months of gestation, one week prepartum and at parturition, that the correlation between eventual dystocia and pelvic area was -.32 at midgestation (significant $P<.01$) but was not significant at breeding ($r=-.20$). Thus, the likelihood of predicting dystocia from pelvic measurements at breeding was limited.

Relationship of Pelvic Measurements to Dystocia

Extensive research has been conducted on the use of internal pelvic measurements to predict dystocia in cattle. Koppe (1933) in a review of the analysis of skeletal measurements in cattle reported that a long and broad pelvis will accomodate a large udder and make parturition easier. Wiltbank and LeFever (1961) reported, from studying 380 heifers over a three year period, that size of the pelvic opening was a better means of predicting calving difficulty than calf weight. A subsequent study, in which pelvic area was used to predict calving difficulty in 51 three-year-old Hereford heifers, revealed a 70% dystocia rate in those heifers predicted to have calving difficulty compared to only 12% in those predicted to not have calving difficulty. Dufour et al. (1974) studied 101 dairy x beef heifers bred to one Angus or one Limousin bull and found that heifers with below average pelvic area had 25% and 37.5% calving difficulty for the Angus and Limousin sire, respectively, compared to 12.5% and 18.8% for heifers with above average pelvic area. They observed similar results in 77 dairy x beef heifers bred to an Angus or Shorthorn bull.

Most studies have indicated pelvic area and calf birth weight are the primary factors effecting dystocia suggesting that both should be considered when attempting to predict dystocia. Phillipson (1976a) in a large study of Swedish Friesian heifers, reported that heifers with calving difficulty have a significantly smaller pelvic opening and less favorable ratio of pelvic area to calf birth weight than non-dystocia heifers. In another study, he concluded that a small pelvic opening or fetal oversize may cause calving difficulty and referenced Mennissier who stated 10% of the variation in calving difficulty is explained by pelvic size and there is a strong interaction between pelvic size and calf size (Phillipson, 1976b).

From a herd of Devon heifers in Australia, Young (1968) reported that, in general, heifers with dystocia had significantly smaller pelvic areas in relation to calf birth weight and in a study of 93 Angus heifers, found heifers with dystocia had pelvises 15.6 sq cm smaller and calves seven pounds heavier than non-dystocia heifers (significant $P<.01$). He concluded that Angus heifers with pelvic area less than 220 sq cm were incompatable with normal birth of a male calf weighing more than 59 lb (Young, 1970).

Short et al. (1977) conducted multiple nonlinear regression analysis of factors causing calving difficulty in 592 two-year-old heifers. Calving difficulty was scored from one, no difficulty, to four, extreme difficulty, and was the dependent variable. With only birth weight and pelvic area in the model R^2 values for calving difficulty were .36, .39 and .39 for linear, quadratic and cubic analysis, respectively. Adding cow weight, cow condition score and sex to the model increased R^2 values very little. Thus it was concluded that the majority of calving difficulty was accounted for from the linear effect of birth weight and pelvic area.

Rice and Wiltbank (1970) studied dystocia in 90 two-year-old Hereford dams measured three months prior to calving and noted an apparent threshold point for size of pelvic area and resulting dystocia. When average pelvic area of the heifers was 218 sq cm, heifers with a pelvic area less than 200 sq cm suffered 68.7% dystocia compared to only 28% dystocia in heifers with pelvises larger than 200 sq cm. They also reported that birth weight and pelvic area were significantly (P<.01) correlated to dystocia (r=.36 and -.34, respectively). Multiple regression analysis of dyctocia on birth weight and pelvic area gave a correlation of .49 accounting for 25% of the variation in dystocia score (1=no dystocia, 4=extreme) (Rice and Wiltbank, 1972). In a second trial they reported, from 93 two-year-old Angus dams, that dystocia was most highly correlated to calf birth weight (r=.44) followed by pelvic area (r=-.32). Multiple correlation of dystocia to calf birth weight and pelvic area at parturition gave an r value of .62 (P<.01) accounting for only 38% of the variability in dystocia score. It was concluded that dystocia could not be accurately predicted from the traits observed.

Laster (1974) reporting on factors effecting pelvic size and dystocia in 943 yearling and two-year-old cows from 14 breed groups and 599 two-year-old Hereford and Angus cows found that heavier two-year-old cows have larger pelvic openings but proportionally larger calves with the relationship similar in all breed groups. He also reported that pelvic size (height or width) independent of cow weight had a significant influence on dystocia but was not a large source of accountable variation. Calving difficulty decreased as pelvic size increased for the two-year-old Hereford and Angus cows. However, no such pattern was observed among the crossbred heifers. It was concluded that the relationship between the traits measured and dystocia were too low to accurately predict dystocia in cattle.

Bellows et al. (1971b) found, from a study of 95 Hereford and 103 Angus heifers, that pelvic area of the dam exerted a signigicant ($P<.05$) negative effect on calving difficulty for both breeds of dam; however, birth weight was the most important factor related to dystocia. Overall, eight variables included in a multiple regression model accounted for less than 50% of the variability in dystocia score with the major portion accounted for by birth weight and pelvic area. Price and Wiltbank (1978) studied factors affecting dystocia in 1,000 heifers and found that dystocia score was most highly related to calf size and pelvic area at breeding. Thirty-seven percent of the variability in dystocia score was accounted for by the ratio of birth weight to calf body length and pelvic area; however, pelvic area alone accounted for only five percent of the variation in dystocia. By plotting the data it was illustrated that independent of calf size, heifers with smaller pelvises have higher dystocia rates.

Similar relationships between pelvic measurements and dystocia have been reported in sheep. Fogarty and Thompson (1974) studied associations between pelvic measurements and dystocia in 29 Horned Dorset ewes. They reported that dystocia incidence was negatively correlated to pelvic diameters and area and approached significance ($r=-.34$, $P=.08$). They also found that ewes with greater than 65% dystocia had significantly ($P<.01$) smaller pelvic areas (73.4 vs. 82.8 sq cm) and significantly ($P<.05$) smaller conjugate diameters (9.9 vs. 10.9 cm) compared to ewes with less dystocia.

Relationships Among Pelvic Measurements and Other Traits

Pelvic area was determined as the product of the measured pelvic height and width, thus pelvic height and width measurements would be expected to have some correlation with pelvic area. Internal pelvic measurements have also been found to be correlated with other physical body measurements such as height, external width at hooks, body weight and etc.

Ward (1971) studied body measurements of Angus x Hereford heifers and found precalving body weight, depth of body and rump length were significantly correlated to vertical and horizontal pelvic measurements and pelvic area (r approximately .4 in all cases). Width at hooks was moderately correlated with vertical (r=.62), horizontal (r=.56) and pelvic area (r=.66) measurements and horizontal and vertical pelvic measurements were correlated with each other and with pelvic area. A subsequent study of Angus x Hereford heifers also showed that cow width at hooks was significantly correlated to verticle and horizontal pelvic measurements and pelvic area. Verticle and horizontal measurements were also significantly correlated to each other. However, cow body measurements were not significantly correlated to calving difficulty (Ward, 1973). Singleton and Nelson (1971) found that pelvic measurements were highly correlated with each other and that pelvic area was influenced by cow breed and weight ($P<.01$) but not by cow age or condition score in 78 crossbred heifers.

Bellows et al. (1971a) conducted an experiment to determine relationships between pelvic area and various body size measurements in 251 three-year-old Hereford heifers and found that body weight was significantly ($P<.01$) correlated to pelvic height ($r=.40$), pelvic width ($r=.47$) and pelvic area ($r=.54$). Hip width and rump length were also significantly ($P<.01$) correlated to all pelvic measurements (r averaged .40). Pelvic height and pelvic width had a correlation of .32 and as expected pelvic area was highly correlated to pelvic height ($r=.82$) and pelvic width ($r=.80$). Multiple regression analysis of body weight, hip width and rump length on pelvic area gave a correlation of .60, accounting for only 36% of the variability in pelvic area. Body weight was the most important factor associated with pelvic area which agrees with results reported by Laster (1974) who found that cow weight was the largest source of variation associated with pelvic area in 943 yearling and two-year-old cows from 14 breed groups. These findings tend to suggest that, within a breed of cattle, larger external skeletal size may be indicative of larger pelvic openings.

Bellows et al. (1971b) found, from 95 Hereford and 103 Angus heifers, that pelvic height, width and area were significantly ($P<.01$) correlated to body weight at the end of the breeding season, midgestation and precalving and was also significantly correlated to weight gain during the first half of gestation. There was also a significant positive correlation of .29 between pelvic area and condition score in Herefords. These positive relationships suggest that large heifers with rapid weight gains during their first pregnancy will have larger pelvic openings. In Angus dams there were significant positive correlations between birth weight of calf and dam's pelvic area indicating cows with larger pelvic areas also have larger calves.

In sheep, Fogarty (1974) measured post-slaughter pelvic diameters of 29 Dorset ewes and found pelvic area was significantly ($P<.01$) correlated to pelvic height and width diameters ($r=.80$), however, correlation coefficients between height and width measurements were low and nonsignificant. He also reported that external measurements of pelvic width taken prior to slaughter were significantly correlated to actual pelvic width measurements taken post-slaughter ($r=.80$, $P<.01$). Quinlivan (1971) also found positive correlations between pelvic width and height and pelvic area from a study involving 21 ewes.

Summary Review of Literature

A major cause of a reduced calf crop is death of the calf at or shortly after birth and the death loss is substantially higher with difficult births. Further, heifers suffering difficulty at parturition have lowered reproductive performance the following breeding season resulting in further reduction of net calf crop.

Birth weight of the calf was the most important factor affecting calving difficulty and may possibly be of greater importance in dams of small breeds. Dam's pelvic area was the second most important factor associated with dystocia but, birth weight and pelvic area together accounted for less than 50% of the variability in calving difficulty.

Calf sex, length of gestation, sire breed, sire within breed and dam breed all significantly affected dystocia in young heifers. The influence of these variables on dystocia may be due largely to their effect on calf birth weight. Male calves were heavier, gestated longer and required more assistance at calving than female calves. Large sire breeds and large sires within a breed caused more calving difficulty than small sires. Heavier breeds of dams also appeared to have more calving difficulty indicating a maternal influence on calf size at birth. Larger dams, even though they had large pelvic areas, had proportionally even larger calves.

The effect of age of cow on dystocia has been well documented. Two-year-old primiparous heifers have more dystocia and higher calf losses than three-year-old heifers or multiparous cows. The nutritional level of the dam or condition score was not found to effect dystocia.

Pelvic area increased in a linear manner indicating that measurements on young heifers could be utilized to depict differences in pelvic size at calving. However, correlations in some studies indicate limited effectiveness from the use of pelvic measurements on young heifers to predict dystocia. Heifers suffering dystocia had smaller pelvic areas and larger calves than heifers without dystocia and as amount of dystocia decreased pelvic area of the dam increased. However, relationships between pelvic area and dystocia were not sufficient to accurately predict dystocia in cattle. In some cases a threshold point for size of pelvic area, in relation to calving difficulty, seemed apparent.

Correlations between pelvic height, width and area were all high. Pelvic area had a slightly higher correlation with dystocia than individual height or width measurements. External body size measurements were highly correlated to internal pelvic measurements and cow's body weight was the major factor associated with pelvic area, indicating larger dams have larger pelvic areas.

Similar relationships between dystocia, pelvic area and birth weight that have been reported in cattle have also been observed in sheep populations.

CHAPTER III

MATERIALS AND METHODS

Data utilized in this study was from records of 1,426 percentage Limousin heifers made available from Dameron Land and Cattle Company, Inc., of Salida, Colorado. Data were collected at the ranch, over a five year period, by Bill Dameron and his staff.

During the time of data collection Dameron Land and Cattle Company was involved in an extensive upgrading program to purebred Limousin. Thus, in keeping with this program, heifers were continually being produced with a higher percentage of Limousin breeding.

The upgrading program to purebred Limousin was initiated in 1972. Limousin bulls were mated by artificial insemination (AI) to primarily Hereford, Hereford x Angus and Angus cows to produce half Limousin calves in the spring of 1972, 1973 and 1974. Each year half Limousin heifers produced from these matings remained in the herd to be used in the upgrading process. Of the heifers entering the herd in 1972 and 1973 about half were produced at the Dameron ranch while the other half were produced elsewhere in contract herds and delivered to the ranch at weaning. Only a small portion of the half-blood heifers produced in 1974 were produced in contract herds. A portion of the bulls that were used at the ranch each year were also used in the contracted herds.

Half Limousin heifers that entered the herd were mated AI to Limousin bulls to produce their first calf in the spring at two years of age. Three-quarter Limousin calves from these matings were produced at the ranch in the spring of 1974, 1975 and 1976 and three-quarter heifers were retained in the breeding herd for use in the upgrading process. In addition, half Limousin cows continued to be used to produce three-quarter Limousin calves in subsequent years.

Three-quarter Limousin heifers were managed similarly to half Limousin heifers to produce seven-eighths Limousin calves as two-year-olds. However, only three-quarter heifers born in 1974 had completed records of pelvic measurements and calving performance and could be included in the analysis.

With the exception of half Limousin heifers born in 1972, all heifers were under similar management regimes each year. Following weaning, heifers were placed on pasture and managed to be of adequate size for breeding at approximately 15 months of age. Averaged over years, heifers gained 1.53 lb per day from weaning to yearling and had an adjusted 365 day weight of 684 lb. In 1972 a random half of the heifers were placed in feedlot, post-weaning, while the other half remained on pasture. Post-weaning daily weight gains were very similar for both groups (1.69 lb per day vs. 1.61 lb per day, respectively).

Pelvic measurements of all heifers were taken at the ranch each year prior to the breeding season and all heifers within a year group were measured the same day. Pelvises were measured by the method described by Rice and Wiltbank (1972) using the Rice pelvimeter developed at Colorado State University. The pelvimeter is a large caliper consisting of two cast aluminum arms, hinged near the middle, with a scale graduated in centimeters attached at one end. The measurement is made by placing the free ends of the caliper on known pelvic landmarks by rectal palpation with the pelvic dimension read from the scale at the opposite end of the caliper remaining outside the animal. Thus, a direct pelvic measurement is obtained. Pelvic height and width measurements were taken on each individual heifer. Pelvic height was measured as the midline between the symphysis pubis and midsacrum and pelvic width was measured as the widest point between the shafts of the ilia. Pelvic area was calculated as the product of the pelvic height and pelvic width.

Due to the upgrading program and the unavailability of purebred Limousin sires for natural service, the breeding season consisted of an intensive all AI management system. Thus, heifers were under close surveillance during breeding and individual breeding dates and service sire were recorded for each heifer.

Heifers remained on pasture at the ranch during the gestation period. At calving each heifer was closely observed and given a subjective calving difficulty score by the herdsman ranging from 1, unassisted birth, to 4, caesarean or pelvic split (Table I). A score of 5 was used to represent abnormal presentations but was deleted from the analysis. Calves were weighed shortly after birth and calving date, sex of calf and birth weight were recorded. Gestation lengths were calculated as days from breeding to calving.

In total, records of each heifer included heifer's sire, breed of dam, birth date, birth weight, calving difficulty, 205-day adjusted weaning weight, 365-day adjusted yearling weight, 15-month pelvic height, 15-month pelvic width, breeding date, calving date, calving difficulty of heifer's first calf, breed of first calf, sire of first calf, sex of first calf, birth weight of first calf and gestation length of first

TABLE I

CALVING DIFFICULTY SCORES

Calving Score	Explanation
1	Unassisted birth.
2	Easy Pull: Primarily hand assistance. No mechanical calf puller necessary.
3	Hard Pull: Mechanical calf puller probably required.
4	Caesarean or pelvic split.
5	Abnormal presentation.

calf. Other variables included in the analysis were calculated as needed.

Statistical Analysis

The majority of data in this study were analyzed through procedures available in the Statistical Analysis System (SAS); a generalized computer program package developed by Barr and Goodnight (1972 and 1976).

Adjusting Pelvic Measurements

Multiple regression analysis was used to determine the effect of breed of heifer, breed of dam, sire, birth year and age on pelvic height, width and area and to find the partial regression coefficient of pelvic height, width and area on the random variable age. These regression coefficients were estimates of linear growth over the range in age of heifers at the time pelvises were measured and were used to adjust pelvic dimensions to a standard age.

An analysis was performed on records of 862 heifers using SAS (76) general linear models procedures. The following model was used.

$$Y_{ijkrm} = \mu + H_i + D_j + S_k + B_r + b_1 X_{1ijkrm} + e_{ijkrm}$$

where

Y_{ijkrm} = The observed pelvic height, width or area of the $ijkrm^{th}$ observation.

μ = population mean.

H_i = fixed effect of the i^{th} breed of heifer; i = 1,2.

D_j = fixed effect of the j^{th} breed of dam; j = 1,2,3,4,5.

S_k = random effect of the k^{th} sire; k = 1,2,3,4,5,6,7,8.

B_r = fixed effect of the r^{th} year of birth; r = 1,2,3.

X_1 = age of the $ijkrm^{th}$ heifer when pelvis was measured.

b_1 = partial regression coefficient of pelvic height, width or area on age.

e_{ijkrm} = random errors associated with the $ijkrm^{th}$ observation.

Heifers were grouped by breed of heifer, breed of dam, sire and birth year and a similar analysis was conducted to determine the effect of group, age and age by group interaction on pelvic height, width and area.

Calving Difficulty

SAS (76) general linear models procedures were utilized to perform multiple regression analysis of factors effecting calving difficulty score. Records of 819 heifers with pelvic measurements and subsequent calving performance were available for analysis. Preliminary analyses were conducted using a model which included all main effects and all possible two and three factor interactions. None of the interactions tested were significant and thus were deleted from the model. Data were then reanalyzed utilizing the following reduced model.

$$Y_{ijkrm} = \mu + H_i + C_j + S_k + I_r + b_1X_{1ijkrm} + b_2X_{2ijkrm} + b_3X_{3ijkrm} + b_4X_{4ijkrm} + b_5X_{5ijkrm} + b_6X_{6ijkrm} + e_{ijkrm}$$

where

Y_{ijkrm} = the observed calving difficulty score of the $ijkrm^{th}$ observation.

μ = population mean.

H_i = fixed effect of the i^{th} breed of heifer; i = 1,2.

C_j = fixed effect of the j^{th} sex of calf; j = 1,2.

S_k = random effect of the k^{th} sire of heifer; k = 1,2,3,4,5,6, 7,8.

I_r = random effect of the r^{th} sire of calf; r = 1,2,3,4,5,6.

X_1 = birth weight of heifers first calf.

X_2 = gestation length of heifers first calf.

X_3 = pre-breeding adjusted pelvic height.

X_4 = pre-breeding adjusted pelvic width.

X_5 = pre-breeding adjusted pelvic area.

X_6 = age of heifer at calving in days.

b_i = partial regression coefficient of calving difficulty score on the variables X_i; i = 1,2,3,4,5,6.

e_{ijkrm} = random errors associated with the $ijkrm^{th}$ observation.

When all three measures of pelvic size (height, width and area) were included in the model none were found significant. Thus, since adjusted pelvic area was calculated as the product of the adjusted pelvic height and width, secondary analyses were conducted which included only adjusted pelvic area or both adjusted pelvic height and width in the model. Further analysis compared R^2 values from including individual estimates of pelvic size in the model.

In order to evaluate the possibility of predicting potential calving difficulty, calving difficulty score was analyzed by a final model which included only those variables that significantly influenced calving score and were available prior to the heifer's first calving.

Simple correlations were calculated between various traits that were representative of heifer size. Simple correlations were also calculated between calving difficulty score and related factors.

Heifer Pelvic Measurements, Age at Calving, Gestation Length and Calf Birth Weight

Pelvic measurements, age of heifer at calving, gestation length and calf birth weight were analyzed using SAS (76) procedures with the following linear model:

$$Y_{ijkl} = \mu + B_i + S_j + D_k + BS_{ij} + SD_{jk} + BSD_{ijk} + e_{ijkl}$$

where

Y_{ijkl} = the observed value of the ijklth observation for a given trait.

μ = population mean.

B_i = fixed effect of the ith breed of heifer; i = 1,2.

S_j = fixed effect of the jth sex of calf; j = 1,2.

D_k = fixed effect of the kth calving difficulty score; k = 1, 2,3,4.

BS_{ij} = interaction of the ith breed of heifer and jth sex of calf.

BD_{ik} = interaction of the ith breed of heifer and kth calving difficulty score.

SD_{jk} = interaction of the jth sex of calf and kth calving difficulty score.

BSD_{ijk} = interaction of the ith breed of heifer, jth sex of calf and kth calving difficulty score.

e_{ijkl} = random errors associated with the ijklth observation.

Since only two levels of breed of heifer and sex of first calf existed, F tests were used to test for significant differences between levels of breed of heifer and sex of calf for each trait. Preliminary F tests were also used to indicate a significant difference in calving difficulty scores and differences between individual calving scores for each trait were done by making simple linear contrasts using the t-statistic as outlined by Steele and Torrie (1960).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter will be divided into three major sections: 1) adjustment of pelvic measurements; 2) factors affecting calving difficulty; and 3) relationships among pelvic size, calf size and calving difficulty.

Adjustment of Pelvic Measurements

The number of heifers measured each year, their unadjusted mean pelvic size and the average age of the heifers at the time pelvic measurements were taken is presented in Table II. Averaged over years, the mean pelvic height was 14.10 cm, mean pelvic width was 12.09 cm and mean pelvic area was 170.65 sq cm. On the average, heifers were 412 days old when pelvic measurements were taken and ranged in age from 354 to 481 days.

Table III and IV present the mean squares from analysis of variance of pelvic height, pelvic width and pelvic area. In Table III, breed of dam, sire and birth year accounted for a significant proportion of the variation in pelvic width and pelvic area; however, only sire and year of birth significantly affected pelvic height. Since half Limousin heifers were dams of the three-quarter heifers, breed of heifer was confounded with breed of dam and could not be accounted for in this analysis. Pelvic dimensions were also significantly affected by age of the heifer at time of measurement indicating that older heifers had

TABLE II

NUMBER OF HEIFERS MEASURED, UNADJUSTED MEAN PELVIC SIZE AND AGE WHEN MEASURED

Year Born	No.	Breed of Heifer	Average Pelvic Ht. (cm)	Average Pelvic Wd. (cm)	Average Pelvic Area (sq.cm)	Measured	Age When Measured (days)	Range in Age (days)
1972	481	1/2 Limousin	13.93	12.68	176.88	4-28-73	407.90	363-481
1973	338	1/2 Limousin	13.95	11.53	161.07	4-22-74	399.81	354-444
1974	194	1/2 Limousin	14.32	11.63	166.68	5-18-75	419.47	388-441
1974	167	3/4 Limousin	14.41	12.31	177.53	5-18-75	439.79	403-476
1975	246	3/4 Limousin	14.24	11.93	170.07	5-8-76	412.97	370-444
Total	1426		14.10	12.09	170.65		412.17	354-481

TABLE III

MEAN SQUARES FROM ANALYSES OF VARIANCE OF PELVIC MEASUREMENTS AND PARTIAL REGRESSION COEFFICIENTS USED TO ADJUST FOR AGE

Source of Variation	df	Mean Square: Pelvic Height	Mean Square: Pelvic Width	Mean Square: Pelvic Area
Breed of Dam	3	.245	2.110*	658.401**
Sire	7	7.785*	2.603*	2695.145*
Birth Year	2	1.921**	52.758*	14,269.202*
Age	1	26.221*	38.160*	23,017.767*
Residual	847	.533	.417	190.267
Partial Regression Coefficient on Age:		.0112* ± .0016	.0135* ± .0014	.3313* ± .0301

**Significant $P < .01$

*Significant $P < .05$

TABLE IV

MEAN SQUARES FROM ANALYSIS OF VARIANCE OF PELVIC MEASUREMENTS - GROUP AND AGE

Source of Variation	df	Mean Square		
		Pelvic Height	Pelvic Width	Pelvic Area
Group[1]	31	.667	.442	191.050
Age	1	16.782*	38.266**	19,502.017**
Age * Group	31	.654	.394	186.345
Residual	788	.525	.410	187.461

**Significant $P < .01$

[1]Heifers were grouped by breed of heifer, breed of dam, sire and birth year.

larger pelvic dimensions.

Similar results have been reported in the literature. Laster (1974) found that pelvic area was significantly influenced by breed of dam and breed of sire. Webster (1977) found breed of heifer significantly effected pelvic area and Singleton et al. (1971 and 1973) found that pelvic area was significantly influenced by breed when studying half Hereford heifers sired by Angus, Brown Swiss, Charolais, Hereford and Red Poll bulls.

In Table IV, heifers were grouped by breed of heifer, breed of dam, sire and birth year and analysis of pelvic height, pelvic width and pelvic area was repeated. The age of the heifers at the time their pelvises were measured still accounted for a significant proportion of the variation in pelvic height, width and area. However, the effect of group and the age by group interaction did not significantly effect pelvic size. Thus, pelvic size was adjusted for age and pooled over breed of heifer, breed of dam, sire and birth year.

The evidence that growth rate and skeletal expansion of young growing animals is linear or near linear over a given period of time has been well presented in the literature. As previously mentioned, heifers in this study ranged from 354 to 481 days of age at the time pelvic measurements were taken and age had a significant effect on pelvic size. Thus, it was decided to correct for age differences in pelvic size by adjusting pelvic dimensions of all heifers to a standard age.

Table III presents the partial regression coefficients of pelvic height, pelvic width and pelvic area on age pooled over breed of heifer, breed of dam, sire and birth year. These linear responses were significant. Thus, the regression coefficients represent estimates of daily pelvic growth over the age span of heifers in this study and were used to adjust pelvic size of all heifers to a standard age of 450 days. Average daily growth was .011 cm per day for pelvic height, .014 cm per day for pelvic width and .331 sq cm per day for pelvic area.

These estimates of pelvic growth are in close agreement with those found in the literature. Webster (1977) reported that pelvic area grew in a linear manner and that estimated daily growth rates were .27 sq cm, .36 sq cm and .38 sq cm for non-pregnant Angus, pregnant Angus and pregnant "exotic" heifers, respectively. Price and Wiltbank (1978) found similar results in a study of 1000 primiparous Angus, Charolais and Angus x Hereford heifers which had been measured three times during gestation. Pelvic growth rate was .275 sq cm per day for the Angus, .250 sq cm per day for the Charolais and .254 sq cm per day for the crossbred heifers.

Table XXI (Appendix) presents the mean squares of pelvic measurements for individual sires and the partial regression coefficients of pelvic dimensions on age by sire. In some instances an individual sire did not significantly influence pelvic size and the resulting estimates of linear growth for heifers of a given sire were near zero or negative. However, some sires were represented by a limited number of heifers and it is unrealistic to assume that a heifer's pelvic size will remain the same or decrease as she ages. Thus, adjustments for age were averaged over sires and based on the overall linear growth estimate.

All correlations between adjusted pelvic measurements (Table V) were highly significant ($P<.01$) as were correlations between adjusted pelvic height, width and area and measures of heifer body weight and daily gain.

TABLE V

SIMPLE CORRELATIONS BETWEEN ADJUSTED PELVIC MEASUREMENTS AND OTHER ESTIMATES OF HEIFER SIZE AND GROWTH

Measurement (N)	Adjusted Pelvic Width (ADJWD)	Adjusted Pelvic Area (ADJA)	Birth Weight (BWT)	Adjusted Weaning Weight (205) (ADJWW)	Average Daily Gain Birth to Weaning (ADGBW)	Actual Yearling Weight (AYW)	Adjusted Yearling Weight (365) (ADJYW)	Average Daily Gain Weaning to Yearling (ADGWY)
Adjusted Height (1383)	.16**	.71**	.18**	.18**	.16**	.22**	.22**	.12**
ADJWD (1383)		.81**	.23**	.27**	.37**	.54**	.44**	.37**
ADJA (1383)			.27**	.30**	.35**	.51**	.44**	.34**
BWT (1170)				.30**	.16**	.27**	.32**	.14**
ADJWW (1383)					.99**	.66**	.83**	-.03
ADGBW (1170)						.74**	.83**	.07*
AYW (1383)							.86**	.55**
ADJYW (1383)								.54**

**Significant P < .01

*Significant P < .05

A correlation of .16 between adjusted pelvic height and width suggests that heifers with wide pelvises have a slight tendency to also have pelvises of greater height. However, this relationship is rather weak, indicating that pelvic height or width could be a limiting factor of a heifer's calving performance independent of the other factor. Simple correlations between adjusted pelvic height and width and adjusted pelvic area were quite high (r=.71 and .81, respectively) indicating that heifers with large pelvic height or width will have large pelvic areas. This was to be expected since pelvic area is the product of the pelvic height times width.

These results are supportive of those found in previous studies. Bellows et al. (1971a) reported a significant correlation between pelvic height and width and pelvic area of .82 and .80, respectively. Ward (1971 and 1973) in seperate studies of body measurements of Angus x Hereford heifers found that horizontal and vertical pelvic measurements were highly correlated with each other and with pelvic area. Fitzhugh et al. (1972) also reported that horizontal and vertical pelvic measurements were positively correlated in Angus, Charolais, Hereford and Santa Gertrudis heifers. Similar results were reported by Fogarty and Thompson (1974) in a study of 29 Horned Dorset ewes. Correlations between pelvic area and pelvic height and width were approximately .80 while the correlation between height and width was small and non-significant.

Simple correlations between adjusted pelvic height, width and area and measures of body weight and daily gain were low to intermediate. Correlations between adjusted pelvic measurements and birth weight averaged .23. Correlations between adjusted pelvic measurements and weaning weight averaged .25 and correlations between adjusted pelvic measurements and average daily gain (ADG) to weaning averaged .29. Although these positive correlations are low, they indicate that heifers with heavy birth weights and weaning weights that gain rapidly tend to have larger pelvic dimensions. These relationships were higher for pelvic width and area than for pelvic height.

Correlations between pelvic measurements and actual or adjusted yearling weights were low for adjusted pelvic height (r=.22) to intermediate for adjusted pelvic width and area (r=.49 and .48, respectively). These correlations again indicate that larger heifers have larger pelvises and that pelvic width and area are more highly related to body weight than pelvic height. Simple correlations between adjusted pelvic height, width and area and ADG weaning to yearling resulted in similar indications. Correlations were generally low but positive with the correlation for adjusted pelvic height (r=.12) lower than correlations for adjusted pelvic width and area (r=.37 and .34, respectively).

Correlations between pelvic measurements and measures of body weight and gain of young heifers have been reported in the literature. Bellows et al. (1971a) presented correlations between pelvic measurements and body weights of three-year-old Hereford heifers taken three weeks prior to calving. Postive correlations of .40, .47 and .54 were found between body weight and pelvic height, width and area, respectively. Bellows et al. (1971b) studied relationships of pelvic measurements taken just prior to calving and body weight and daily gains during gestation of Hereford and Angus two-year-old heifers. Correlations between pelvic height, width and area and body weight of Hereford heifers averaged .27, .38 and .42, respectively, and in Angus heifers averaged .20, .52 and .49, respectively. In general, correlations between pelvic measurements and weight gain during early gestation were significant but low (approximately r=.20) and correlations with weight gain in late gestation were low and non-significant. Price and Wiltbank (1978) reported that pelvic area measurements were significantly correlated to dam weight at breeding (r=.55, on the average) and Laster (1974) reported that heavier cows have larger pelvic openings.

Factors Affecting Calving Difficulty

Means of random variables included in the analysis of calving difficulty score are presented in Table VI. Calves from half Limousin heifers were significantly heavier (7.9 lb) at birth than calves from three-quarter Limousin heifers and male calves were significantly heavier than female calves from both half and three-quarter heifers (2.4 and 5.4 lb, respectively). Bill Dameron (personal communication) has indicated that the difference in birth weight of calves from half and three-quarter Limousin heifers might have been due, in part, to selection of bulls known to sire small calves. Gestation length was similar for half and three-quarter heifers with male calves having slightly longer gestations in both crossbred groups.

Adjusted pelvic measurements were also similar in both breeds of heifers and did not differ significantly. It is important to notice that there are two estimates of adjusted pelvic area. Adjusted pelvic area one (1) was calculated by adjusting the actual pelvic area of the heifer to a standard age of 450 days based on the estimates of pelvic growth previously presented. Adjusted pelvic area two (2) was calculated as the product of the adjusted pelvic height and adjusted pelvic

TABLE VI

MEANS, STANDARD ERROR'S AND THE RANGE OF VARIABLES INCLUDED IN THE ANALYSIS OF CALVING DIFFICULTY OF HALF AND THREE-QUARTER LIMOUSIN HEIFERS

		Breed of Heifer			
		1/2 (707)		3/4 (112)	
Variable		Mean	Range	Mean	Range
Birth Weight of Calf (lbs)	M	$78.70^{a*} \pm .471$	50.0-110.0	$72.28^{b*} \pm 1.187$	50.0-95.0
	F	$76.30^{a} \pm .438$	50.0-105.0	$66.85^{b} \pm .890$	55.0-90.0
Gestation Length (days)	M	$288.26^{a} \pm .253$	274.0-309.0	$288.14^{a} \pm .583$	279.0-295.0
	F	$287.64^{a} \pm .222$	271.0-309.0	$286.69^{a} \pm .474$	277.0-294.0
Adjusted Pelvic Height (cm)		$14.55^{a} \pm .029$	12.48-17.20	$14.69^{a} \pm .070$	12.93-17.29
Adjusted Pelvic Width (cm)		$12.75^{a} \pm .033$	8.58-15.26	$12.59^{a} \pm .054$	11.24-14.53
Adjusted Pelvic Area (sq.cm)	1	$185.64^{a} \pm .610$	127.75-239.68	$185.01^{a} \pm 1.285$	160.51-229.63
Adjusted Pelvic Area (sq.cm)	2	$185.39^{a} \pm .691$	123.49-242.20	$185.05^{a} \pm 1.261$	160.61-230.37
Age at First Calving (days)		$725.42^{a} \pm .917$	661.0-811.0	$756.22^{b} \pm 1.673$	714.0-794.0

[a,b]Means in the same row not sharing a common superscript differ significantly ($P < .01$).

*Indicates a significant difference for sex of calf ($P < .01$).

width. Both methods of calculating adjusted pelvic area resulted in very nearly the same value; thus, adjusted pelvic area one (1) is used as the single measure of adjusted pelvic area in the following analyses. Age of heifer at first calving was also included in the analsis of calving difficulty score. The average age of half Limousin heifers at first calving was 725 days and half Limousin heifers were 31 days younger than three-quarter Limousin heifers at the first parturition.

Table VII presents mean squares from the analysis of variance of calving difficulty score of half and three-quarter Limousin heifers determined by the complete model. Factors found to account for significant ($P<.01$) variability in calving difficulty score were sire of calf, birth weight of calf and heifers age at first calving. Although none of the remaining effects were found significant, adjusted pelvic height and width were near significance ($P<.10$) and gestation length was slightly nonsignificant ($.1<P<.15$).

None of the interactions were found significant and were dropped from the model. The analysis of calving difficulty score was then repeated using a reduced model with only main effects included. Mean squares of this analysis are presented in Table VIII. Sex of calf, sire of calf, birth weight of calf and age of heifer at calving accounted for significant ($P<.01$) variability in calving difficulty score. Although adjusted pelvic height and width approached significance, estimates of pelvic size still failed to account for a large amount of the variation in calving difficulty score when all estimates of pelvic size were included in the model. Adjusted pelvic area was calculated by multiplying pelvic height times width and then adjusting for age,

TABLE VII

MEAN SQUARES FROM ANALYSIS OF VARIANCE OF CALVING DIFFICULTY SCORE

Source	df	Mean Square	
Breed of heifer (BOH)	1	.0044	
Sex of calf (SEXFC)	1	.025	
Sire of heifer(SIRE)	7	.5254	
Sire of calf (SIREFC)	5	1.6513**	
Birth weight of calf (BWFC)	1	60.3126**	
Gestation length (GLFC)	1	1.1765	
Adjusted pelvic height (ADJHT)	1	1.4080+	
Adjusted pelvic width (ADJWD)	1	1.5444+	
Adjusted pelvic area (ADJA)	1	.7534	
Age at first calving (AAFC)	1	10.8104**	
BWFC*BOH*SEXFC	3	.1302	
BWFC*BOH	1	.021	
BWFC*SEXFC	1	.028	
BWFC*BOH*SEXFC	1	.341	
GLFC*BOH*SEXFC	3	.5272	
GLFC*BOH	1	.335	
GLFC*SEXFC	1	1.245	
GLFC*BOH*SEXFC	1	.121	
ADJHT*BOH*SEXFC	3	.0010	
ADJHT*BOH	1	.0007	
ADJHT*SEXFC	1	.005	
ADJHT*BOH*SEXFC	1	.003	
ADJWD*BOH*SEXFC	3	.0032	
ADJWD*BOH	1	.00004	
ADJWD*SEXFC	1	.00004	
ADJWD*BOH*SEXFC	1	.003	
ADJA*BOH*SEXFC	3	.0010	
ADJA*BOH	1	.0004	
ADJA*SEXFC	1	.001	
ADJA*BOH*SEXFC	1	.002	
AAFC*BOH*SEXFC	3	.1985	
AAFC*BOH	1	.0006	
AAFC*SEXFC	1	.006	
AAFC*BOH*SEXFC	1	.588	
Residual error	759	.5186	R^2 = .365

** Significant P<.01

+ Approached Significance P<.10

TABLE VIII

MEAN SQUARES FROM ANALYSIS OF VARIANCE OF CALVING DIFFICULTY SCORE - MAIN EFFECTS ONLY

Source	df	Mean Square	
Breed of Heifer (BOH)	1	.829	
Sex of Calf (SEXFC)	1	8.090**	
Sire of Heifer (SIRE)	7	.538	
Sire of Calf (SIREFC)	5	2.083**	
Birth Weight of Calf (BWFC)	1	61.853**	
Gestation Length (GLFC)	1	1.223	
Adjusted Pelvic Height (ADJHT)	1	1.492+	
Adjusted Pelvic Width (ADJWD)	1	1.613+	
Adjusted Pelvic Area (ADJA)	1	.799	
Age at First Calving (AAFC)	1	11.361**	
Residual Error	777	.515	$R^2 = .354$

**Significant $P < .01$

+Approached significance $P < .10$

resulting in a confounding of these traits in the analysis. Thus, further analyses were conducted utilizing a model that included all main effects in combination with either adjusted pelvic height and width as an estimate of pelvic size or with adjusted pelvic area as an estimate of pelvic size.

Table IX presents mean squares from analysis of variance of calving difficulty score with adjusted pelvic height and width or adjusted pelvic area as an estimate of pelvic size. Factors found to significantly influence calving difficulty were sex of calf, sire of calf, calf birth weight, age of heifer at calving and heifer's adjusted pelvic height and width or adjusted pelvic area. R^2 values of .353 when adjusted pelvic height and width were included in the model and .351 when adjusted pelvic area was in the model indicate that pelvic area and the combination of pelvic height and width were of equal value in predicting dystocia.

It was of further interest to determine which single, independent measure of pelvic size had the greatest influence on calving performance. Table X presents mean squares from analysis of calving difficulty score comparing independent estimates of pelvic size in combination with significant main effects. Although each estimate of pelvic size was found to account for a significant portion of the variability in calving difficulty score, the model which included adjusted pelvic area had the highest R^2 value (R^2=.342) indicating that pelvic area was the most important single estimate of pelvic size influencing calving difficulty. R^2 values between models including adjusted pelvic width and height differed slightly (R^2=.315 and .290, respectively).

TABLE IX

MEAN SQUARES FROM ANALYSIS OF VARIANCE OF CALVING DIFFICULTY SCORE - ADJUSTED HEIGHT AND WIDTH VERSUS ADJUSTED AREA IN MODEL

Source	Adjusted Height and Width			Adjusted Area		
	df	Mean Square		df	Mean Square	
Breed of Heifer	1	.996		1	.983	
Sex of Calf	1	8.232*		1	8.187**	
Sire of Heifer	7	.545		7	.568	
Sire of Calf	5	2.621**		5	3.008**	
Birth Weight of Calf	1	61.335**		1	60.948**	
Gestation Length	1	1.210		1	1.245	
Adjusted Pelvic Height	1	17.364**		—	—	
Adjusted Pelvic Width	1	27.109**		—	—	
Adjusted Pelvic Area	—	—		1	11.458**	
Age at First Calving	1	11.425		1	11.458**	
Residual Error	778	.516	$R^2 = .353$	779	.516	$R^2 = .351$

**Significant $P < .01$

TABLE X

MEAN SQUARES FROM ANALYSIS OF VARIANCE OF CALVING DIFFICULTY SCORE COMPARING INDIVIDUAL ESTIMATES OF PELVIC SIZE

Source	df	Mean Square	
Breed of heifer (BOH)	1	.030	
Sex of calf (SEXFC)	1	6.959**	
Sire of calf(SIREFC)	5	8.494**	
Birth weight of calf (BWFC)	1	63.063**	
Adjusted pelvic height	1	32.885**	
Age at first calving	1	8.990**	
Residual error	787	.559	R^2 = .290
BOH	1	1.757+	
SEXFC	1	8.988**	
SIREFC	5	3.081**	
BWFC	1	66.437**	
Adjusted pelvic width	1	48.120**	
AAFC	1	10.934**	
Residual error	787	.540	R^2 = .315
BOH	1	1.274	
SEXFC	1	8.328**	
SIREFC	5	4.140**	
BWFC	1	70.447**	
Adjusted pelvic area	1	65.338**	
AAFC	1	11.572**	
Residual error	787	.518	R^2 = .342

** Significant $P<.01$
* Significant $P<.05$
+ Approached Significance $P<.10$

Table XI presents mean squares and the R^2 value from an analysis of calving difficulty score utilyzing only those variables that are available prior to calving. Although all factors known prior to calving (breed of heifer, sire of calf and adjusted pelvic area) had a significant influence on calving difficulty score, they accounted for only 18.2% of the total variability in calving score. Thus, indicating that knowledge of a heifers pelvic capacity prior to breeding and other factors that were available in this study prior to calving were insufficient or of limited use in predicting dystocia in young heifers calving at two years of age.

When adjusted pelvic area was replaced by birth weight of calf in this simplified model 21.3% of the variability in calving difficulty score was accounted for. Indicating that birth weight of calf, in comparison to pelvic area, would be of greater concern when considering calving performance of young heifers.

Similar results have been previously reported. Laster et al. (1973) at the United States Meat Animal Research Center (USMARC) studied factors affecting calving performance and reported that sire breed, dam breed, dam age, calf sex and calf birth weight were significant sources of variation in percent dystocia. Smith et al. (1976), also at USMARC found that sire within breed, dam breed, dam age, calf sex and calf birth weight significantly influenced calving difficulty of crossbred cows and heifers. Brinks et al. (1973) found that year, sex of calf, age of dam, day of birth, line of sire, sire within line and several interactions significantly influenced calving difficulty but accounted for only 15.6% of the variation in dystocia of two-year-old Hereford heifers. Nelson and Huber (1971) also reported that birth weight and

TABLE XI

MEAN SQUARES FROM ANALYSIS OF VARIANCE OF CALVING DIFFICULTY SCORE - PREDICTOR VARIABLES ONLY

Source	df	Mean Square	
Breed of Heifer	1	3.359*	
Sire of Calf	5	9.136**	
Adjusted Pelvic Area	1	45.291**	
Residual Error	79	.641	R^2 = .182
Breed of Heifer	1	.886	
Sire of Calf	5	6.816**	
Birth Weight of Calf	1	64.511**	
Residual Error	790	.617	R^2 = .213

**Significant $P < .01$

*Significant $P < .05$

sex of calf significantly influenced dystocia in cows. However, Joandet et al. (1973) in an Argentinan study reported that the incidence of dystocia in 2,046 Angus cows was not effected by sire breed, dam age, calving year or sex of calf. Reports in the literature dealing with the effects of pelvic size on dystocia have also yielded similar results. Laster (1974) found that pelvic size (height or width) independent of cow weight had a significant influence on dystocia in 599 two-year-old Hereford and Angus cows but did not account for a large source of variation. He concluded that birth weight of the calf was the most important factor affecting dystocia and that the relationship between dystocia and the physical measurements and subjective scores of cows in the study were to low to accurately predict dystocia. Bellows et al. (1971b) studied eight factors in association with calving difficulty of 198 Hereford and Angus first-calf heifers and reported that pelvic area of the dam had a significant effect on calving difficulty score but birth weight of the calf was the most important cause of dystocia. They found that all eight variables accounted for less than 50% of the variability in calving difficulty score. In another study Price and Wiltbank (1978) reported that dystocia score was most highly related to calf size and dam's pelvic area; but, together they accounted for only 37% of the variability in dystocia score. Birth weight alone accounted for 19% of the variation in calving score while pelvic area alone accounted for only 5% of the variability and adding other variables to the model resulted in little increase in R^2 values. Thus, calf size was concluded to be the most important factor influencing calving difficulty.

Simple correlations between calving difficulty score and associated factors are presented in Table XII. Correlations between calving difficulty score and calf birth weight, gestation length, adjusted pelvic measurements and age of heifer at calving were all highly significant. Positive correlations of .39 and .20 for calving score and calf birth weight and gestation length, respectively, indicate that heifers with higher dystocia scores (more calving difficulty) had heavier calves at birth and these calves had longer gestations. The correlation of .29 between calf birth weight and gestation length lends support to this idea.

Correlations between adjusted pelvic measurements and calving difficulty score ranged from -.17 for adjusted pelvic height to an average of -.27 for adjusted pelvic width and area. These correlations suggest that heifers with small pelvises have a higher frequency of calving difficulties and pelvic width and area have a greater influence on calving performance of young heifers than pelvic height.

These results are in good agreement with those reported by Rice (1969) and Rice and Wiltbank (1970 and 1972) who found correlations of dystocia score (scored 1-4) with calf birth weight and dam's pelvic area of .36 and -.34, respectively, in 90 two-year-old Hereford heifers. In a second trial of 93 two-year-old Angus heifers they reported correlations with dystocia score of .44 and -.32 for calf birth weight and dam's pelvic area, respectively. Price and Wiltbank (1978) reported correlations between pelvic area at calving and dystocia of -.34 and -.47 for crossbred and Charolais heifers, respectively, and found pelvic area at breeding significantly correlated to dystocia in Angus heifers (r=-.42). Others have also reported significant correlations of dam's pelvic size to dystocia (Cadle and Ruttle, 1976; Bellows et

TABLE XII

SIMPLE CORRELATIONS BETWEEN CALVING DIFFICULTY SCORE (CDIFF) AND ASSOCIATED FACTORS

Measurement (N)	Birth Weight of First Calf (BWFC)	Gestation Length of First Calf (GLFC)	Adjusted Pelvic Height (ADJHT)	Adjusted Pelvic Width (ADJWD)	Adjusted Pelvic Area (ADJA)	Age at First Calving (AAFC)
CDIFF (818)	.39**	.20**	-.17**	-.25**	-.28**	-.15**
BWFC (818)		.29**	.07*	.15**	.16**	-.11**
GLFC (818)			.01	.004	.01	-.06
AAFC (818)			.03	-.16**	-.10**	—

**Significant P < .01

*Significant P < .05

al. 1971b; Singleton et al. 1973; and Laster, 1974). Ward (1971) also reported a significant correlation between calving difficulty and calf birth weight (r=.46); however, Sagebiel et al. (1969) reported slightly lower correlations of dystocia score and calf birth weight at .36 for Angus, .24 for Hereford and .16 for Charolais heifers (calving scored 1-8).

It is important to point out that as a single factor, calf birth weight accounted for 15.2% of the variation in calving difficulty score while adjusted pelvic area accounted for only 7.8% of the variability in dystocia score. Multiple regression analysis of calving difficulty score including both variables, significant main effects and age of heifer at calving (which alone accounted for only 2.3% of the variability in calving score) accounted for 34.2% of the variability in calving difficulty score indicating that it is the interrelationship between calf birth weight and pelvic size that effects calving performance of young heifers.

The correlation of dystocia score to length of gestation in this study was in good agreement with that reported by Price and Wiltbank (1978) who reported a low but significant correlation of .19 between dystocia score and gestation length. However, Sagebiel et al. (1969) reported correlations of calving score to gestation length were low and nonsignificant.

The correlation of -.15 for dystocia score and age of heifer at calving and -.11 for calf birth weight and age of heifer at calving indicate a slight tendency for heifers experiencing greater calving difficulty to be younger at calving and to have heavier calves. Thus, it would appear that part of the reason younger heifers experienced more calving difficulty was because they had heavier calves.

Correlations between age of heifer at calving and adjusted pelvic width and area were highly significant (r=.16 and .10, respectively) suggesting that older heifers tended to have smaller pelvises. At first thought these correlations, even though they are low, do not appear logical. However, in retrospect, large rapid growing heifers tended to have larger pelvises and heifers within a breed that grow rapidly tend to reach puberty at an earlier age. Thus, I would suggest that heifers with lower daily gains may have been slower to reach puberty and bred later in the breeding season resulting in smaller heifers being older at calving. Correlations between length and adjusted pelvic measurements were low and nonsignificant.

Average birth weights and gestation lengths of male and female calves are presented in Table XIII by calving difficulty score and breed of heifer. Male calves from half Limousin heifers averaged 2.4 lb heavier at birth and resulted in 18% more calving difficulty than female calves. Sixty-six percent of the heifers having male calves experienced some degree of calving difficulty while only 48% of those heifers having female calves required assistance. Overall, calves from half Limousin heifers that calved unassisted were 6.8 lb lighter at birth than calves from heifers that required assistance (74.3 vs. 81.1 lb). For each increment increase in calving difficulty score from 1-4, birth weight of calves increased by 4.4, 3.0 and 1.4 lb, respectively. Although the difference in birth weight of 1.4 lb between scores three and four was not significant, these data suggest that at heavier birth weights, smaller increases in calf birth weight were required to cause an increased amount of calving difficulty.

TABLE XIII

UNADJUSTED MEAN BIRTH WEIGHT AND GESTATION LENGTH BY CALVING DIFFICULTY SCORE

Breed of Heifer (N)		Calving Difficulty Score[1] 1	2	3	4
1/2 Limousin (706)		(305)	(252)	(104)	(45)
Calf Birth Weight (lb)	Male (332)	$74.90^{a} \pm .82$	$79.34^{b} \pm .57$	$82.06^{c} \pm 1.04$	$83.81^{c} \pm 2.02$
	Female (374)	$73.60^{a} \pm .57$	$77.91^{b} \pm .64$	$81.25^{c} \pm 1.43$	$82.32^{c} \pm 1.88$
Gestation Length (days)	Male (332)	$287.32^{a} \pm .47$	$287.86^{a} \pm .36$	$289.63^{b} \pm .59$	$290.97^{b} \pm .71$
	Female (374)	$286.98^{a} \pm .32$	$288.09^{b} \pm .35$	$288.71^{b} \pm .66$	$289.00^{b} \pm .85$
3/4 Limousin (112)		(70)	(32)	(10)	(0)
Calf Birth Weight (lb)	Male (51)	$69.96^{a} \pm 1.82$	$74.38^{b} \pm 1.77$	$74.16^{a,b} \pm 2.56$	
	Female (61)	$65.37^{a} \pm .89$	$68.36^{a} \pm 1.56$	$79.75^{b} \pm 4.09$	
Gestation Length (days)	Male (51)	$287.92^{a} \pm 1.03$	$288.48^{a} \pm .73$	$287.83^{a} \pm 1.30$	
	Female (61)	$287.11^{a} \pm .54$	$284.73^{b} \pm .99$	$287.25^{a,b} \pm 2.02$	

[a,b,c]Means in the same row not sharing a common superscript differ significantly ($P < .05$).

[1]Calving scored 1 = unassisted birth, 2 = easy pull, 3 = hard pull and 4 = caesarean.

There was a slight increase in gestation length for each increment increase in calving difficulty score. Length of gestation of male calves with a calving score of one or two was significantly less than those with a calving score of three or four (287.59 vs 290.3 days) and female calves that were born unassisted had on the average a 1.62 days shorter gestation than those requiring assistance. Thus, heavier calf birth weights in the higher calving difficulty scores may have been due, in part, to the longer gestation lengths of those calves.

The same general patterns were observed in three-quarter Limousin heifers. Male calves averaged 5.43 lb heavier at birth and resulted in 28% more calving difficulty than female calves (52.9 vs 24.6%). Male calves also had a 1.45 days longer gestation. Calves from three-quarter Limousin heifers that calved unassisted were 6.5 lb lighter than calves from heifers requiring assistance. Although the same pattern of birth weight and gestation length differences was observed between calving scores, differences were inconsistant, due probably to the limited number of observations in each calving score category.

Similar results were reported by Nelson and Huber (1971) who found that crossbred male calves from Hereford cows weighed 5.06 lb more at birth than female calves and required 15% more assistance. Laster et al. (1973) reported that crossbred male calves from Hereford and Angus cows were heavier (77.3 vs 70.6 lb) and experienced more dystocia (28.4 vs 16.9%) than female calves and cows with longer gestation lengths experienced more calving difficulty. Price and Wiltbank (1978) also found that male calves required more assistance at birth and reported that male calves were larger at birth and gestated longer. Others that have reported similar results are Sagebiel et al., 1969; Bellows et al., 1971b and Anderson and Bellows, 1967.

Calf birth weights from heifers calving unassisted or requiring calving assistance have also been presented in the literature. Monteiro (1969) reported a difference in birth weights of calves from normal or difficult calvings of 8.3 lb in a study of 458 calves from Friesian, Ayrshire and Jersey dams. Young (1970) found that Angus heifers with dystocia had calves that were 7.0 lb heavier at birth than non-dystocia heifers. Dufour et al. (1974) reported similar results from a study of dairy x beef heifers in which birth weight of calves from difficult calvings averaged 7.0 lb heavier than those from unassisted births and Webster (1977) found that mean birth weight of calves from heifers requiring assistance were significantly larger than those not requiring assistance.

Table XIV presents the average adjusted pelvic measurements and average age of heifers at calving by calving difficulty score. In general, pelvic dimensions of half and three-quarter Limousin heifers that calved unassisted were larger than pelvic dimensions of heifers experiencing calving difficulty and those heifers that had difficulty at calving were younger. Adjusted pelvic height of half Limousin heifers that calved unassisted or required slight assistance was significantly larger (.35 cm) than adjusted pelvic height of heifers requiring major assistance or caesarean. Differences in calving score 1-2 and 3-4 were not significant for adjusted pelvic height. Half Limousin heifers that calved unassisted had significantly larger adjusted pelvic width than heifers with calving difficulty (13.0 vs. 12.5 cm) and heifers requiring slight or major assistance had significantly larger pelvic width than heifers requiring caesareans (12.59 vs. 12.20 cm). The dif-

TABLE XIV

MEAN ADJUSTED PELVIC MEASUREMENTS AND AGE OF HEIFER AT CALVING BY CALVING DIFFICULTY SCORE

Breed of Heifer (N)	Calving Difficulty Score[1]			
	1	2	3	4
1/2 Limousin (706)	(305)	(252)	(104)	(45)
Pelvic Height (cm)	$14.65^{a} \pm .05$	$14.59^{a} \pm .05$	$14.31^{b} \pm .07$	$14.23^{b} \pm .10$
Pelvic Width (cm)	$13.00^{a} \pm .05$	$12.65^{b} \pm .05$	$12.52^{b} \pm .08$	$12.20^{c} \pm .16$
Pelvic Area (sq.cm)	$190.30^{a} \pm .90$	$184.65^{b} \pm .96$	$179.48^{c} \pm 1.49$	$174.37^{b} \pm 2.31$
Age at Calving (days)	$726.77^{a} \pm 1.38$	$726.53^{a,b} \pm 1.53$	$722.49^{a,b,c} \pm 2.59$	$716.84^{c} \pm 3.01$
3/4 Limousin (112)	(70)	(32)	(10)	(0)
Pelvic Height (cm)	$14.74^{a} \pm .09$	$14.61^{a} \pm .15$	$14.26^{a} \pm .16$	
Pelvic Width (cm)	$12.62^{a} \pm .07$	$12.63^{a} \pm .10$	$12.28^{b} \pm .16$	
Pelvic Area (sq.cm)	$186.07^{a} \pm 1.60$	$184.41^{a} \pm 2.46$	$179.55^{a} \pm 3.33$	
Age at Calving (days)	$757.86^{a} \pm 2.07$	$755.38^{a,b} \pm 3.12$	$747.50^{b} \pm 5.63$	

^{a,b,c} Means in the same row not sharing a common superscript differ significantly ($P < .05$).

[1] Calving scored 1 = unassisted birth, 2 = easy pull, 3 = hard pull and 4 = caesarean.

ferences in adjusted pelvic width of heifers requiring slight or major assistance was not significant. Adjusted pelvic area of half Limousin heifers differed significantly between each calving difficulty score. Half Limousin heifers that calved unassisted had pelvic areas 5.65 sq cm larger than heifers requiring only slight assistance. Heifers requiring minor assistance had 5.2 sq cm larger pelvic areas than those requiring major calving assistance and the difference in pelvic area of heifers requiring major assistance or caesarean was 5.1 sq cm.

The difference in adjusted pelvic measurements of three-quarter Limousin heifers that required no assistance, slight assistance or major assistance was less than that observed in half Limousin heifers and most differences were nonsignificant. However, the same general trends were observed in which heifers calving unassisted had larger pelvic dimensions than heifers that required slight or major calving assistance. None of the three-quarter Limousin heifers required a caesarean.

Similar results have been reported by Young (1968b) who, in a study of 149 Devon heifers, found that heifers with dystocia had significantly smaller pelvic areas than heifers with no dystocia. In 1970, Young again reported a study involving 93 Angus heifers and found that dystocia heifers had significantly smaller pelvic areas and in some cases the pelvic height and width diameters were also significantly smaller. Webster (1971) from a study of 928 heifers reported that heifers not requiring calving assistance had significantly larger pelvic areas and Phillipson (1976) found that Swedish Freisian heifers with calving difficulty had significantly smaller pelvic areas than heifers calving normally. In a study of sheep, Fogarty and Thompson (1974) reported that ewes with greater than 65% dystocia had significantly smaller pelvic areas and pelvic width.

A significant difference existed for age at calving between half Limousin heifers that calved unassisted or with slight assistance and those that required caesareans. Heifers with caesareans were, on the average, ten days younger at calving. Differences between other calving difficulty scores was not significant; however, there was a gradual decrease in heifers age at first calving as calving difficulty score increased. This was also observed in three-quarter Limousin heifers where heifers that calved unassisted were significantly older than heifers that required major assistance by ten days.

Relationships Between Calving Difficulty, Calf Birth Weight and Heifers Pelvic Size

This study suggests that calving performance of young heifers is primarily affected by an interrelationship of calf birth weight and heifer's pelvic size. Many other studies have yielded similar results. Dufour et al. (1974) found that heifers with below average pelvic area averaged 33.4% calving difficulty compared to only 19.3% in heifers with above average pelvic area. Rice and Wiltbank (1970 and 1972) found that heifers with less than 200 sq cm pelvic areas had 68.7% dystocia compared to only 28% dystocia in heifers with pelvises greater than 200 sq cm in area when herd average was 218 sq cm. Moore (1956) reported that the amount of calving difficulty a heifer experiences is dependent on her own size as well as her calf's size. Menissier et al. (1974) also reported a strong interaction between pelvic size and calf size from a study of calving difficulty of three French beef breeds.

Young (1968a, 1968b and 1970) reported the primary cause of dystocia in beef heifers was foeto-pelvic disproportion. Phillipson (1976a) reported similar results from a study of Swedish Friesian heifers stating dystocia heifers had a less favorable ratio of pelvic area to calf birth weight than non-dystocia heifers and Price and Wiltbank (1978) found that as calf birth weight increased the need for larger pelvises increased. They also reported that heifers with small calves (40-50 lb) had little or no difficulty at calving even with small pelvises.

To better examine the relationship between heifer pelvic size and subsequent calving difficulty in this study, heifers were placed into categories based on pelvic area. Cross classified frequency tables were generated which gave the number and percentage of heifers in a given pelvic category that had a calving difficulty score of one, two, three or four. The percentage of heifers within a given pelvic area category with each calving score are presented in bar graphs to facilitate comparisons and discussion.

Pelvic area categories were determined by finding the total range in adjusted pelvic area from smallest to largest and dividing this range into thirds giving a small, intermediate and large category. Eighty-three percent of the heifers had pelvises in the intermediate range of 165-207 sq cm and consequently, this category was subdivided into halves to give a low and high intermediate group (Figure 1). Thus, four pelvic area categories evolved: Small=121-164 sq cm, low intermediate=165-186 sq cm, high intermediate=187-207 sq cm and large=208-250 sq cm.

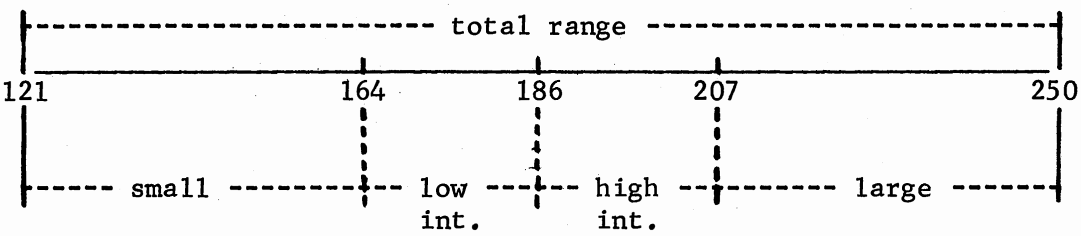

Figure 1. Pelvic Area Categories

The pelvic area category by calving difficulty score cross classification frequency table for half Limousin heifers is presented in Table XV. Seven and one half percent of all half Limousin heifers had pelvic areas in the small category (121-164 sq cm). Forty-four percent had pelvises in the low intermediate range of 165-186 sq cm while 39.2% had pelvises in the high intermediate range of 187- 207 sq cm. Only 9.2% of the half Limousin heifers had pelvises in the large pelvic area category of 208-250 sq cm.

Heifers were also divided into categories based on adjusted pelvic height and width and cross classification frequency tables with calving difficulty score are presented in Tables XXIII and XXIV of the Appendix.

The percentage of half Limousin heifers within each pelvic area category that had a calving score of one, two, three or four is presented graphically in Figure 2. The percentage of half Limousin heifers that calved unassisted continually increased for each larger pelvic area category ranging from 15% for heifers with small pelvises (121-164 sq cm) to 69% for heifers with large pelvic areas (208-250 sq cm).

Eighty-five percent of the heifers with small pelvic areas required some degree of calving assistance and 45% required major assistance

TABLE XV

FREQUENCY TABLE OF PELVIC AREA OF 1/2 LIMOUSIN HEIFERS
BY CALVING DIFFICULTY SCORE
AND AREA CATEGORIES

Area Category (sq cm)	Calving Difficulty Score 1	2	3	4	Total n %
121-164					
n	8	21	16	8	53
% of Total	1.13	2.97	2.27	1.13	7.51
% of Area Category	15.09	39.62	30.19	15.09	
% of Calving Score	2.62	8.33	15.38	17.78	
165-186					
n	116	113	54	28	311
% of Total	16.43	16.01	7.65	3.97	44.05
% of Area Category	37.30	36.33	17.36	9.00	
% of Calving Score	38.03	44.84	51.92	62.22	
187-207					
n	136	102	31	8	277
% of Total	19.26	14.45	4.39	1.13	39.24
% of Area Category	49.10	36.82	11.19	2.89	
% of Calving Score	44.59	40.48	29.81	17.78	
208-250					
n	45	16	3	1	65
% of Total	6.37	2.27	.42	.14	9.21
% of Area Category	69.23	24.62	4.62	1.54	
% of Calving Score	14.75	6.35	2.88	2.22	
Total					
n	305	252	104	45	706
%	43.20	35.69	14.73	6.37	100.0

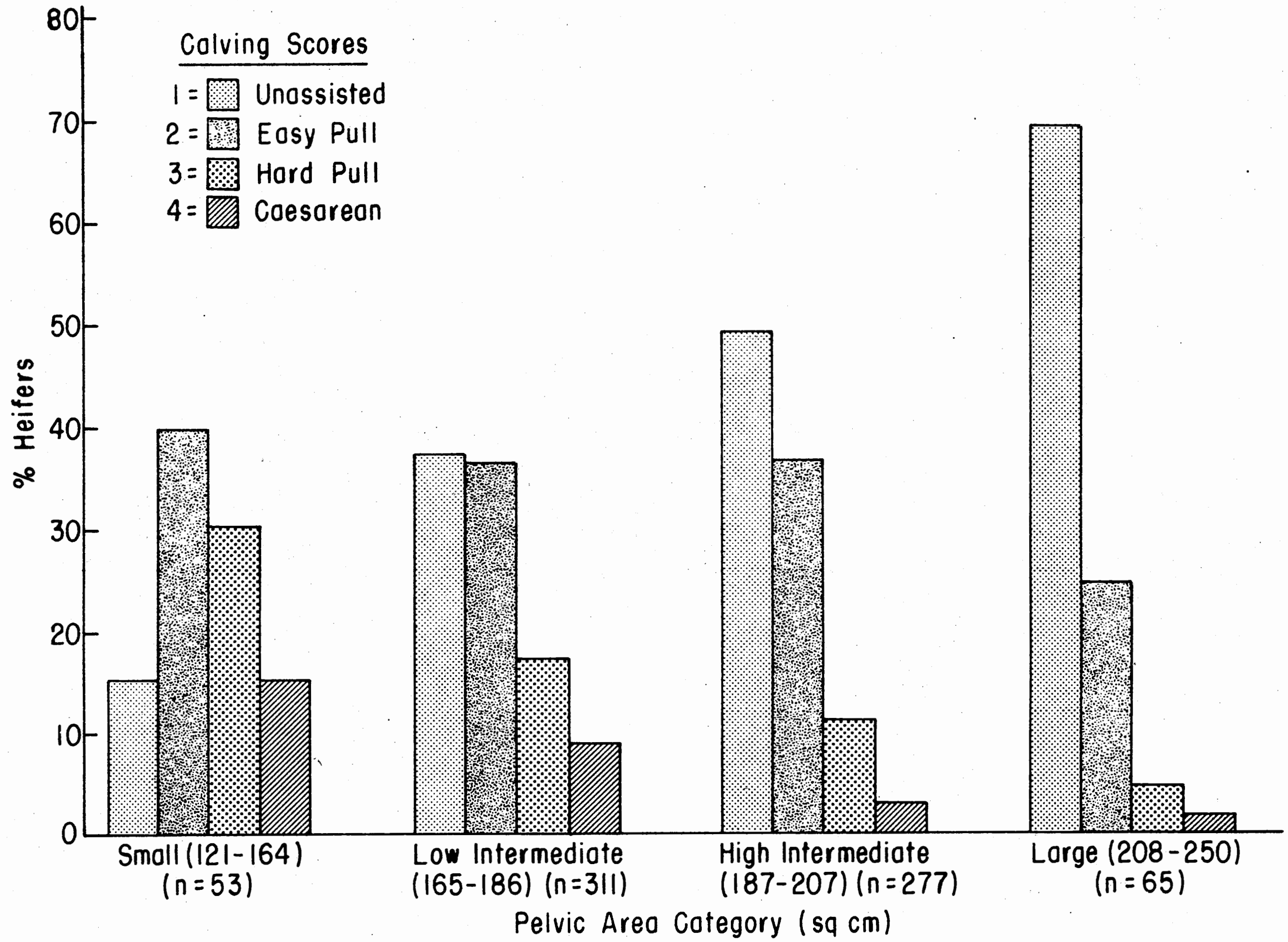

Figure 2. Percentage of Calving Difficulty of 1/2 Limousin Heifers for Each Pelvic Area Category

or caesarean. Of the heifers with pelvises in the low intermediate range, 63% required some assistance at calving and 26% required major assistance or caesarean. The percentage of heifers requiring major assistance was further reduced to 14% in those heifers with pelvic areas in the high intermediate category and only six percent of the heifers with large pelvic areas required more than slight assistance.

Only 7.5% of all the half Limousin heifers had pelvic areas in the small category (121-164 sq cm). However, 85% of these heifers required some degree of calving assistance. It would appear that pre-breeding pelvic measurements could be used as a management tool to identify heifers with the highest probability of having calving difficulty and these heifers could be removed from the herd without removing a large percentage of the total heifers from which to select.

The percentage of three-quarter Limousin heifers within each pelvic area category that had a calving difficulty score of one, two, three or four is presented in Figure 3 and the corresponding frequency table is presented in Table XVI. Although the number of three-quarter heifers in each pelvic area category was small, the same general trends were observed as were seen in the half Limousin heifers. Three-quarter Limousin heifers with large pelvic areas required less major calving assistance and there was an increase in the percent of unassisted births as pelvic areas went from small to high intermediate. The decrease in the percent of three-quarter heifers that calved unassisted from the high intermediate to large pelvic category is probably a reflection of the limited number of heifers with pelvises in the large category. These relationships in three-quarter Limousin heifers support the suggestion that pelvic measurements might be used as a management tool to

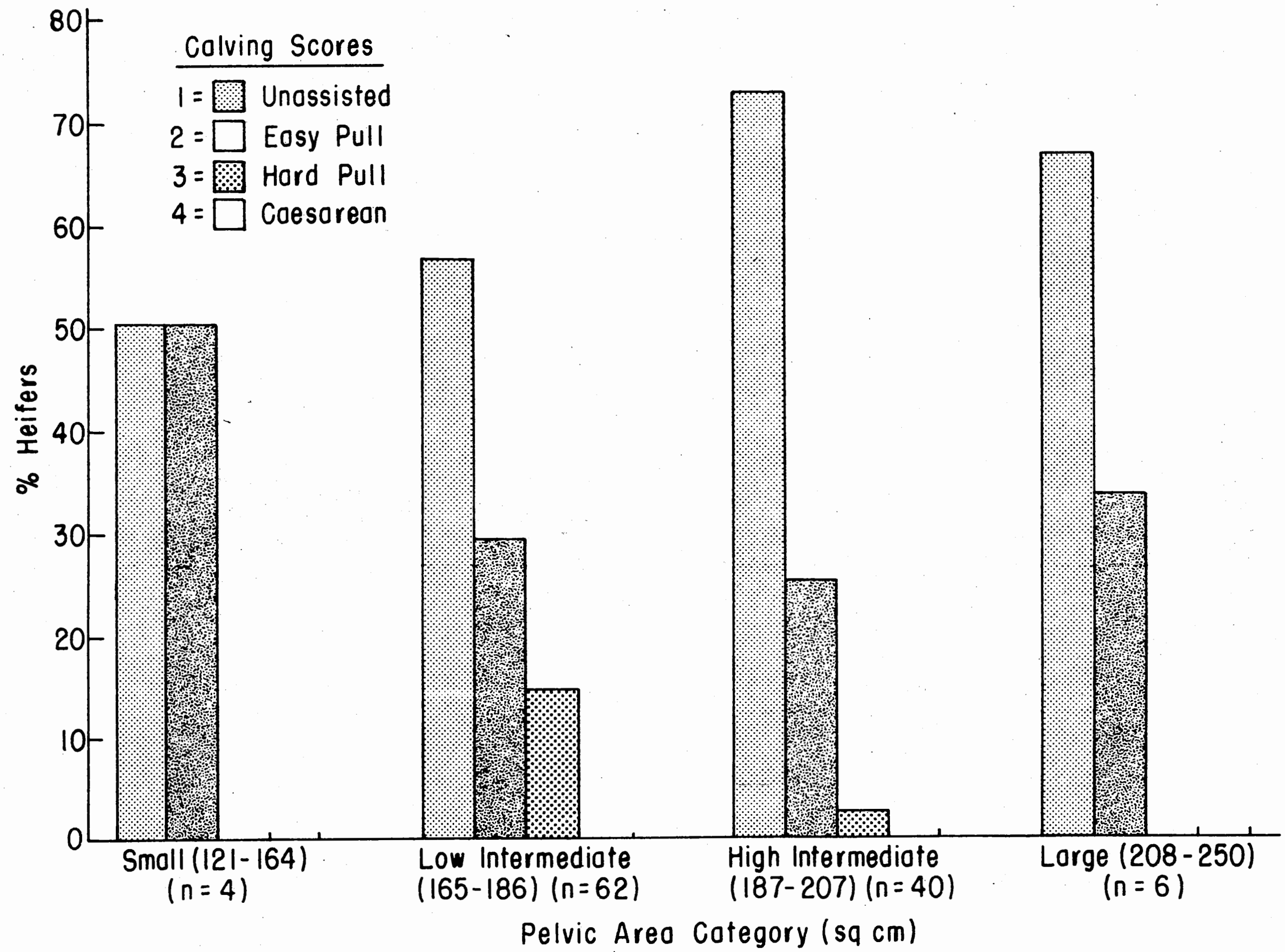

Figure 3. Percentage of Calving Difficulty of 3/4 Limousin Heifers for Each Pelvic Area Category

TABLE XVI

FREQUENCY TABLE OF PELVIC AREA OF 3/4 LIMOUSIN HEIFERS
BY CALVING DIFFICULTY SCORE
AND AREA CATEGORIES

Area Category (sq cm)	Calving Difficulty Score 1	2	3	4	Total n %
121-164					
n	2	2	0	0	4
% of Total	1.79	1.79			3.57
% of Area Category	50.00	50.00			
% of Calving Score	2.86	6.25			
165-186					
n	35	18	9	0	62
% of Total	31.25	16.07	8.04		55.36
% of Area Category	56.45	29.03	14.52		
% of Calving Score	50.00	56.25	90.00		
187-207					
n	29	10	1	0	40
% of Total	25.89	8.93	.89		35.71
% of Area Category	72.50	25.00	2.50		
% of Calving Score	41.43	31.25	10.00		
208-250					
n	4	2	0	0	6
% of Total	3.57	1.79			5.36
% of Area Category	66.67	33.33			
% of Calving Score	5.71	6.25			
Total					
n	70	32	10		112
%	62.50	28.57	8.93		100.0

identify heifers that have a high risk of encountering difficulty at calving. Frequency tables for adjusted pelvic height and width and calving difficulty score of three-quarter Limousin heifers are also presented in the Appendix (Tables XXV and XXVI, respectively).

Half Limousin heifers were also grouped according to birth weight of their calves and similar three-way frequency tables were generated to examine the interrelationship of pelvic size, calf birth weight and calving difficulty (Tables XVII, XVIII, XIX and XX). Birth weight categories were arbitrarily chosen to include the range of calf birth weights from all heifers. Birth weight categories were 50-65 lb, 66-75 lb, 76-85 lb, 86-95 lb and 96-110 lb. Some birth weight-pelvic area categories are represented by only a limited number of heifers.

Figure 4 presents, for each birth weight group, the percentage of half Limousin heifers with small pelvises (121-164 sq cm) that had a calving score of one, two, three or four. Heifers with small pelvic areas had some major calving difficulty even when calves were small (less than 65 lb) and as calf birth weight increased the percent of heifers of this pelvic size requiring assistance also increased to the point that no heifer having a calf larger than 85 lb calved unassisted. Of the heifers with small pelvises that had calves weighing 66 to 75 lb only 12% calved unassisted while 24% required major assistance or caesarean. When calves weighed from 76-85 lb, 63% of the heifers required major assistance or caesarean.

Figure 5 represents the percentage of calving difficulties of half Limousin heifers with pelvic areas in the low intermediate range (165-186 sq cm) for each birth weight group. Eighty-three percent of the heifers that had calves weighing less than 65 lb calved unassisted and

TABLE XVII

BIRTH WEIGHT BY CALVING DIFFICULTY SCORE FREQUENCY TABLE FOR 1/2 LIMOUSIN HEIFERS IN THE SMALL PELVIC AREA CATEGORY (121-164 sq cm)

Birth Weight Category (lb)	Calving Difficulty Score 1	2	3	4	Total n %
50-65					
n	2	0	2	1	5
% of Total	3.77		3.77	1.89	9.43
% of Birth Wt. Category	40.00		40.00	20.00	
% of Calving Score	25.00		12.50	12.50	
66-75					
n	3	16	5	1	25
% of Total	5.66	30.19	9.43	1.89	47.17
% of Birth Wt. Category	12.00	64.00	20.00	4.00	
% of Calving Score	37.50	76.19	31.25	12.50	
76-85					
n	3	4	8	4	19
% of Total	5.66	7.55	15.09	7.55	35.85
% of Birth Wt. Category	15.79	21.05	42.11	21.05	
% of Calving Score	37.50	19.05	50.00	50.00	
89-95					
n	0	1	1	1	3
% of Total		1.89	1.89	1.89	5.66
% of Birth Wt. Category		33.33	33.33	33.33	
% of Calving Score		4.76	6.25	12.50	
96-110					
n	0	0	0	1	1
% of Total				1.89	1.89
% of Birth Wt. Category				100.00	
% of Calving Score				12.50	
Total					
n	8	21	16	8	53
%	15.09	39.62	30.19	15.09	100.0

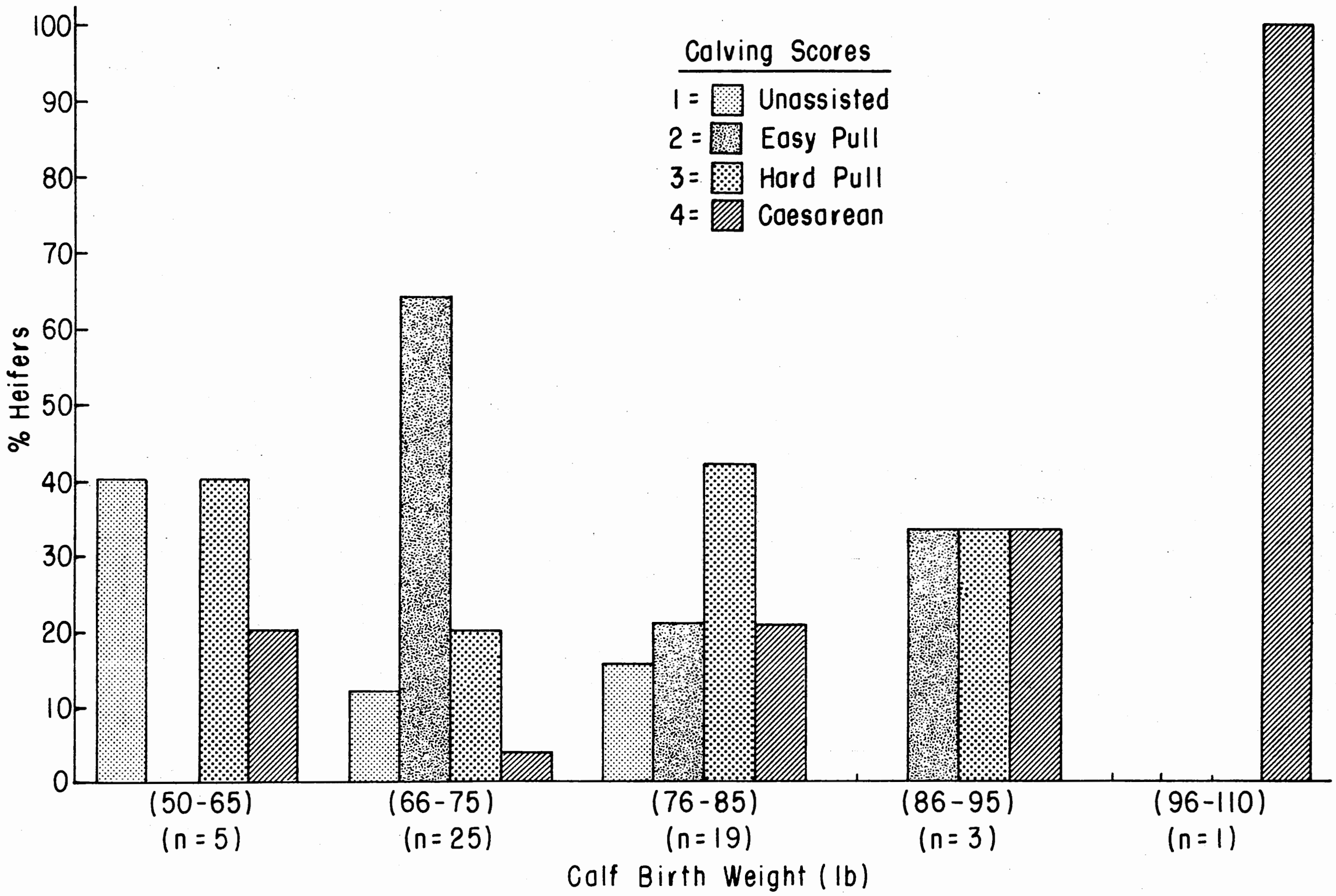

Figure 4. Percentage of Calving Difficulty of 1/2 Limousin Heifers with Small Pelvic Areas (121-164 sq cm) by Calf Birth Weight

TABLE XVIII

BIRTH WEIGHT BY CALVING DIFFICULTY SCORE FREQUENCY TABLE FOR 1/2 LIMOUSIN HEIFERS IN THE LOW INTERMEDIATE PELVIC AREA CATEGORY (165-186 sq cm)

Birth Weight Category (lb)	Calving Difficulty Score				Total n %
	1	2	3	4	
50-65					
n	25	5	1	0	31
% of Total	8.00	1.61	.32		9.93
% of Birth Wt. Category	83.33	16.67	3.33		
% of Calving Score	22.00	4.42	1.85		
66-75					
n	51	50	15	4	120
% of Total	16.40	16.08	4.82	1.29	38.59
% of Birth Wt. Category	42.50	41.67	12.50	3.33	
% of Calving Score	43.97	44.25	27.78	14.29	
76-85					
n	35	51	28	14	128
% of Total	11.25	16.40	9.00	4.50	41.16
% of Birth Wt. Category	27.34	39.84	21.88	10.94	
% of Calving Score	30.17	45.13	51.85	50.00	
86-95					
n	5	7	8	10	30
% of Total	1.61	2.25	2.57	3.22	9.65
% of Birth Wt. Category	16.67	23.33	26.67	33.33	
% of Calving Score	4.31	6.19	14.81	35.71	
96-110					
n	0	0	2	0	2
% of Total			.64		.64
% of Birth Wt. Category			100.00		
% of Calving Score			3.70		
Total					
n	116	113	54	28	311
%	37.30	36.33	17.36	9.00	100.0

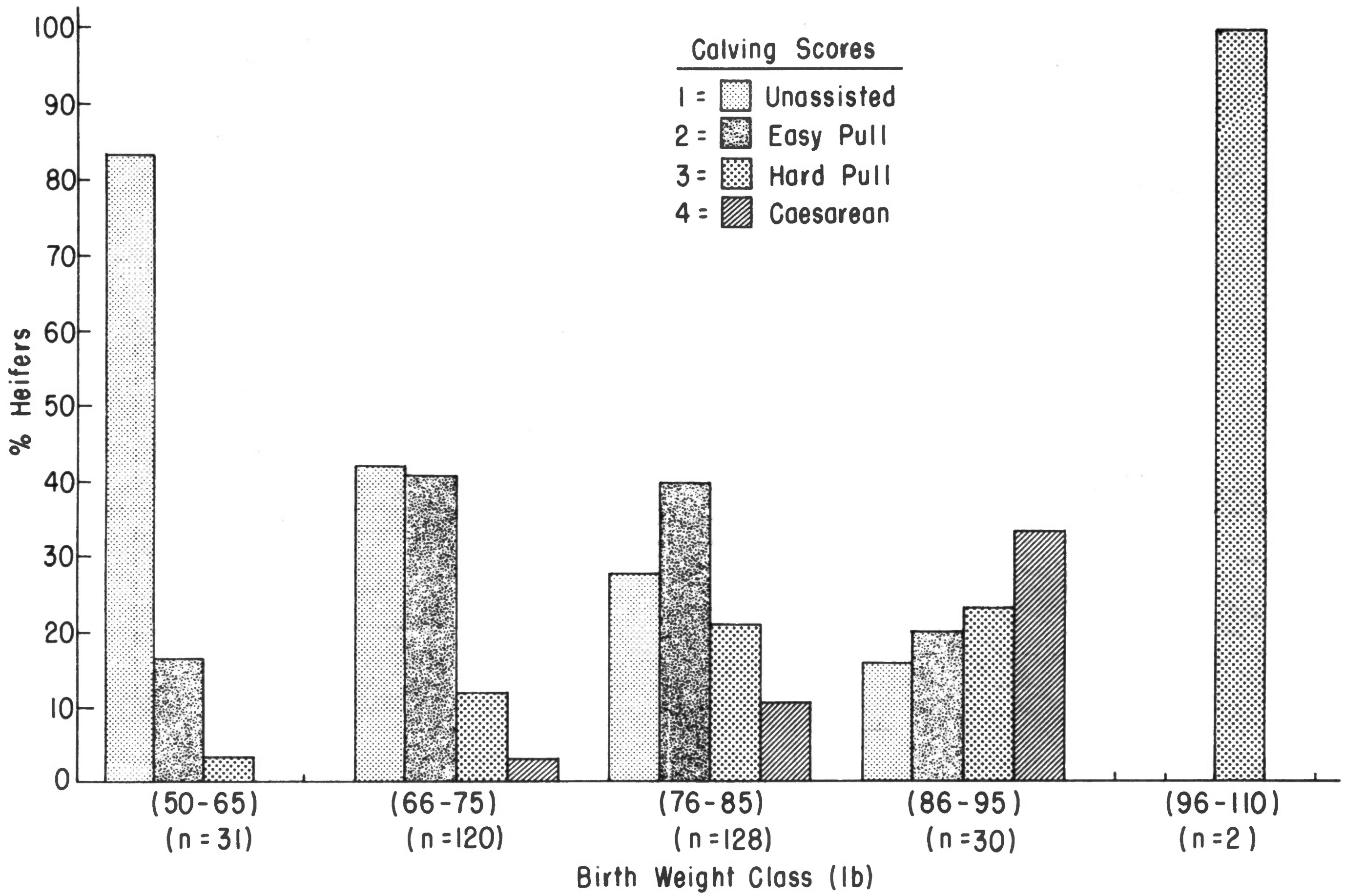

Figure 5. Percentage of Calving Difficulty of 1/2 Limousin Heifers with Low Intermediate Pelvic Areas (165-186 sq cm) by Calf Birth Weight

none required a caesarean. From this point, as calf birth weight increased the percent heifers that calved unassisted decreased and the percent heifers requiring major assistance or caesarean increased. Only 17% of the heifers that had calves weighing more than 85 lb calved unassisted and the percentage heifers with calves weighing from 86-95 lb requiring major assistance or caesarean climbed to 60 percent.

Half Limousin heifers with pelvic areas in the high intermediate range (187-207 sq cm) required little calving assistance when calves weighed less than 85 lb (Figure 6). When calves weighed from 86-95 lb, 38% of the heifers required more than slight assistance and all three heifers of this pelvic category that had calves weighing more than 95 lb required major assistance or caesarean.

Figure 7 represents half Limousin heifers with large pelvic areas (208-250 sq cm). Only five percent of the heifers in this category required major calving assistance when their calves weighed less than 95 lb and no major calving assistance was required for calves that weighed less than 75 lb. Three heifers with large pelvic areas had calves that weighed more than 96 lb and one required a caesarean.

Figures 3-6 indicate that half Limousin heifers that had calves weighing 65 lb or less required little assistance at calving regardless of pelvic size. Heifers with small pelvic areas (121-164 sq cm) had more calving difficulties than heifers with larger pelvic openings and had a high percentage of calving difficulties when calves weighed more than 65 lb. Heifers with intermediate pelvic areas of 165-207 sq cm seemed quite compatable with calves weighing up to 85 lb; however, only heifers with pelvises larger than 208 sq cm appeared capable of having a calf that weighed more than 85 lb with limited calving assistance.

TABLE XIX

BIRTH WEIGHT BY CALVING DIFFICULTY SCORE FREQUENCY TABLE FOR 1/2 LIMOUSIN HEIFERS IN THE HIGH INTERMEDIATE PELVIC AREA CATEGORY (187-207 sq cm)

Birth Weight Category (lb)	Calving Difficulty Score 1	2	3	4	Total n %
50-65					
n	19	1	1	0	21
% of Total	6.86	.36	.36		7.58
% of Birth Wt. Category	90.48	4.76	4.76		
% of Calving Score	13.97	.98	3.23		
66-75					
n	60	30	1	3	94
% of Total	21.66	10.83	.36	1.08	33.94
% of Birth Wt. Category	63.83	31.91	1.06	3.19	
% of Calving Score	44.12	29.41	3.23	37.50	
76-85					
n	51	53	14	2	120
% of Total	18.41	19.13	5.05	.72	43.32
% of Birth Wt. Category	42.50	44.17	11.67	1.67	
% of Calving Score	37.50	51.96	45.16	25.00	
86-95					
n	6	18	13	2	39
% of Total	2.17	6.50	4.69	.72	14.08
% of Birth Wt. Category	15.38	46.15	33.33	5.13	
% of Calving Score	4.41	17.65	41.94	25.00	
96-110					
n	0	0	2	1	3
% of Total			.72	.36	1.08
% of Birth Wt. Category			66.67	33.33	
% of Calving Score			6.45	12.50	
Total					
n	136	102	31	8	277
%	49.10	36.82	11.19	2.89	100.0

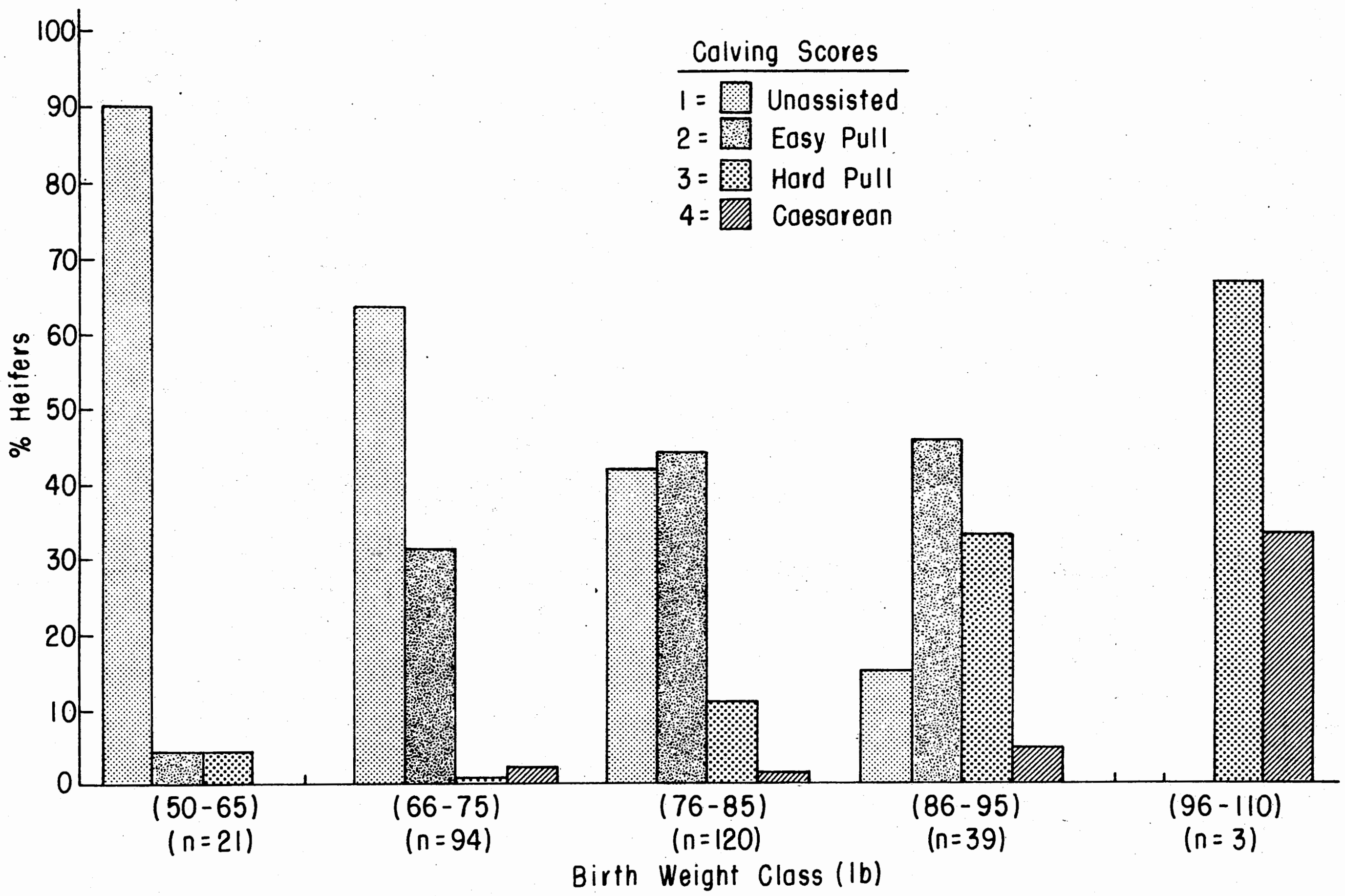

Figure 6. Percentage of Calving Difficulty of 1/2 Limousin Heifers with High Intermediate Pelvic Areas (187-207 sq cm) by Calf Birth Weight

TABLE XX

BIRTH WEIGHT BY CALVING DIFFICULTY SCORE FREQUENCY TABLE FOR 1/2 LIMOUSIN HEIFERS IN THE LARGE PELVIC AREA CATEGORY (208-250 sq cm)

Birth Weight Category (lb)	Calving Difficulty Score 1	2	3	4	Total n %
50-65					
n	3	0	0	0	3
% of Total	4.62				4.62
% of Birth Wt. Category	100.00				
% of Calving Score	6.67				
66-75					
n	12	1	0	0	13
% of Total	18.46	1.54			20.00
% of Birth Wt. Category	92.31	7.69			
% of Calving Score	26.67	6.25			
76-85					
n	27	8	2	0	37
% of Total	41.54	12.31	3.08		56.92
% of Birth Wt. Category	72.97	21.62	5.41		
% of Calving Score	60.00	50.00	66.67		
86-95					
n	3	5	1	0	9
% of Total	4.62	7.69	1.54		13.85
% of Birth Wt. Category	33.33	55.56	11.11		
% of Calving Score	6.67	31.25	33.33		
96-105					
n	0	2	0	1	3
% of Total		3.08		1.54	4.62
% of Birth Wt. Category		66.67		33.33	
% of Calving Score		12.50		100.00	
Total					
n	45	16	3	1	65
%	69.23	24.62	4.62	1.54	100.00

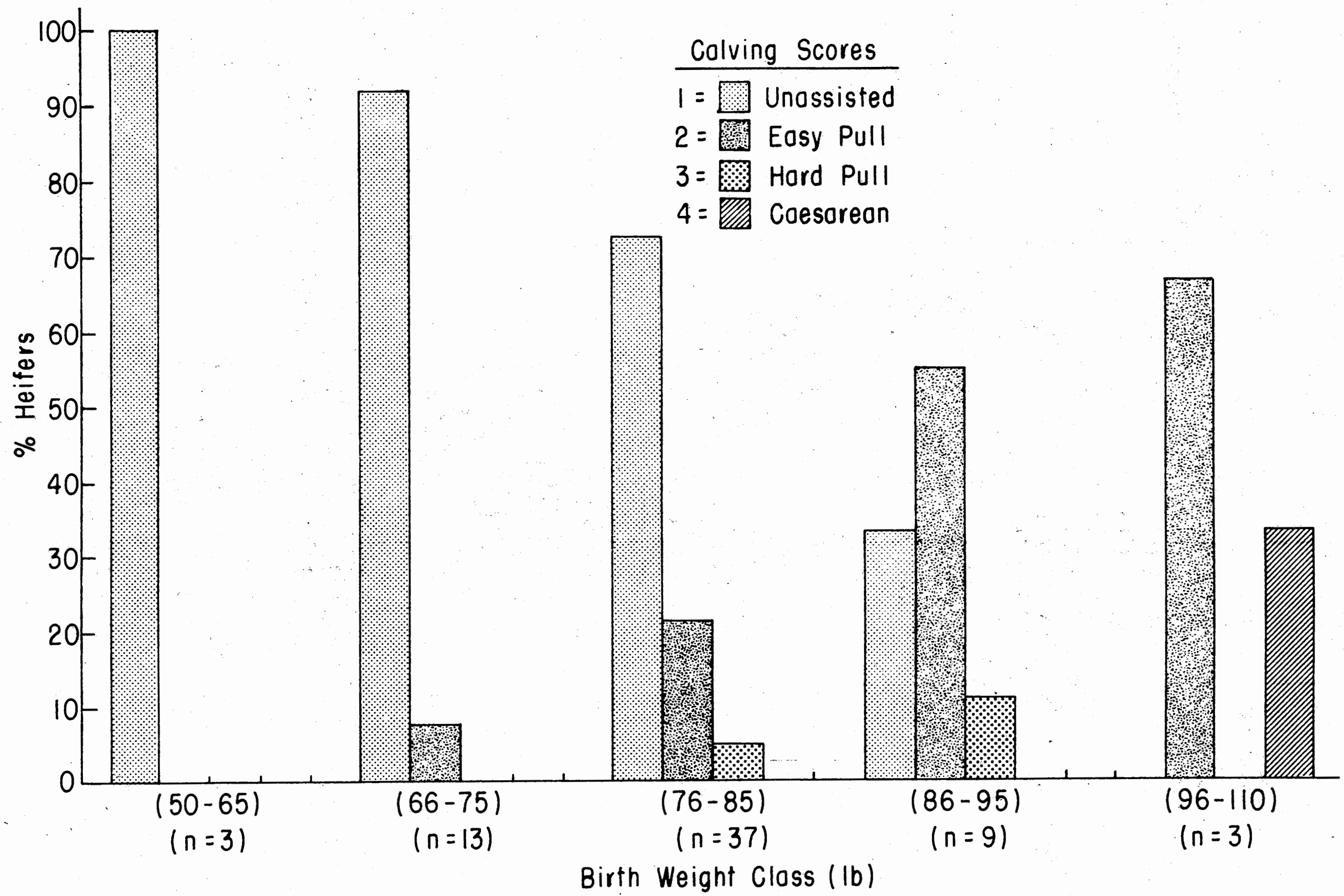

Figure 7. Percentage of Calving Difficulty of 1/2 Limousin Heifers with Large Pelvic Areas (208-250 sq cm) by Calf Birth Weight

Indications were that even heifers with large pelvises might encounter calving difficulty when giving birth to very large calves.

These data agree with other studies and in general indicate that heifers with small pelvic openings encountered more calving difficulty than heifers with large pelvic openings and pelvic size has a limiting effect on the size of calf a heifer can accomodate at calving. These data also suggest that 5-10% of the heifers produced will be of insufficient pelvic size to give birth to even an average size calf without some degree of calving assistance. Thus, it would appear that pelvic measurements taken on a heifer prior to breeding might be an effective management tool to identify those heifers with the highest risk of experiencing difficulty at calving. Removing these high risk heifers from the herd would reduce management problems and labor costs during the calving season as well as reduce capitol losses due to increased calf losses from dystocia births and poorer reproductive performance of heifers suffering calving difficulty. Multiple economic advantages could be realized by removing these heifers from the herd without critically reducing the number of heifers from which to select possible replacements. Pelvic measurements could also be utilized to selectively breed heifers that were suspect of calving difficulties to bulls known to sire smaller calves while heifers with large pelvic areas that were capable of having larger calves could be mated to larger more muscular bulls to maximize their productive output. Heifers could be grouped by pelvic size and more attention could be directed towards heifers that were suspected of calving problems.

Three-way frequency tables of adjusted pelvic area, calf birth weight and calving difficulty score were also generated for three-quarter Limousin heifers and are presented in Appendix Tables XXVII, XXVIII, XXIX and XXX. However, numbers of heifers calving within any given cross classification were to few to be indicative of real trends.

CHAPTER V

SUMMARY

The purpose of this study was to identify factors affecting calving difficulty and to determine the relationship of pre-breeding pelvic size to subsequent calving difficulty in percentage Limousin heifers calving at two years of age.

Records of pre-breeding pelvic measurements of 1,426 half and three-quarter Limousin heifers were obtained from a Colorado cattle ranch. Subsequent heifer calving performance was also available on 918 of these heifers. Half Limousin heifers were produced in the spring of 1972, 1973 and 1974 by mating Limousin bulls to primarily Hereford and Hereford x Angus cows and some Angus cows. Limousin bulls were mated to half Limousin heifers to produce three-quarter blood calves as two-year-olds and three-quarter Limousin heifers from these matings were, in turn, mated to produce seven-eighths Limousin calves at two years of age.

Heifers ran with their dams on pasture until weaning and following weaning were managed primarily on pasture with supplement to be of adequate size for breeding at 15 months of age. Averaged over all years heifers gained 1.52 pounds per day and had adjusted yearling weights of 684 pounds. Pelvic height and width measurements were taken each year just prior to the breeding season and all heifers entering the breeding season in a given year were measured the same day. Heif-

ers remained on pasture during gestation and at calving were closely observed by the herdsman and given a subjective calving score of 1-unassisted birth, 2-easy pull, 3-hard pull, 4-caesarean or pelvic split or 5-abnormal presentation.

Heifers ranged from 354 to 481 days of age at the time pelvic measurements were taken with a mean age of 412 days. Over all years, heifers' pelvic measurements averaged 14.20 cm, 12.09 cm and 170.65 sq cm for pelvic height, width and area, respectively. Factors found to significantly ($P<.05$) effect pelvic measurements were breed of dam, sire, birth year and age. However, when heifers were grouped by breed of heifer, breed of dam, sire and birth year only age had a significant influence on pelvic size. Thus, estimates of daily pelvic growth over the range in age of heifers were calculated as the partial regression coefficient of pelvic height, width and area on age and were used to adjust pelvic size to a standard age of 450 days. Daily growth estimates were .011 cm per day, .014 cm per day and .331 sq cm per day for pelvic height, width and area, respectively.

Simple correlations between adjusted pelvic measurements and heifer body weight and daily gain were highly significant ($P<.01$). Adjusted pelvic height and width had a low correlation of .16; however, adjusted pelvic height and width and adjusted pelvic area were highly correlated (.71 and .81, respectively). These correlations suggest pelvic height and width are highly related to pelvic area but basically independent of each other. There was a low correlation between a heifers pelvic size and her own birth weight, weaning weight or average daily gain from birth to weaning averaging approximately .26. Correlations between pelvic measurements and yearling weight were low for adjusted pelvic height (r=.22) but intermediate for adjusted pelvic width and area averaging .49, suggesting that larger heifers have larger pelvises and pelvic width and area are more highly related to heifer body weight than is pelvic height.

Factors found to significantly ($P<.01$) effect calving difficulty score were sire of calf, sex of calf, calf birth weight, heifers age at calving and pelvic size. None of the interactions were significant. Only 36.5% of the total variability in calving score was accounted for by all the variables. When analysis of calving score was performed utilizing only those variables that were available prior to a heifer calving (breed of heifer, sire of calf and pelvic size) only 18.2% of the variation in dystocia score was accounted for.

Correlations of calving difficulty score with calf birth weight and gestation length were highly significant ($P<.01$) at .39 and .20, respectively, indicating heifers with greater calving difficulty had heavier calves which were gestated longer. Correlations between calving difficulty score and adjusted pelvic measurements were also highly significant ranging from -.17 for adjusted pelvic height to -.27 for adjusted pelvic width and area suggesting that heifers with more dystocia tend to have smaller pelvises. The significant ($P<.01$) correlation of .39 between calving difficulty score and birth weight would suggest that calf size was the most important factor influencing calving performance of young heifers.

Male calves from half and three-quarter Limousin heifers were significantly ($P<.01$) heavier at birth than female calves (2.4 and 5.4 lb for half and three-quarter heifers, respectively) and resulted in 18% to 28% more calving difficulty. Male calves also tended to be gestated longer. Overall, calves from half Limousin heifers that calved unassisted were 6.8 lb lighter at birth than calves from heifers requiring assistance and calf birth weights increased by 4.4, 3.0 and 1.4 lb for each increment increase in calving difficulty score from one to four ($P<.01$). Calves from three-quarter heifers that calved unassisted were 6.5 lb lighter than calves from heifers requiring assistance; however, birth weight differences between calving scores were not consistent. Gestation length also increased as calving difficulty score increased. Calves born unassisted from half blood heifers had, on the average, a 2.2 day shorter gestation than calves requiring major assistance or caesarean. Differences in gestation length between calving difficulty scores were not consistent in three-quarter heifers.

Pelvic measurements of half and three-quarter Limousin heifers that calved unassisted were larger than pelvic dimensions of heifers experiencing calving difficulty and heifers that had difficulty at calving were younger. Half Limousin heifers that calved unassisted had pelvic areas 5.65 sq cm larger than heifers requiring slight assistance ($P<.01$). Heifers requiring minor assistance had significantly ($P<.01$) larger pelvic areas than those requiring major assistance (5.2 sq cm) and the difference in pelvic area of heifers requiring major assistance or caesarean was 5.1 sq cm ($P<.05$). The difference in pelvic areas of three-quarter Limousin heifers that required no assistance, slight assistance or major assistance was not significant averaging only 3.26 sq cm.

Heifers were placed into categories based on adjusted pelvic area. Pelvic area categories were: small = 121-164 sq cm, low intermediate = 165-186 sq cm, high intermediate = 187-207 sq cm and large = 208-250 sq cm. Only 15% of the half Limousin heifers with small pelvises calved unassisted compared to 37% of the heifers in the low intermediate category, 49% in the high intermediate category and 69% in the large pelvic area category. Only 7.5% of all the heifers had pelvic areas in the small category and 85% of those required calving assistance. Thus, these data would suggest that culling 5-10% of all heifers based on pelvic size would remove a high percentage of the heifers with the highest probability of having calving difficulty even though factors known prior to calving did not account for a large portion of the variation in calving difficulty score. The same general trends were seen in three-quarter Limousin heifers; however, the number of heifers in each pelvic area category was small and differences were not as apparent.

Heifers were also grouped by birth weight of their calves to examine the interrelationship of pelvic size, birth weight and calving difficulty. In general, heifers that had calves weighing 65 lb or less required little assistance at calving regardless of pelvic size. Hiefers with small pelvic areas required a high percentage of assistance when calves weighed more than 65 lb and no heifer having a calf larger than 85 lb calved unassisted. Heifers with intermediate pelvic areas seemed compatable with calves weighing up to 85 pounds. Only heifers with pelvises in the large category appeared capable of having a calf that weighed more than 85 lb with limited calving assistance. Implications were that pelvic measurements could be used as a management tool to effectively aid in reducing calving problems by either culling heifers with small pelvises from the herd or mating them to bulls that are expected to sire calves with light birth weights.

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A P P E N D I X

TABLE XXI

MEAN SQUARES AND PARTIAL REGRESSION COEFFICIENTS OF PELVIC SIZE ON AGE FOR INDIVIDUAL SIRES FROM MULTIPLE REGRESSION ANALYSIS

			Mean Square			Partial Regression Coefficients		
Sire	df	No. Observations	Pelvic Height	Pelvic Width	Pelvic Area	Pelvic Height	Pelvic Width	Pelvic Area
All Sires	7	1330	2.411*	4.855*	1409.500*	.012* ± .001	.013* ± .001	.334* ± .022
1	1	419	25.852*	56.193*	28133.200*	.012* ± .002	.018* ± .002	.397* ± .037
2	1	139	29.698*	.550	5977.761*	.017* ± .002	.002 ± .002	.245* ± .049
3	1	185	7.174*	36.595*	14145.736*	.014* ± .004	.032* ± .004	.627* ± .082
4	1	335	24.698*	30.322*	18219.147*	.014* ± .002	.015* ± .002	.367* ± .042
5	1	6	2.723*	.046	246.431	-.079** ± .036	.010 ± .035	-.755 ± .746
6	1	3	.787	.251	8.039	-.205 ± .174	.116 ± .169	-.656 ± 3.59
7	1	222	.123	.984	325.375	.001 ± .003	.004 ± .003	.072 ± .062
8	1	21	.147	.006	9.313	.012 ± .023	-.002 ± .022	.092 ± .467
Residual	1316		.566	.536	240.899			

** Significant $P<.01$
* Significant $P<.05$

TABLE XXII

MEAN SQUARES FROM ANALYSIS OF VARIANCE OF CALVING DIFFICULTY SCORE - BREED OF HEIFER BY SEX OF FIRST CALF AND BREED OF HEIFER BY SIRE INTERACTIONS INCLUDED

Source	df	Mean Square	
BOH	1	.829	
SEXFC	1	8.303**	
SIRE	7	.654	
SIREFC	5	1.864**	
BWFC	1	62.870**	
GLFC	1	1.304	
ADJHT	1	1.683+	
ADJWD	1	1.777+	
ADJA	1	.930	
AAFC	1	11.740**	
BOH*SEXFC	1	1.359	
BOH*SIRE	2	.101	
Residual	774	.515	$R^2 = .357$

** Significant $P < .01$

+ Approached significance $P < .10$

TABLE XXIII

FREQUENCY TABLE OF PELVIC HEIGHT OF 1/2 LIMOUSIN HEIFERS BY CALVING DIFFICULTY SCORE AND HEIGHT CATEGORIES

Height Category (cm)	Calving Difficulty Score 1	2	3	4	Total n %
12.2-13.9					
n	89	75	42	25	231
% of Total	12.61	10.62	.95	3.54	32.72
% of Height Category	38.53	32.47	18.18	10.82	
% of Calving Score	29.18	29.76	40.38	55.56	
14.0-15.6					
n	208	172	62	20	462
% of Total	29.46	24.36	8.78	2.83	65.44
% of Height Category	45.02	37.23	13.42	4.33	
% of Calving Score	68.20	68.25	59.62	44.44	
15.7-17.3					
n	8	5	0	0	13
% of Total	1.13	.71			1.84
% of Height Category	61.54	38.46			
% of Calving Score	2.62	1.98			
Total					
n	305	252	104	45	706
%	43.20	35.69	14.73	6.37	100.0

TABLE XXIV

FREQUENCY TABLE OF PELVIC WIDTH OF 1/2 LIMOUSIN HEIFERS BY CALVING DIFFICULTY SCORE AND WIDTH CATEGORIES

Width Category (cm)	Calving Difficulty Score 1	2	3	4	Total n %
8.4-10.7					
n	3	11	6	5	25
% of Total	.42	1.56	.85	.71	3.54
% of Width Category	12.00	44.00	24.00	20.00	
% of Calving Score	.98	4.37	5.77	11.11	
10.8-13.0					
n	243	213	90	38	584
% of Total	34.42	30.17	12.75	5.38	82.72
% of Width Category	41.61	36.47	15.41	6.51	
% of Calving Score	79.67	84.52	86.54	84.44	
13.1-15.3					
n	59	28	8	2	97
% of Total	8.36	3.97	1.13	.28	13.74
% of Width Category	60.82	28.87	8.25	2.06	
% of Calving Score	19.34	11.11	7.69	4.44	
Total					
n	305	252	104	45	706
%	43.20	35.69	14.73	6.37	100.0

TABLE XXV

FREQUENCY TABLE OF PELVIC HEIGHT OF 3/4 LIMOUSIN HEIFERS BY CALVING DIFFICULTY SCORE AND HEIGHT CATEGORIES

Height Category (cm)	Calving Difficulty Score 1	2	3	4	Total n %
12.2-13.9					
n	19	10	4	0	33
% of Total	16.96	8.93	3.57		29.46
% of Height Category	57.58	30.30	12.12		
% of Calving Score	27.14	31.25	40.00		
14.0-15.6					
n	51	20	6	0	77
% of Total	45.54	17.86	5.36		68.75
% of Height Category	66.23	25.97	7.79		
% of Calving Score	72.86	62.50	60.00		
15.7-17.3					
n	0	2	0	0	2
% of Total		1.79			1.79
% of Height Category		100.00			
% of Calving Score		6.25			
Total					
n	70	32	10	0	112
%	62.50	28.57	8.93		100.0

TABLE XXVI

FREQUENCY TABLE OF PELVIC WIDTH OF 3/4 LIMOUSIN HEIFERS BY CALVING DIFFICULTY SCORE AND WIDTH CATEGORIES

Width Category (cm)	Calving Difficulty Score 1	2	3	4	Total n %
8.4-10.7					
n	0	0	0	0	0
10.8-13.0					
n	66	31	10	0	107
% of Total	58.93	27.68	8.93		95.54
% of Width Category	61.68	28.97	9.35		
% of Calving Score	94.29	96.88	100.00		
13.1-15.3					
n	4	1	0	0	5
% of Total	3.57	.89			4.46
% of Width Category	80.00	20.00			
% of Calving Score	5.71	3.13			
Total					
n	70	32	10	0	112
%	62.50	28.57	8.93		100.0

TABLE XXVII

BIRTH WEIGHT BY CALVING DIFFICULTY SCORE FREQUENCY TABLE FOR 3/4 LIMOUSIN HEIFERS IN THE SMALL PELVIC AREA CATEGORY (121-164 sq cm)

Birth Weight Category (lb)	Calving Difficulty Score				Total
	1	2	3	4	n %
50-65					
n	0	1	0	0	1
% of Total		25.00			25.00
% of Birth Wt. Category		100.00			
% of Calving Score		50.00			
66-75					
n	2	1	0	0	3
% of Total	50.00	25.00			75.00
% of Birth Wt. Category	66.67	33.33			
% of Calving Score	100.00	50.00			
76-85					
n	0	0	0	0	0
86-95					
n	0	0	0	0	0
96-110					
n	0	0	0	0	0
Total					
n	2	2	0	0	4
%	50.00	50.00			100.0

TABLE XXVIII

BIRTH WEIGHT BY CALVING DIFFICULTY SCORE FREQUENCY TABLE FOR 3/4 LIMOUSIN HEIFERS IN THE LOW INTERMEDIATE PELVIC AREA CATEGORY (165-186 sq cm)

Birth Weight Category (lb)	Calving Difficulty Score				Total n %
	1	2	3	4	
50-65					
n	21	5	0	0	26
% of Total	33.87	8.06			41.93
% of Birth Wt. Category	80.77	19.23			
% of Calving Score	60.00	27.78			
66-75					
n	13	10	4	0	27
% of Total	20.97	16.13	6.45		43.55
% of Birth Wt. Category	48.15	37.04	14.81		
% of Calving Score	37.14	55.56	44.44		
76-85					
n	1	3	5	0	9
% of Total	1.61	4.84	8.06		14.52
% of Birth Wt. Category	11.11	33.33	55.56		
% of Calving Score	2.86	16.67	55.56		
86-95					
n	0	0	0	0	0
96-110					
n	0	0	0	0	0
Total					
n	35	18	9	0	62
%	56.45	29.03	14.52		100.0

TABLE XXIX

BIRTH WEIGHT BY CALVING DIFFICULTY SCORE FREQUENCY TABLE FOR 3/4 LIMOUSIN HEIFERS IN THE HIGH INTERMEDIATE PELVIC AREA CATEGORY (187-207 sq cm)

Birth Weight Category (lb)	Calving Difficulty Score 1	2	3	4	Total n %
50-65					
n	15	1	0	0	16
% of Total	37.50	2.50			40.00
% of Birth Wt. Category	93.75	6.25			
% of Calving Score	51.72	10.00			
66-75					
n	12	6	0	0	18
% of Total	30.00	15.00			45.00
% of Birth Wt. Category	66.67	33.33			
% of Calving Score	41.38	60.00			
76-85					
n	2	2	0	0	4
% of Total	5.00	5.00			10.00
% of Birth Wt. Category	50.00	50.00			
% of Calving Score	6.90	20.00			
86-95					
n	0	1	1	0	2
% of Total		2.50	2.50		5.00
% of Birth Wt. Category		50.00	50.00		
% of Calving Score		10.00	100.00		
96-110					
n	0	0	0	0	0
Total					
n	29	10	1	0	40
%	72.50	25.00	2.50		100.0

TABLE XXX

BIRTH WEIGHT BY CALVING DIFFICULTY SCORE FREQUENCY TABLE FOR 3/4 LIMOUSIN HEIFERS IN THE LARGE PELVIC AREA CATEGORY (208-250 sq cm)

Birth Weight Category (lb)	Calving Difficulty Score				Total n %
	1	2	3	4	
50-65					
n	1	0	0	0	1
% of Total	16.67				16.67
% of Birth Wt. Category	100.00				
% of Calving Score	25.0				
66-75					
n	1	1	0	0	2
% of Total	16.67	16.67			33.33
% of Birth Wt. Category	50.00	50.00			
% of Calving Score	25.00	50.00			
76-85					
n	1	0	0	0	1
% of Total	16.67				16.67
% of Birth Wt. Category	100.00				
% of Calving Score	25.00				
86-95					
n	1	1	0	0	2
% of Total	16.67	16.67			33.33
% of Birth Wt. Category	50.00	50.00			
% of Calving Score	25.00	50.00			
96-110					
n	0	0	0	0	0
Total					
n	4	2	0	0	6
%	66.67	33.33			100.0

VITA[2]

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Master of Science

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