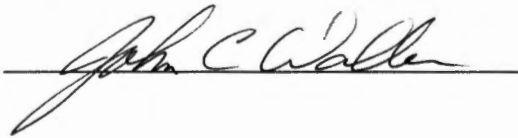


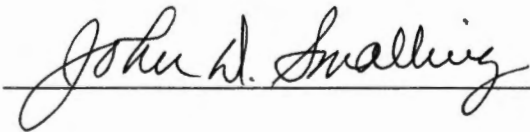
To the Graduate Council:

I am submitting herewith a thesis written by Kevin W. Thompson entitled "Pelvic Area as a Tool for Selection of Beef Replacement Heifers." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.


F. Neal Schrick, Major Professor

We have read this thesis
and recommend its acceptance:





Accepted for the Council:


Associate Vice Chancellor and
Dean of The Graduate School

**PELVIC AREA AS A TOOL FOR SELECTION OF
BEEF REPLACEMENT HEIFERS**

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Kevin W. Thompson

December 1996

~~AD-VET-MED.~~

Thesis

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ABSTRACT

The objective of this study was to examine the usefulness of pelvimetry in the selection of first-calf heifers to reduce the incidence of dystocia. Data from 345 Angus (AN) and 112 Polled Hereford (PH) heifers born during the years 1987-1991 and their subsequent calving records were utilized within this analysis. Preselection of heifers was based upon weaning weight (Angus, 246 kg and Polled Hereford, 243 kg). Prebreeding measures included: weaning weight, weaning hip height, yearling weight, yearling hip height, yearling pelvic area (categorization: smallest 25%, intermediate 50% and largest 25%), and frame score. Postbreeding measures included: precalving weight, precalving hip height and precalving pelvic area (smallest 25%, intermediate and largest 25%). A dystocia score was assigned to each birth of 328 AN and 104 PH calves (1 = no assistance, 2 = hand pull, 3 = mechanical assistance and 4 = caesarean). In addition, calf birth weight, sex of calf and date of birth were recorded for each calving. Data analyzed within the statistical (single group) model indicated that calf birth weight was the most important variable associated with dystocia score for both AN and PH heifers (20 and 21%, respectively, of the variation in dystocia). Yearling pelvic height and width accounted for 11% and yearling pelvic area for only 8% of the variation in dystocia score within the AN heifers. However, within the PH heifers, 21% of the variation in dystocia was explained by yearling pelvic height and width. Analysis of the AN data set within the prediction model indicated sire birth weight EPD, dam birth weight, weaning hip height and yearling hip height as the most significant discriminating variables within the

categorization of dystocia (1, 2 or 4). Though these four variables were highly significant ($P < .05$), the Average Canonical Square Correlations (ACSC) per variable only ranged from 0.048 to 0.099. Cross validation was utilized in testing the models predictive ability and resulted in an average error rate of 58%. Sire birth weight EPD was the only significant variable identified within the PH data set (ASCCof .04). Sire birth weight EPD, dam birth weight, weaning hip height and yearling hip height were utilized within the cross validation procedure for the PH heifers and attained an average error rate of 79%. In conclusion, results of the statistical model indicated that nonpelvic size measures can be useful in explaining the variation in dystocia without the use of yearling pelvic measurements. However, yearling pelvic measures within the PH heifers did account for significantly larger amounts of variation than models including only nonpelvic measures. In addition, predictive analysis of the data set indicated that nonpelvic size measures were more useful than yearling pelvic height, width and area. Consequently, variables included in these data sets were unable to accurately predict and classify heifers within a dystocia level.

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1. INTRODUCTION

Profitable production of beef cattle requires that the broadest and most important facet of the industry be carried out with maximum efficiency and minimal setbacks. This facet is known as maternal function or reproduction. Efficient production within the industry is obtained where heifers are expected to produce their first calf at two years of age and rebreed within the 85-day postpartum period. Furthermore, these first-calf cows must maintain an increasing growth curve while requiring energy inputs for both growth and lactation. The importance of reproduction for the beef cattle industry in relative economic values is ten times as crucial as production (weaning and yearling performance) and twenty times as valuable as the end product (carcass quality; Willham, 1973).

Dystocia is defined as a difficult or abnormal parturition. The major cause of dystocia is a disproportion between the pelvic size of the dam and the size of the fetus (Bellows, 1984). Feto-Pelvic Incompatibility (FPI) as termed by Meirjering (1984) describes the contrast between disproportionate fetus versus dam pelvis, dam pelvis versus fetus or equal mismatches of both fetus and pelvic inlet. To a lesser extent, dystocia is also caused by the failure of the fetus to attain normal positioning at time of parturition. The percent incidences of malpresentation resulting in dystocia have been reported to range between 4.1% (Basarab et al., 1993) to less than 1% (Peltz et al., 1997). Therefore, malpresentations are of small relevance to the total incidences of dystocia. However, Bellows et al. (1987) reported 62% of calf mortalities because of abnormal presentations were associated with either breech or backward presentations.

The effect of dystocia on subsequent reproductive performance has been well

documented and implicated in reduction of net calf crop. The reduction in net calf crop results from direct effects of neonatal and postnatal calf loss (Patterson et al., 1987) and subsequent reduced pregnancy rates of dams which experienced calving difficulty. In a study involving 893 calf losses, nearly 80% of those calves dying within one to three days of parturition were either directly or indirectly related to dystocia (Bellows, 1984). As reviewed by Meirjering (1984), 40 to 60% of stillbirth cases can be attributed to dystocia. Furthermore, culling rates of cows experiencing dystocia increased by 2 to 30% because of factors such as calving lesions, depressed fertility, decreased milk yields and concerns of repeated calving problems.

2. REVIEW OF THE LITERATURE

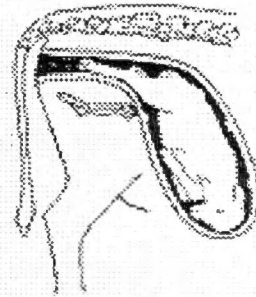
Stages of Parturition in Cattle

The birth process has been segmented into three stages (length of occurrence): Stage 1 (two to six hours), Stage 2 (30 minutes to two hours) and Stage 3 (four to five hours; Taylor, 1994). Prior to Stage 1 of parturition, the fetus rotates into the birth position. Normal birth position occurs with the calf positioned upright with the forelimbs directed toward the cervical end of the uterus and the head resting on and between the forelimbs (Figure 1). Parturition will proceed more easily with normal fetal positioning; however, approximately 5% of all parturitions experience some deviation from normal positioning (Taylor, 1994). With these deviations, assistance is required in repositioning of the fetus before parturition can continue. Impeded parturition as a result of malpresentation ranges from the fetus having one forelimb back to varying degrees of breech positioning (Figure 1).

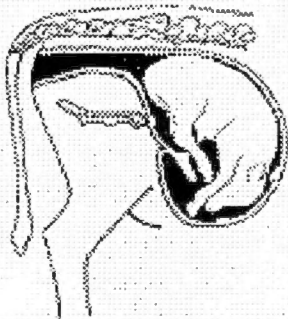
With the dam in good physical and nutritional health, the fetus in normal birth position and given compatibility between the pelvis of the dam and the size of the fetus, the following stages of parturition should occur unassisted: Stage 1 of parturition begins with the dilation of the cervix and is completed when the cervix is fully dilated and the fetus has entered into the cervix as a result of uterine contractions; Stage 2 of parturition involves uterine contractions of increasing strength and frequency until expulsion of the fetus; Stage 3 of parturition is initiated after the birth of the calf and concludes with the expulsion of the placenta.



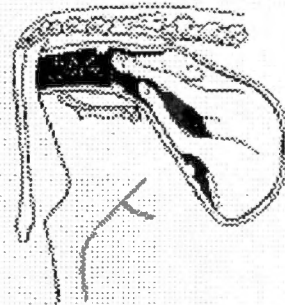
Normal Presentation



Posterior Presentation



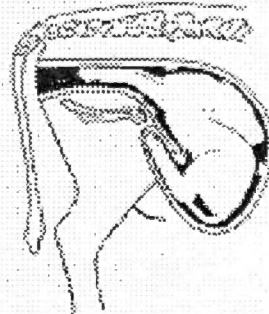
Posterior position with rear legs extending under the calf



Anterior position with the rear legs extended beneath the body



Posterior presentation with fetus in an upside down position



Anterior position with the head and neck turned back over the body

Figure 1. Various calf positions during parturition (Taylor, 1994).

Dystocia vs. Production

Of factors attributing directly to calf loss, dystocia ranked highest at 60.2% (373 deaths out of 620 recorded postnatal calf deaths; Bellows et al., 1987). Within the dystocia complex, 83.7% of the deaths resulted from delayed/difficult parturition. The remaining factors were intrauterine umbilical hemorrhage (8%), brain damage (2.4%), placental fluid-filled trachea (2.4%), technician error (2.1%), heart-lung injuries (0.5%), intestinal rupture (0.3%) and skull fracture (0.3%) (Bellows et al., 1987). A reduction in efficiency of dams experiencing calving difficulty is expressed in reduced milk production, failure to rebreed or delayed breeding, increased management, veterinary assistance and increased cost of cow maintenance (Laster et al., 1973; Bellows et al., 1987; Andersen et al., 1993). In 722 cows and heifers which had experienced calf loss from the previous pregnancy experienced an 8.3% reduction in a conception rate compared to a contemporary group which had not experienced calf loss during their previous pregnancy (Patterson et al., 1987). Two- and three-year old first-calf heifers experienced a 7.0% lower conception rate following calving difficulty versus their contemporary group.

Calf loss resulting from calving difficulties has a major economic impact on the net calf crop directly through calf deaths and indirectly through reduced pregnancy rates (Patterson et al., 1987). Their study involving 13,296 calves over a fifteen year period indicated that 50% of all calf mortality resulted from dystocia and was the single highest category of death loss. Brinks et al. (1973) concluded from 2971 calving records over a sixteen year period that only 59% of the calves born to 2-year old heifers, which experienced calving difficulty, were weaned compared to 70% of calves from dams

experiencing no calving stress during parturition. During the subsequent year, heifers that experienced dystocia as 2-year olds weaned 21 kg less calf and had 14% less net calf crop than heifers experiencing no calving difficulties. Furthermore, calving interval of first-calf heifers experiencing dystocia was increased thirteen days over that of heifers which had no calving difficulties.

Laster et al. (1973) reported only 59% of the heifers which experienced calving difficulty exhibited estrous behavior during a 45-day breeding period, with 50.6% of these heifers establishing pregnancy. In contrast, cattle not experiencing dystocia had an observed estrus of 74.3% and a 68.2% pregnancy rate. Cows experiencing dystocia calved almost six days later than those not experiencing stressful parturition and the increase in calving intervals was strongly related to a longer postpartum interval following dystocia.

Predictability of Dystocia

Pelvic Dimension as a Predictor

Meirjering (1984) stated that Feto-Pelvic Incompatibility (FPI) was the number one cause of dystocia in cattle. Logically, several studies have explored the practicality of pelvimetry as a tool in predicting and reducing the incidence of dystocia in replacement heifers.

Before proceeding further into the use of pelvimetry as a tool for heifer selection, the anatomical boundaries and mechanics of attaining pelvic dimensions will be discussed.

Anatomical Boundaries

As reviewed by Meirjering (1984), measures of pelvic dimensions can be taken

with moderate accuracy and repeatability. Measurements for pelvic area are calculated from a measure of pelvic height and width taken in centimeters. The two measures are then multiplied to give the area in square centimeters. Pelvic height is attained by assessing the perpendicular distance from the cranial end of the symphysis pubis to the ventral surface of the midsacrum (Figure 2). Pelvic width is a measure of the largest distance between the shafts of the ilia (Figure 2; Meirjering, 1984). In other words, pelvic height is the vertical distance between the pubis symphysis and the sacral vertebrae and pelvic width is the horizontal distance between the shafts of the ilia at the widest point (Donkersgoed et al., 1990).

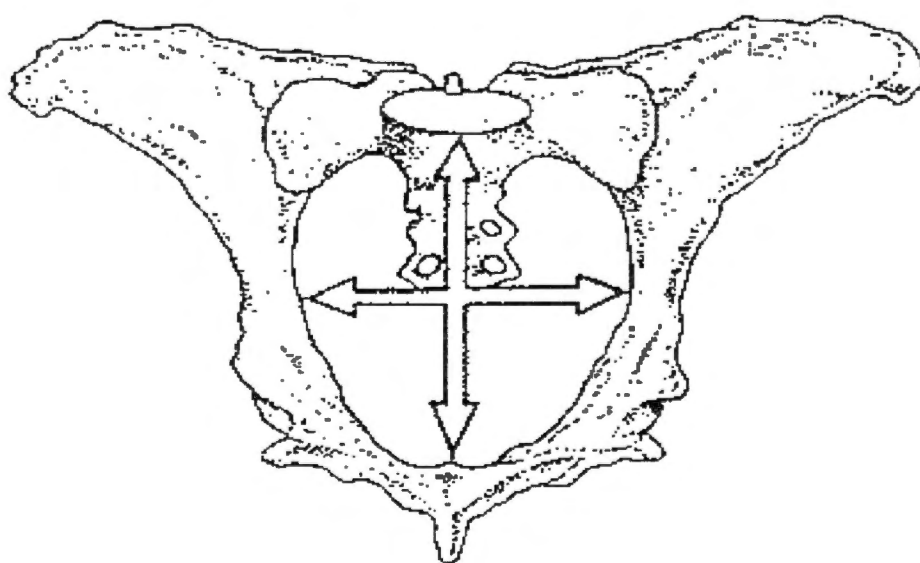


Figure 2. Anatomical diagram of the bovine pelvis (Deutscher, 1989).

Mechanics of Pelvimetry

Currently, two instruments are available to obtain dimensions of the pelvic inlet. Both devices are designed for rectal use and guidance via a technician. The Rice Pelvimeter is of cast aluminum construction and uses a sliding caliper action for measurement of horizontal and vertical dimensions (Figure 3). The Krautman-Litton Bovine Pelvic Meter uses hydraulic action to operate a calibrated cylinder to determine the appropriate measures of dimension (Figure 4). With use of either instrument, accuracy and repeatability to any degree can only be obtained through practice/experience and familiarity with both the instrument and the anatomical structure of the bovine pelvis (Deutscher, 1988).

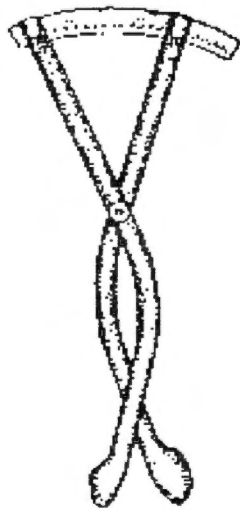


Figure 3. Rice Pelvimeter
(Deutscher, 1988)

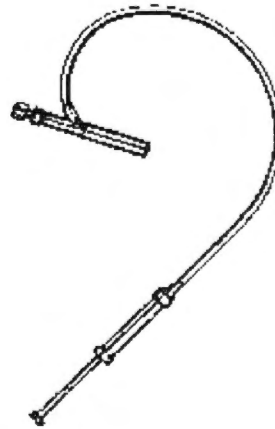


Figure 4. Krautman-Litton Pelvimeter
(Deutscher, 1988)

Pros and Cons of Pelvimetry as a Selection Tool

The need for a practical, predictive measure of dystocia in first parity heifers is well justified because of neonatal mortality, postnatal calf weakness and death loss, decreased performance, lower pregnancy rates, increased calving intervals and increased attrition (Meirjering, 1984; Bellows et al., 1987; Patterson et al., 1987). The subject of pelvimetry has received widespread attention as a possible tool for replacement heifer selection. This subject has resulted in considerable contrasts in research results and conclusions.

Utilizing a computer simulated model to examine the effects of selection of heifers based on yearling pelvic area, sire birth weight expected progeny differences (EPD), their resulting effect on predicting dystocia scores and frequency of dystocia, Cook et al. (1993) reported that a 1 kg decrease in sire birth weight EPD would affect dystocia scores by a 0.12 unit decrease and a four percent reduction in dystocia frequency. With every 10% increase in a yearling pelvic area, only 0.02 units decrease in dystocia score was observed. Cook et al. (1993) concluded that selection based upon sire birth weight EPD was a more effective means of reducing the incidence and frequency of dystocia than measurement of yearling pelvic area.

In a study on approximately one thousand first-calf heifers, Price and Wiltbank (1978b) evaluated the relationship of heifer size, calf size and sire on dystocia. With pelvic area taken at postbreeding, midgestation and two week prior to calving, heifers with 210 cm or larger pelvic areas had only 15% incidence of dystocia, while heifers with 170 cm or smaller pelvic areas had an 81% occurrence of dystocia with similar sized calves.

Furthermore, heifers with smaller pelvic areas had a high frequency of dystocia independent of calf size; whereas, heifers having very large calves even with a large pelvic area had a high rate of dystocia. The authors concluded, that in order to accurately predict dystocia in first-calf heifers, calf size must be predictable. Finally, pelvic area along with heifer weight, calf sire, and breed of calf were only able to account for 24% of the variation in calf birth weight.

Donkersgoed et al. (1990) used 197 two-year old heifers in examining the effect of pelvic area measurements on predictability of calving difficulty. Pelvic area measures were taken prior to both the breeding and calving seasons. Association among pelvic area measurements, calf birth weight and calving difficulty resulted in only 19 to 34% sensitivity. Therefore, pelvic area measurements before the breeding and/or calving seasons were determined to be poor indicators of dystocia in first-calf heifers. Furthermore, only five percent of the explained variation in dystocia was predicted by yearling pelvic height.

Johnson et al. (1988) indicated that a reduction in birth weight and increase in pelvic area appear to be the most effective method of reducing incidences of dystocia. Naazie et al. (1989) observed pelvic measurements alone would not influence dystocia scores. However, smaller pelvic dimensions were associated with higher dystocia scores.

Donkersgoed et al. (1993) examined pelvic dimension, pelvic area/birth weight ratios and pelvic area/heifer weight ratios and their ability to accurately predict dystocia in first calf heifers. In examination of 256 heifers with pelvic area measured via two experienced technicians, Donkersgoed et al. (1993) observed the three selection measures

to be of poor predictive value. Data emphasized technicians precision of the measurements were low to moderate between technicians. Factors implicated in the imprecision between the two technicians were different technical knowledge, difficulty in restraining some heifers, factors resulting in fatigue of the technician (fecal material in rectum, rectal straining and multiple animals) and imprecise structural landmarks. Another explanation of the low to moderate predictive value of pelvimetry was variation in the growth pattern between the measures of prebreeding and calving pelvic areas (Donkersgoed et al., 1993).

Effect of Calf Birth Weight

In a vast majority of the studies exploring dystocia, calf birth weight is often implicated as the most important factor associated with difficult parturitions in first-calf heifers and even in multiparous females. Accepted heritabilities in beef cattle for birth weight range from 0.4 to 0.45 (as reviewed by Holland and Odde, 1992). As reviewed by Price and Wiltbank (1978a), birth weight is influenced by sex of the calf, dam's gestation period, breed, sire, heterosis, inbreeding and genotype. Of all factors reviewed, size of calf and dam pelvic area are the major causes of dystocia.

The phenotypic correlation between birth weight and dystocia has been commonly reported from 0.3 to 0.4 (Burfening, 1991). A genetic correlation as high as .9 has been reported between calving difficulty and the calf's birth weight for first-calf heifers.

Naazie et al. (1989) examined the relevance of body weight measures of the calf, sire, dam, pelvic measures, body condition scores and calving dates on dystocia in first-calf heifers. The incidences of abnormal or difficult calvings were 31.1%. Calf's weight at

birth possessed the strongest correlation to calving difficulty. Bellows et al. (1996) also observed birth weight of calf to be correlated to calving difficulty. Furthermore, Peltz et al. (1997) reported that calf birth weight and dam's parity had the highest degree of influence upon the occurrence of dystocia in examination of 2191 calvings over an eleven year period.

Price and Wiltbank (1978b) examined the factors of dam size, calf size, sire influence on calf structure and their relationships to dystocia to develop a method of predicting dystocia in first-calf heifers. Birth weight and body length ratios of the calf were highly correlated to dystocia in the crossbred and Angus heifers, while birth weight was the single most influencing trait correlated with dystocia in Charolais dams. Therefore, calf size needs to be a predictable trait in order to make any inferences on the frequency or degree of dystocia in first-calf heifers.

Johnson et al. (1988) observed that precalving pelvic area and calf birth weight had the highest correlated variables to dystocia. However, precalving pelvic dimensions were taken at 23 months of age, thus eliminating prior heifer selection for reducing dystocia.

Correlations ranging from 0.44 to 0.48 between calf birth weight and dystocia indicate the effects of calf birth weight in first-calf heifers on calving difficulty (Price and Wiltbank, 1978a). A 2.3% increase in incidences of dystocia was produced by each kg of increase in calf size. Furthermore, sire birth weight EPDs were an effective means of controlling the occurrence of dystocia in first-calf heifers based on a computer simulation model designed to compare the relationship of dam pelvic area and sire birth weight EPDs on calving difficulty (Cook et al., 1993).

Effect of Calf Sex

The incidence of dystocia in bull calves is nearly two times more frequent than for heifer calves (as reviewed by Burfening, 1991). A difference between predicted and actual percent calving difficulty between male and female calves of 4.5% suggests the anatomical differences between male and female calves play a role in dystocia (Laster et al., 1973). This may be attributed to the fact that bull calves are larger in both bone and muscle structure, resulting in an overall larger body dimension. It is also theorized that the male fetus may cause hormonal effects upon the dam during gestation. Lower blood and urinary estrogen levels in the dam before parturition may increase the occurrence of dystocia (Burfening, 1991).

Anabolic effects of testosterone may be the causative factor resulting in an increase of muscle mass during gestation and heavier birth weights in male calves at parturition (Holland and Odde, 1992). Significant testosterone production by the fetus begins at Day 45 of gestation, and fetal weight differences because of the sex of the fetus are measurable as early as 80 days into gestation (Holland and Odde, 1992).

In a study by Ellis et al. (1965), bull calves weighed 2.7 kg heavier at birth than did heifer calves. Furthermore, age of dam was related to calf birth weight. Birth weight of the calf increased as the age of the dam increased to the point of six to seven years of age when birth weights then began to decline. Calves born in November and December were lighter at birth than calves born later in the season, largely because of management and environment. Sex, age of dam, year, season of birth and breed cross were all significant sources of variation in calves' birth weight.

In a study of dam effects upon dystocia, sex of the calf ranked second in importance to calf birth weight as being related to the frequency of dystocia (70% of the variation at first parity; Rutter et al., 1983). Several studies have indicated sex of the calf was related to increased incidence of dystocia (Price and Wiltbank, 1978a; Meijering, 1984). Furthermore, male calves experienced a greater frequency of assistance and a higher average calving difficulty score than did heifer calves (Bellows et al., 1971).

Other Factors Associated With Dystocia

Laster et al. (1973) examined the effects of sire breed, dam breed, dam size, calf sex and calf birth weight on dam reproductive efficiency. Sire breeds within this study included Hereford, Angus, Jersey, South Devon, Limousin, Simmental and Charolais with dams of the Hereford and Angus breeds. A significantly lower frequency of dystocia was observed for calves sired by Angus, Hereford and Jersey bulls. As related to dystocia, age of dam proved a definite factor, with two-year old heifers being $36.0 \pm 2.9\%$ higher than three-year old cows and $44.6 \pm 3.0\%$ more likely than 4- and 5-year olds to experience dystocia. It was found that calf birth weight for the Hereford-Angus crosses were 1.55 ± 0.26 kg higher than the purebred Hereford and Angus calves. Gregor et al. (1965) also observed an increase in birth weights attributed to heterosis.

Effect of Gestation Length

Correlations between the dam's gestation length and the calves' birth weight were reported to range from 0 to .61 (positive low to high correlation; Holland and Odde, 1992). However, the relative increase in calf weight dependent upon gestation length had only slight to nonsignificant effects upon occurrence of calving difficulty (Holland and

Odde, 1992). Dam's gestation length is more likely dependent upon calf birth weight than the calf's birth weight is upon the gestation length; thus leaving calf birth weight as the more significant variable associated with dystocia (as reviewed by Holland and Odde, 1992).

Relationship of Pelvic Growth to Growth Traits

The correlation between pelvic area and measures of weight, hip height and distance between hooks and pins was moderate and resulted in no change with age, thus concluding pelvic area growth to be more reliant upon frame size and weight (Gaines et al., 1993). In a study of 129 Holstein X Hereford heifers (Gaines et al., 1993), pelvic areas were measured at 10, 16 and 22 months of age and showed pelvic growth to be nonlinear with age ($0.27 \pm 0.2 \text{ cm sq. /day}$ from prebreeding to breeding and $0.13 \pm 0.13 \text{ cm sq./day}$ from breeding to calving). A high variation in pelvic area measurements the month prior to calving was observed which resulted in a low correlation between calving and precalving measures.

Effect of Sire Traits on Dystocia

Kriese and co-workers (1994) reported that selecting a bull with increased yearling pelvic area measurements will result in a slight increase in his daughter's pelvic dimension ($r=0.61$). However, this resulting increase will have little effect upon her likelihood of experiencing dystocia as a first-calf heifer.

As reviewed by Holland and Odde (1992), a highly significant effect of sire on calf birth weight exists. These effects vary between breed and within breed of sire. Breed effects upon birth weight are greatly varied between breeds and less deviated within

breed. Holland and Odde (1992) calculated a range of 28.9 kg difference in average birth weight between purebred cattle and ranges as high as 12.55 kg to 3.86 kg within a single breed.

As summarized by Burfening (1991), the selection of bulls with low age-of-dam adjusted birth weight has been proven effective in controlling calf birth weights born to first parity heifers. According to Meirjering (1984), birth weight and dystocia are antagonistic as related to economics, in that birth weight has a positive correlation to future gaining performance. Likewise, calves which are too small at birth may experience lack of vigor, be unable to tolerant cold stress, be susceptible to pathogens and may fail to recover from normal calving stress (as reviewed by Holland and Odde, 1992). Furthermore, mortality rates in low birth weight calves have been reported to be equal to that of high birth weight calves. Bellows et al. (1996) inferred that deviations above or below a threshold birth weight could result in a higher incidence of dystocia.

3. STATEMENT OF THE PROBLEM

Cows experiencing dystocia (calving difficulty) have a four to five times higher calf mortality rate than those experiencing normal parturition (Taylor, 1994). Bellows (1984) observed that 61% of calf deaths within the first three days of parturition were associated with dystocia. Cows experiencing dystocia also have increased postpartum intervals and lower conception rates (Laster et al., 1973). Findings by Bellows and co-workers (1987) suggested increased management at time of calving would result in a significant decrease in calf mortality and may improve subsequent reproductive performance in dams experiencing calving difficulty. Furthermore, dystocia also affected the cows subsequent productivity in terms of percent calves weaned and calf weaning weight (Brinks et al., 1973).

The factor most strongly associated with dystocia is the disproportion between calf birth weight and the dams' pelvic inlet (Bellows et al., 1971; Price and Wiltbank, 1978a). Measurements of pelvic area as an indicator of future calving difficulty has been investigated intensively and been the source of conflicting research findings. Prebreeding and precalfing measurements of pelvic area have been used in the development of pelvic area (PA) to calf birth weight (CBWT; predicted) or heifers body weight ratios with reportedly 75 to 80% accuracy in predicting dystocia (Johnson et al., 1988; Deutscher, 1989).

Basarab et al. (1993) reported 86% of the heifers identified as difficult calvers utilizing PA/CBWT ratios actually experienced no calving difficulty. Likewise, 85.7% of the heifers were incorrectly diagnosed as difficult calvers with use of pelvic area/body

weight ratios. Heifer pelvic area/calf birth weight or pelvic area/heifer body weight ratios used as a heifer selection tool may reduce the incidence of dystocia by 10% as a short term effect. However, the resulting short term benefit may have the opposite long term effect because of selection on increasingly larger pelvic area and its resulting effects on cow size and birth weight (Basarab et al., 1993).

In light of the effects of dystocia upon the efficiency and profitability of the beef industry, this study was conducted to determine the relevance of pelvimetry and its usefulness as an added tool in selection of replacement heifers. In addition to measures of pelvic dimension, weaning and postweaning growth measures were examined as to their effects upon the incidence of dystocia and their relationship to yearling pelvic size.

4. MATERIALS AND METHODS

General

During the years 1987-1991, weaning and yearling growth measures were taken on 457 preselected AN (n=345) and PH heifers (n=112) sired by AI and natural service sires. Preselection of heifers was based upon weaning weight (AN, 246 kg and PH, 243 kg). Following selection, heifers were placed on a 2.3 kg/head/day growth ration (1.46 kg corn and .68 kg protein supplement). Heifers were weighed and hip heights were recorded at weaning (217 and 213 days of age for AN and PH, respectively), breeding (430 and 416 days of age for Angus and Polled Hereford heifers, respectively) and precalfing. Estrus was synchronized with Synchro-Mate B (Sanofi Animal Health, Inc.; Overland Park, KS) and heifers were “timed bred” following implant removal. Angus and PH heifers were bred first service artificially to AN and PH sires, respectively. Twenty-four days following the AI timed breeding, heifers were placed with cleanup bulls respective to their breed for an additional sixty days.

Pelvic area measurements were determined by an experienced technician with the Rice Pelvimeter (Lane Manufacturing; Denver, CO). Measurements were assessed prior to breeding and calving. Pelvic area was determined by multiplying the vertical distance from the symphysis pubis to the midsacrum by the widest measure between the shafts of the ilia.

An experienced farm manager and/or herdsmen were responsible for observing and assisting (when necessary) calving and assessing a dystocia score for each parturition. The calving difficulty scores were assigned as 1 = no assistance, 2 = hand pulled, 3 = hard pull,

mechanical assistance required, and 4 = caesarean. Malpresentations were categorized within the (1 through 4) dystocia scale according to the amount of difficulty in delivery. In addition, calf birth weight, sex and date of calving were recorded.

Statistical Analysis

All possible combinations of group variables were analyzed by breed to determine those variables most associated with dystocia in first-calf heifers. General Linear Model procedures were used in the analysis of variance with least square means and standard errors being generated by Proc Mixed (SAS, 1996). Correlations were calculated between growth parameters of heifers and dystocia score. Furthermore, pelvic area values were separated into three categories based upon the smallest 25%, middle 50% and largest 25% in pelvic area to aid in determining effects of pelvic area on calving difficulty scores.

A second analysis was conducted to determine the value of weaning and breeding variables for predicting dystocia scores in first-calf heifers. Prebreeding and breeding variables were utilized within the analysis in order to provide a true predictive estimate of dystocia, whereas, precalving data would not result in prevention of dystocia. The analysis was conducted utilizing stepwise discriminant analysis (SAS, 1989) to select significant ($P < .15$) prebreeding and breeding variables that could be included in the prediction model. Proc Discm was used to “cross validate” and test predictive performance of selected models.

5. RESULTS

General

Angus and PH heifers did not differ ($P>.05$) in yearling pelvic width and height measures. No differences were observed in weaning weight, weaning hip height and weaning age between AN and PH; however, PH heifers were 0.18 units larger in frame score (Table 1; $P<.05$). Angus replacements were 11.53 kg heavier as yearlings than the PH females (Table 1; $P<.05$). PH replacements were 1.37 cm taller at the hip as yearlings compared to the AN females (Table 1; $P<.05$). Weight of the replacement females differed at parturition by 4.74 kg with PH females being heavier than the Angus (Table 1; $P<.05$).

Of the 328 AN calves born, (76 males, 152 females) with AN calves experiencing 20.4% dystocia with 69% of these male and 31% female. One hundred four PH calves were born (51 male, 53 female) with the incidence of dystocia at 31.7% of which 39% were male and 24% were female. Polled Hereford calves were 2.35 kg heavier at birth than AN calves (Table 2; $P<.05$). Male calves of the AN breed were 1.84 kg heavier at birth than AN female calves (Table 2; $P<.05$); however, birth weight of PH calves did not differ between sexes. Dystocia score differed 0.28 units between AN and PH calves with PH experiencing the higher frequency of dystocia (Table 2; $P<.05$). Angus and PH male calves experienced a greater dystocia frequency than female calves within the same breed (Table 2; $P<.05$).

Table 1. Measurements of Angus and Polled Hereford heifers

Group	Angus ^a	Polled Hereford ^a
Dam traits (prebreeding)		
Dam birth weight (kg)	33.74 ± .26 ^b	38.56 ± .46 ^c
Weaning weight (kg)	245.99 ± 1.65	243.60 ± 2.89
Weaning hip height (cm)	111.81 ± .23	112.45 ± .41
Weaning age (days)	217.22 ± 1.15	213.02 ± 2.01
Yearling weight (kg)	322.69 ± 1.75 ^b	311.16 ± 3.07 ^c
Yearling hip height (cm)	122.17 ± .30	123.55 ± .53
Yearling age (days)	430.92 ± 1.93	416.75 ± 3.38
Yearling pelvic height (cm)	15.81 ± .10	15.81 ± .18
Yearling pelvic width (cm)	13.29 ± .06	13.47 ± .11
Frame score	5.47 ± .04 ^b	5.65 ± .06 ^c
Dam traits (postbreeding)		
Precalving weight (kg)	472.41 ± 2.57	NA
Precalving hip height (cm)	130.30 ± .28	NA
Precalving pelvic height (cm)	15.81 ± .10	15.81 ± .18
Precalving pelvic width (cm)	13.29 ± .06	13.47 ± .11

^a Measurements are reported as least square means ± standard error.

^{b,c} Values with different superscripts within rows differ (P<.05).

Table 2. Measurements of Angus and Polled Hereford calves.

Group	Angus ^a	Polled Hereford ^a
Combined birth weight (kg)	29.97 ± .22 ^b	32.32 ± .40 ^c
Male calves (kg)	30.89 ± .30 ^d	33.04 ± .58
Female calves (kg)	29.06 ± .33 ^c	31.61 ± .56
Combined Dystocia score	1.21 ± .03 ^b	1.49 ± .06 ^c
Dystocia (male)	1.26 ± .04 ^d	1.64 ± .08 ^d
Dystocia (female)	1.17 ± .04 ^c	1.30 ± .08 ^c

^a Measurements are reported as least square means ± standard error.

^{b,c} Values with different superscripts within rows differ (P<.05).

^{d,c} Values with different superscripts within columns differ (P<.05).

Correlations of the sire birth weight Expected Progeny Differences (EPD) to all dam size variables within the model expressed that the smaller heifers were mated to sires with the larger birth weight (EPD). Correlations between dystocia score (Table 3) with yearling hip height, yearling weight, weaning hip height, frame and yearling pelvic area all possessed a significant (P<.05) negative correlation; however, the correlations were very low with yearling hip height with the highest correlation of (r=-0.17). Results of correlations between yearling pelvic area with weaning weight, weaning hip height, frame score, yearling hip height and yearling weight indicate that heifer growth was moderately correlated (r=.36 to .55) with yearling pelvic area (Table 4; P<.05).

Table 3. Correlation between growth parameters with dystocia score

Group	Correlation	P value
Weaning weight	-.08	0.08
Weaning hip height	-.15	0.002
Yearling weight	-.15	0.002
Yearling hip height	-.17	0.002
Yearling pelvic height	-.11	0.023
Yearling pelvic width	-.14	0.004
Yearling pelvic area	-.14	0.003
Frame score	-.15	0.002
Precalving weight	-.06	0.35
Precalving hip height	-.11	0.07
Precalving pelvic height	-.11	0.05
Precalving pelvic width	-.09	0.12
Precalving pelvic area	-.11	0.04

Table 4. Correlation between prebreeding growth parameters with yearling pelvic area

<u>Group</u>	<u>Correlation</u>	<u>P value</u>
Weaning weight	.53	0.0001
Weaning hip height	.48	0.0001
Frame score	.36	0.0001
Yearling weight	.42	0.0001
Yearling hip height	.48	0.0001

Scientific Analysis

Single group

Single group model results for both AN and PH dams rank the birth weight of the calf highest in explained variation in dystocia score (20 and 21%, respectively; Table 5 and 6). For AN dams, sire differences were responsible for explaining 19% of the variation within calving difficulty and ranked as the second most important variable. When pelvic measures were placed into the model statement, yearling pelvic width and height were able to explain 11% and yearling pelvic area only 8% of the variation in dystocia for the AN breed. However, 21% of the variation in calving difficulty score was explained by yearling pelvic width and height in the PH females.

Two group model

Within the AN heifers, sire differences included in the model with calf birth weight were able to account for 29% of the variation in dystocia score, with yearling pelvic width

Table 5. Analysis of variance of single and multiple group models within the Angus

Group	R ²
Single group model	
Calf birth weight	.20
Sire	.19
Yearling pelvic width	.11
Sire birth weight EPD	.10
Weaning hip height	.10
Two group models	
Calf birth weight * sire	.29
Calf birth weight * yearling pelvic width	.24
Three group models	
Calf birth weight * sire * yearling pelvic width	.33
Calf birth weight * weaning hip height * sire	.32
Four group models	
Calf birth weight * weaning hip height * sire * yearling pelvic width	.37
Calf birth weight * weaning hip height * dam birth weight * sire	.35

Table 6. Analysis of variance of single and multiple group models within the Polled Hereford

Group	R ²
Single group model	
Calf birth weight	.21
Yearling pelvic width	.21
Sire	.18
Calf birth month	.18
Calf sex	.17
Two group models	
Calf birth weight * yearling pelvic width	.39
Calf sex * calf birth month	.39
Three group models	
Calf sex * calf birth month * yearling pelvic width	.58
Calf sex * calf birth month * dam birth weight	.50
Four group models	
Calf sex * calf birth month * yearling pelvic width * yearling pelvic area	.71
Calf birth weight * calf sex * calf birth month * weaning hip height	.62

and height and calf birth weight analyzed as a two group model explained 24% of the variation (Table 5). Within the PH heifers, calf birth weight and yearling pelvic width and height accounted for 39% of the variation within dystocia score (Table 6). Nonpelvic variables within the PH breed, such as calf sex plus calf birth month and dam birth weight plus sire differences were able to explain 37 and 36% of the differences in dystocia score, respectively.

Three group model

Among the Angus data when yearling pelvic width and height are added to the model statement with calf birth weight plus sire differences, the R^2 value increased to 33% explanation of dystocia (Table 5). Likewise, with a nonpelvic variable replacing yearling pelvic width and height, the model was able to explain 32% of the variation in dystocia score.

Within the PH data, calf sex plus calf birth month plus yearling pelvic width and height were able to explain 58% of the variation in dystocia (Table 6). Of the three group models not including pelvic variables, calf sex plus calf birth month plus dam birth weight and calf sex plus calf birth month plus weaning hip height were both able to explain 50% of the variation.

Four group model

For AN females, calf birth weight plus weaning hip height plus sire plus yearling pelvic width and height resulted in 37% of the explained variation of dystocia score (Table 5). And similarly, with birth weight of the dam replacing yearling pelvic width and height,

the model was able to explain 35% of the variation in dystocia. In analysis of the four group models for PH females, a significantly important difference between models containing pelvic measures and those without was noticeable. Calf sex plus calf birth month plus yearling pelvic width and height plus yearling pelvic area was able to account for up to 71% of the variation in dystocia scores where as, calf birth weight plus calf sex plus calf birth month plus weaning hip height resulted in only 62% explained variation (Table 6).

Results of the group model analysis for the AN females indicated that nonpelvic size measures can be as useful in explaining the variation in dystocia without including yearling pelvic measures. However, yearling pelvic measures within the PH accounts for a significantly larger amount of variation than those models only containing nonpelvic size measures.

Weaning weights and yearling hip heights were able to explain 39% of the variation within yearling pelvic area ($P=.0001$). With weaning hip height and yearling weight added to the model, the ability to explain the variation in a yearling pelvic area was increased to only 42%, and weaning weight and yearling hip heights remained the significant variables ($P=.0001$).

Analysis of single variable R^2 , Calf Traits

For the AN breed, both calf birth weight and calf sex were examined for their effects upon dystocia. Calf birth weight was the most important explaining 20% of the variation in calving difficulty score with calf sex ranking second in importance. Likewise, calf birth weight ranked first with 21% explanation of variance within the PH breed.

Dam variables affecting dystocia

Prebreeding

Of the prebreeding variables examined (Table 2) in the AN dams, yearling hip height ranked as the most important variable explaining 16% of the variation in dystocia with yearling pelvic width and height, weaning hip height and calf birth month accounting for 11, 10, 9 and 9%, respectively, of the variation in calving difficulty scores. Yearling pelvic width and height and yearling hip height for the PH dams ranked as the two most important traits, each explaining 21% of the variation.

Postbreeding

Within the AN breed, precalving weight and gain ranked as the most important postbreeding variable explaining 12% of the variation in dystocia score with precalving area and precalving pelvic width and height accounting for only 8 and 10%, respectively. However, within the PH dams, precalving pelvic width and height accounted for 43% of the variation in dystocia. Caution should be taken when comparing the precalving data of the PH to other variables since only a small number of observations were available (n=70).

Sire Variables and Relationship to Dystocia

For both the AN and PH, individual sire differences accounted for the highest degree of variation in dystocia score (AN, 19% and PH, 19%), with sire birth weight EPD accounting for only 10% variation for AN and 8% for PH.

In comparison of all variables and their ability to explain the variation within dystocia for the AN females, calf birth weight ranked highest (20%) followed by sire

differences (19%) and yearling hip height (18%). However, an important difference was noticeable within the PH females with yearling pelvic width and height, calf birth weight and yearling hip height each accounting for 21% of the variation in dystocia.

Analysis of Dystocia by Sire Birth Weight EPD

Plotted data (Figures 5-10) illustrates that as the sire birth weight EPD (across breed) decreased (more negative) the number of observations and severity of dystocia tended to increase, with 6 of the 8 dystocia score of 4 resulting from matings with -4 or less sire birth weight expected progeny difference, and 5 of the 6 dystocia score 3 resulting from sires with -4 or less birth weight EPD. Two possible explanations may account for this unexpected relationship between the sire birth weight EPD and dystocia. First the accuracies for expected progeny differences of sire birth weight were low and not representative of their true genetic potential for birth weight. Second, the quadratic relationship of calf birth weight to dystocia seen within this data set and in agreement with Bellows et al. (1996). Data would imply that an increase in dystocia score occurs with the extremely heavy birth weight calves. However, a similar relationship with light birth weight calves was observed as evidenced by the upturn in the dystocia curve for the light birth weight calves. Although, the low number of observations for 22.7 kg birth weights does warrant caution in the interpretation of results (Figure 5).

In a three-dimensional analysis of dystocia*calf birth weight*yearling pelvic area category (by breed), a definite flattening of the quadratic line results with fewer dystocia score of 2 for the AN dams within the largest 25 percentile of yearling pelvic area (Figure 7). Both intermediate and the small 25 percentile categories show a trend of sharper

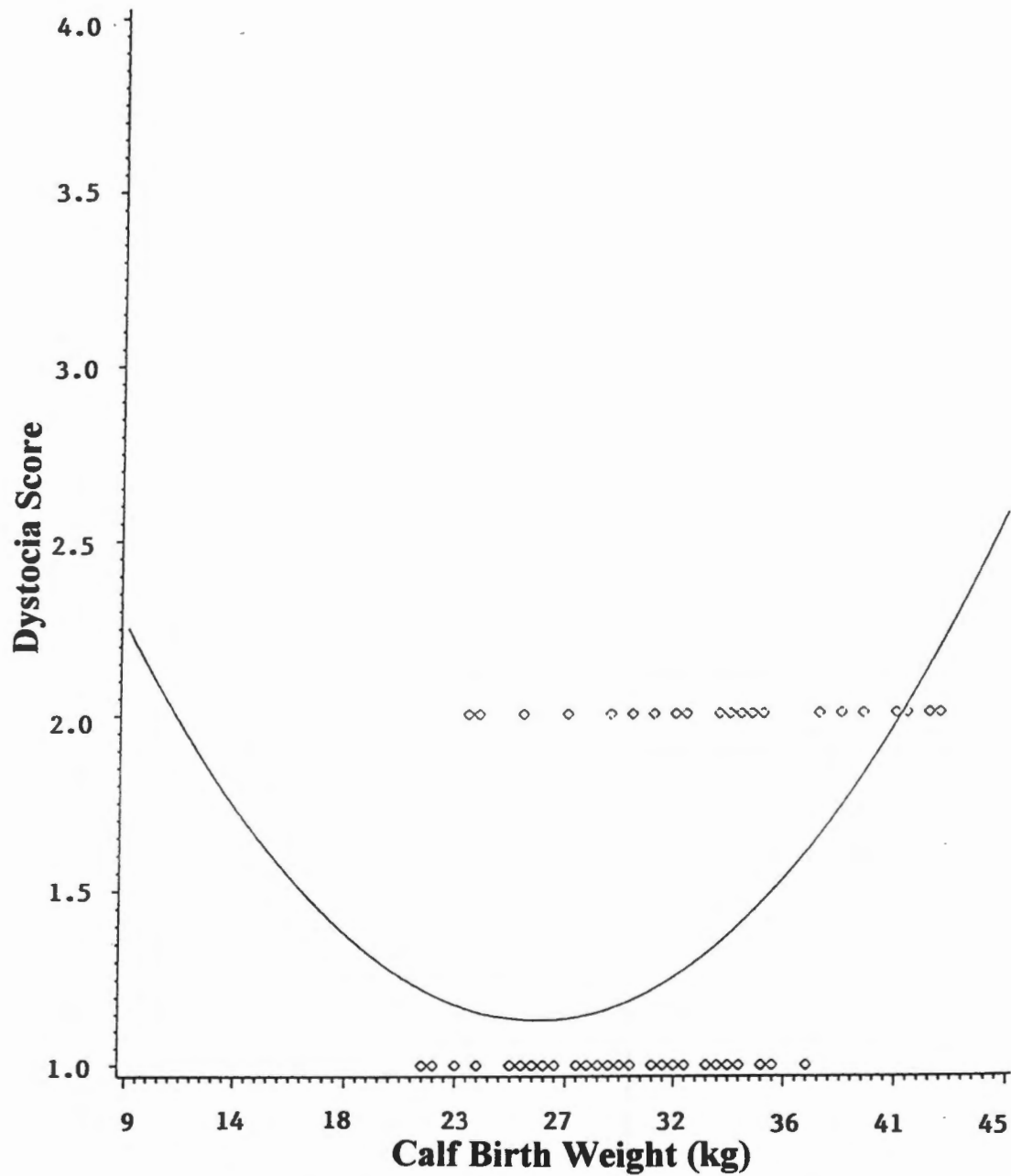


Figure 5. Quadratic Relationship between Calf Birth Weight and Dystocia Score within the Smallest 25% Yearling Pelvic Area Category of Angus heifers.

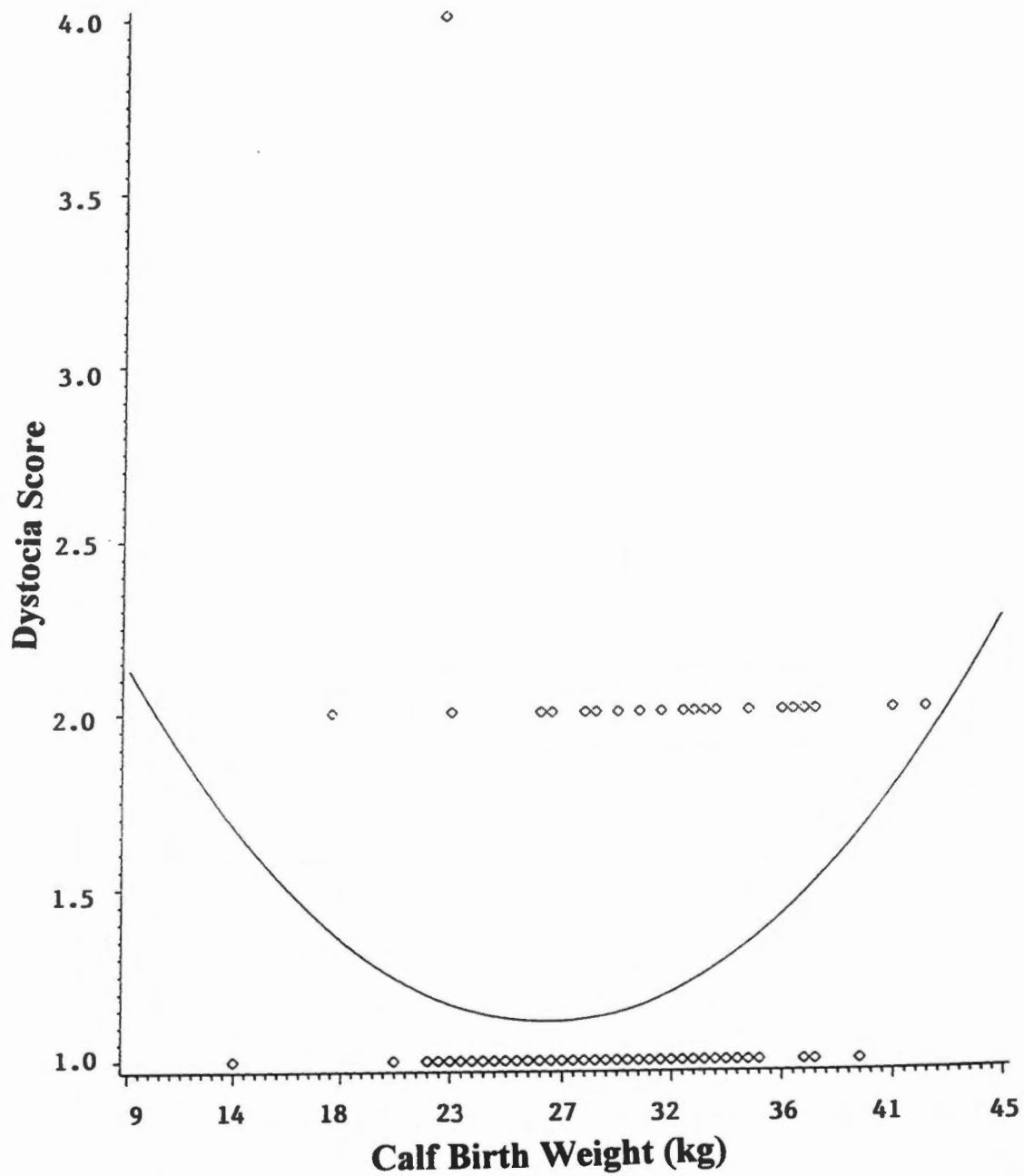


Figure 6. Quadratic Relationship between Calf Birth Weight and Dystocia Score within the Intermediate Yearling Pelvic Area Category of Angus heifers.

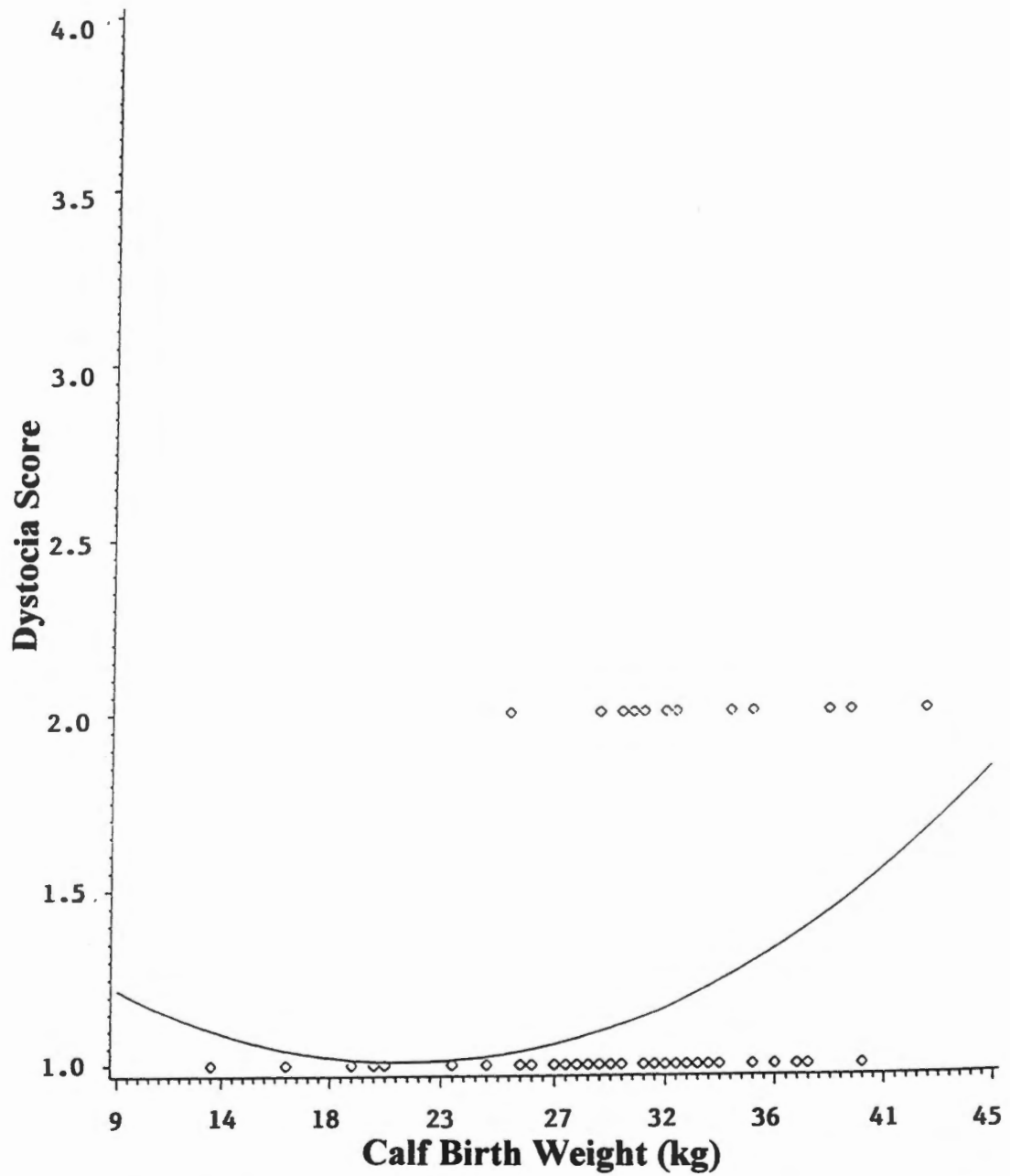


Figure 7. Quadratic Relationship between Calf Birth Weight and Dystocia Score within the Largest 25% Yearling Pelvic Area Category of Angus heifers.

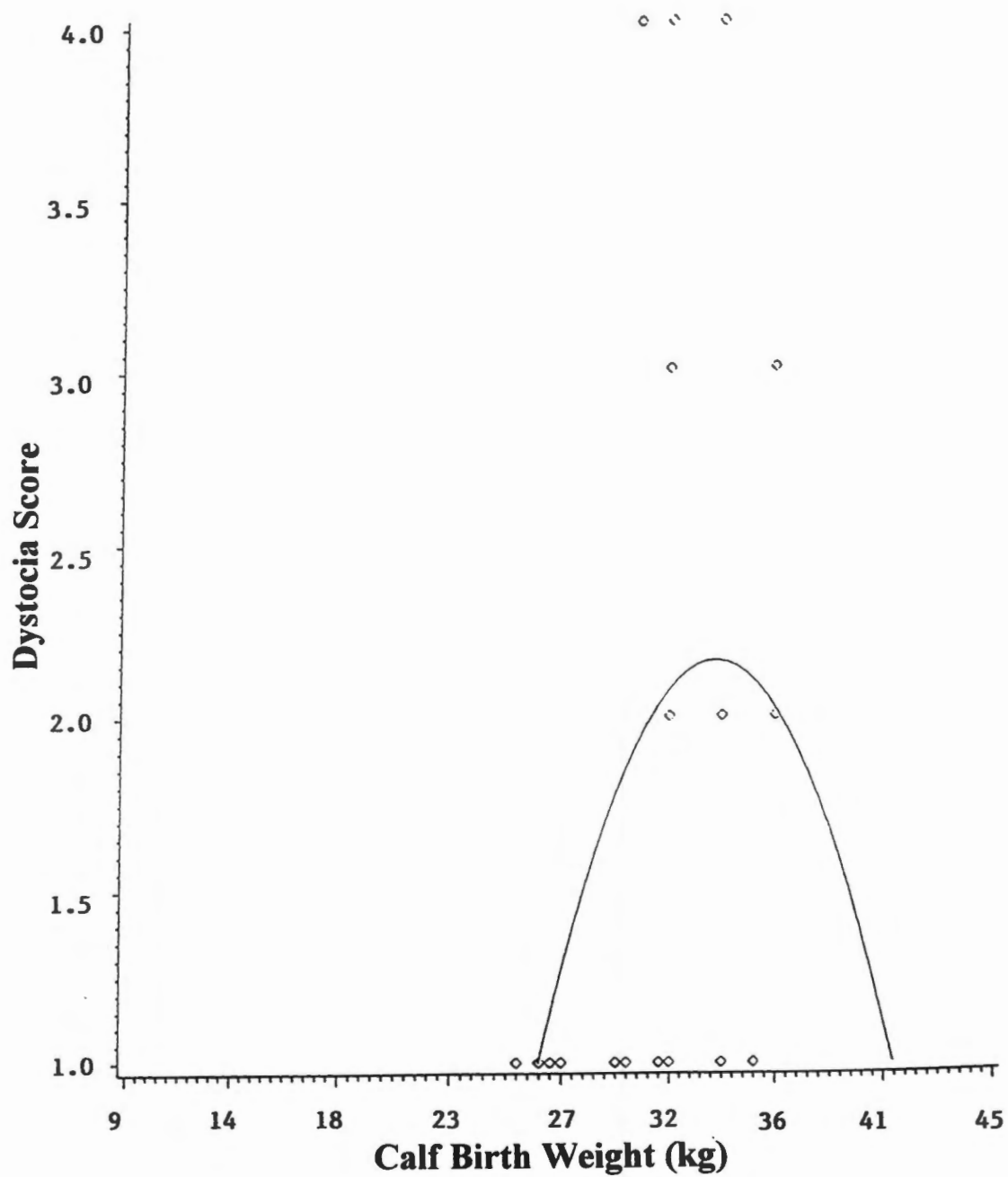


Figure 8. Quadratic Relationship between Calf Birth Weight and Dystocia Score within the Smallest 25% Yearling Pelvic Area Category of Polled Hereford heifers.

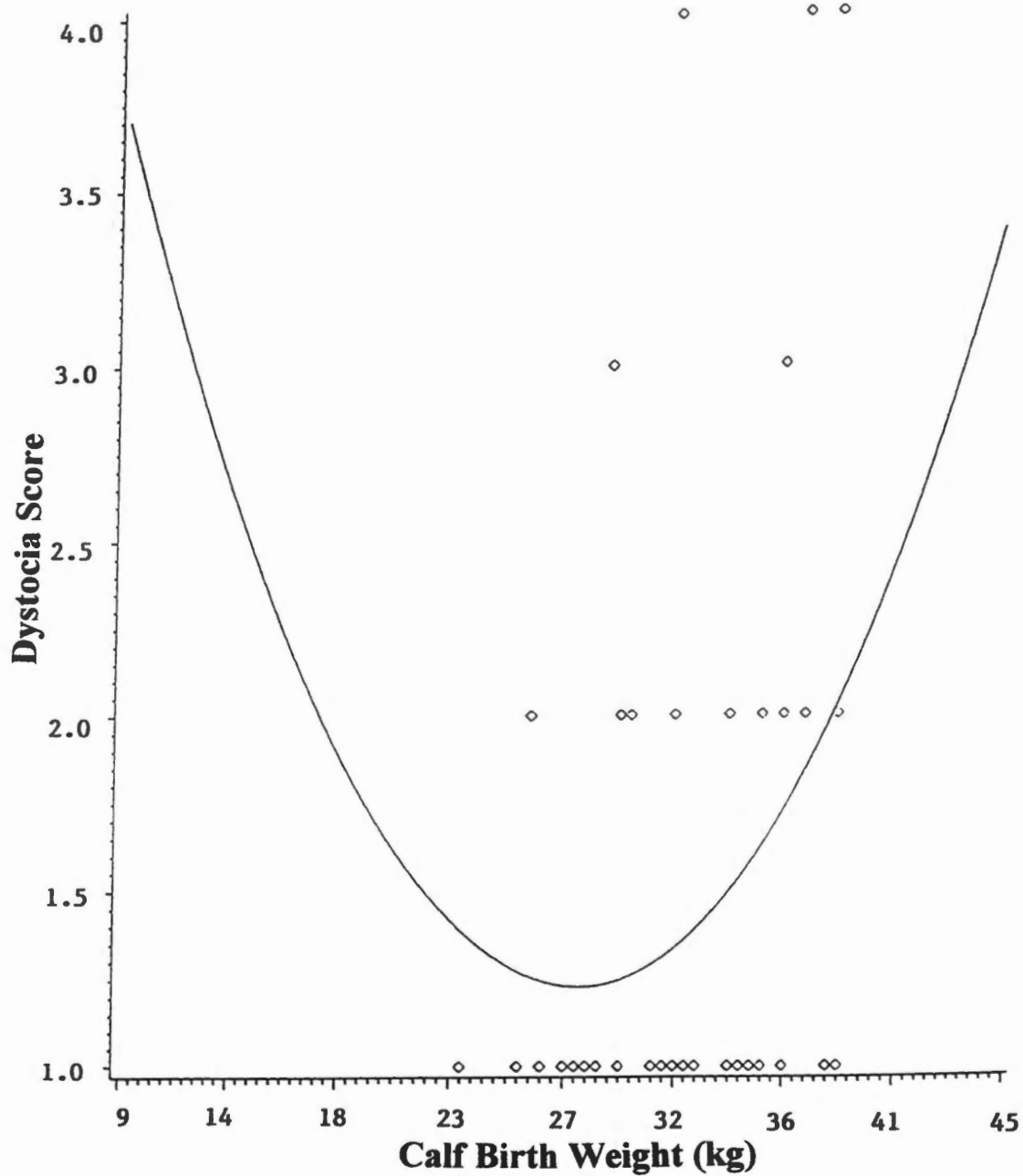


Figure 9. Quadratic Relationship between Calf Birth Weight and Dystocia Score within the Intermediate Yearling Pelvic Area Category of Polled Hereford heifers.

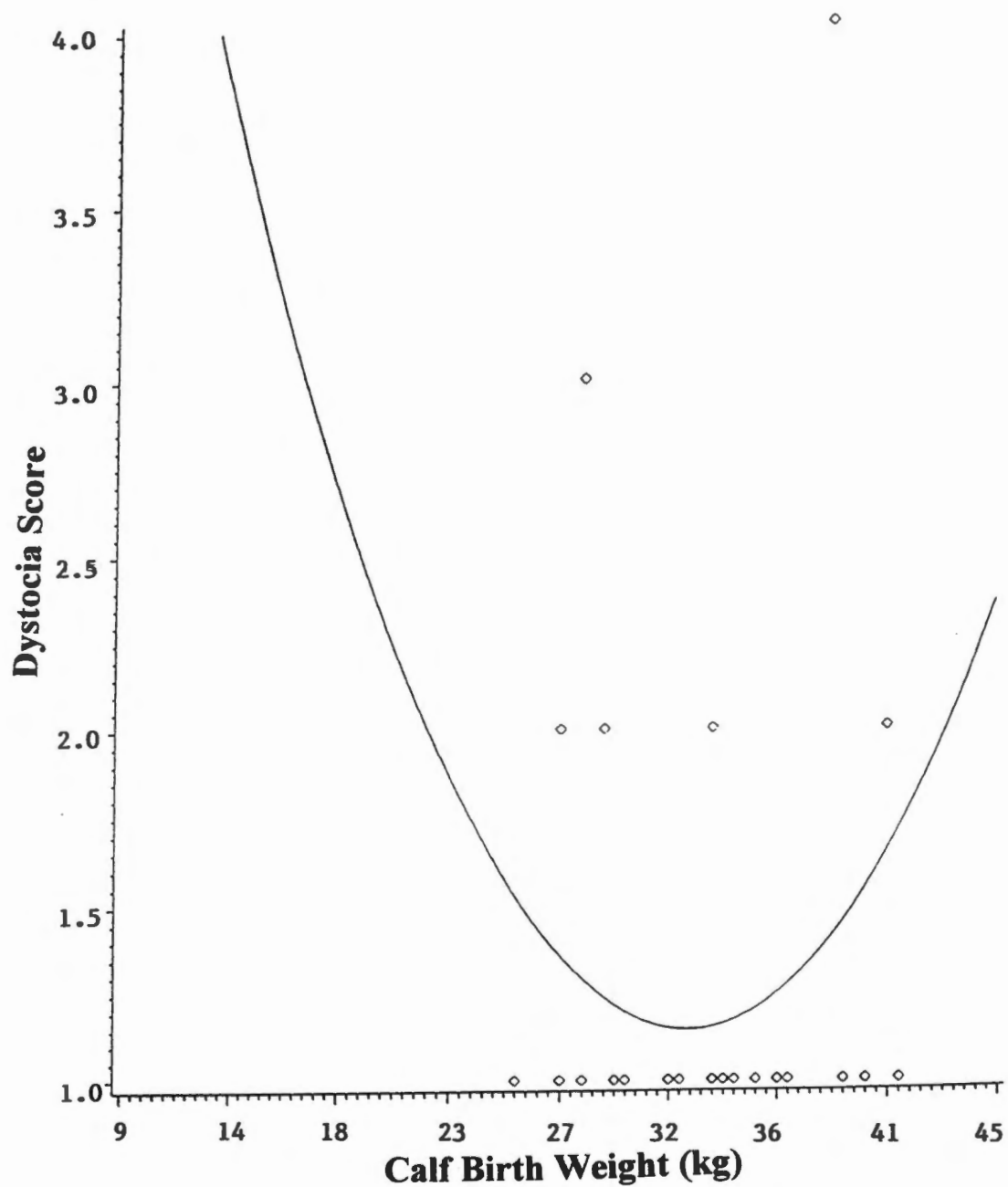


Figure 10. Quadratic Relationship between Calf Birth Weight and Dystocia Score within the Largest 25% Yearling Pelvic Area Category of Polled Hereford heifers.

upturns at both ends of quadratic line. However, no significant increases or decreases in dystocia between all categories of yearling pelvic area were observed within the AN breed. Within the PH data set, a significant increase in dystocia was evident in the heifers with the smallest yearling pelvic areas (lower 25th percentile) compared to the intermediate and the largest 25th percential (Figure 11; $P < .05$). In addition, a negative quadratic relationship occurred between calf birth weight and dystocia (Figure 8) for the PH heifers within the smallest 25th percentile. This negative effect can be explained by the narrow range of birth weight in the category (26 kg to 35 kg) as well as an increase in dystocia scores of 3 and 4. Polled Hereford heifers within the intermediate percentile and the largest 25% categories differ significantly ($P < .05$) with the average dystocia score at .34 units higher in the intermediate percentile heifers.

Prediction Model

Stepwise discriminant analysis of prebreeding dam and sire related variables were included within the prediction model in order to maintain a practical application. Due to lack of dystocia scores of 3, only levels of 1, 2 and 4 were utilized in categorizing the AN replacement heifers into a level of dystocia. Polled Hereford females had sufficient numbers of all four dystocia levels hence categories 1, 2, 3 and 4 were included within the prediction model. Variables utilized in the stepwise analysis included sire birth weight EPD, dam birth weight, calf birth month, weaning weight, weaning hip height, yearling

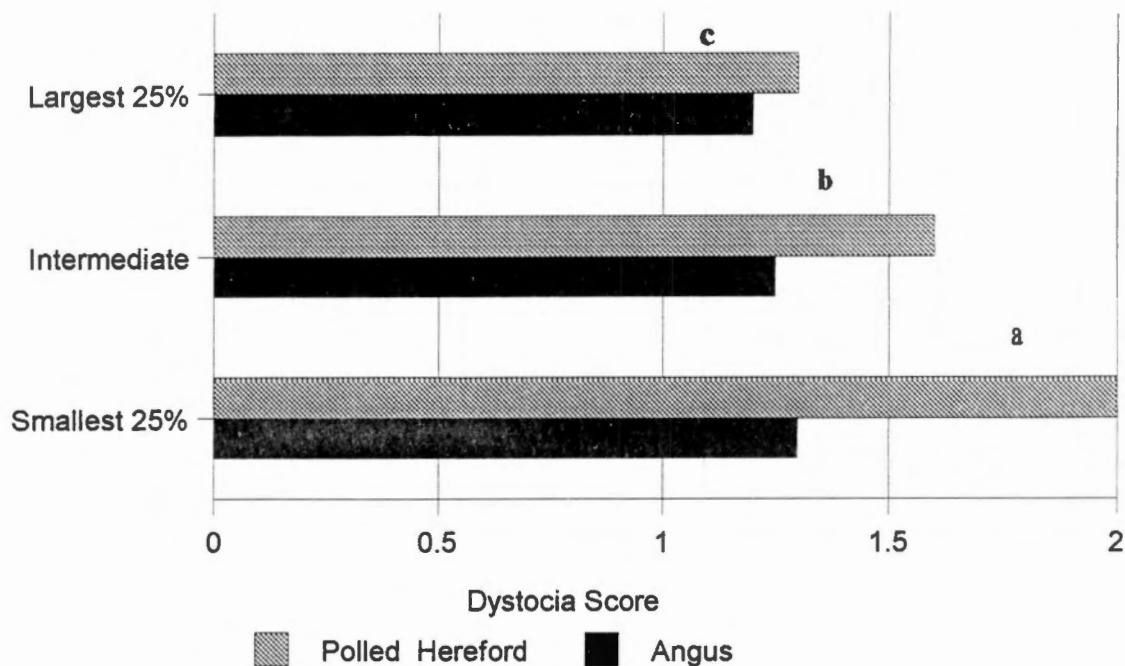


Figure 11. Dystocia scores by pelvic area categories and breed.

^{a,b,c} Bars with different superscripts differ ($P < .05$).

weight, yearling hip height, yearling pelvic area, yearling pelvic width and yearling pelvic height.

Through stepwise discriminant analysis, sire birth weight EPD, dam birth weight, weaning hip height and yearling hip height were identified as the most significant discriminating variables within the categorization of Angus replacement females into a level of dystocia (1, 2 or 4). Though these four variables were highly significant ($P < .05$), the Average Canonical Square Correlations per variable only ranged from .048 to .099 resulting in an extremely poor predictive value of the model. With the discriminant function, the model reported a 23% average error rate in correct classifications. However, given the model was tested upon the same data it was develop and frequency of the

dystocia score 4 was only one observation, the practical value of predicting dystocia categories is extremely limited. For a more usable approach, cross validation was utilized to test the predictive value upon the data set. Predictive value of the model decreased with resulting average error rates increasing to 58%.

The same procedures were utilized within the PH data set. Stepwise discriminant analysis selected sire birth EPD as the only significant variable associated with classification of heifers into a dystocia level (ASCC = .04). Sire birth weight EPD, dam birth weight and yearling hip height were utilized within the cross validation procedure and reported an average error rate of 79%.

6. DISCUSSION

The importance of calf birth weight upon dystocia within this study agrees with Naazie et al. (1989), Bellows et al. (1996) and Peltz et al. (1997), in ranking as the most influencing calf variable for both AN and PH dams. Within the AN breed, calf birth weight was the most significant variable in the explanation of dystocia across calf, dam and sire variables (Naazie et al., 1989; Bellows et al., 1996).

One of many factors being associated with birth weight is calf sex with males nearly twice as likely to experience dystocia as female calves (Burfening, 1991). Sex of the calf within this study significantly influenced the weight of the calf at birth with males of both breeds being heavier (Ellis et al., 1965; Bellows et al., 1996). The dystocia score between males and females did not differ within the AN data, but was significantly different within the PH breed with males experiencing 0.34 units higher dystocia score than females. The differences may be accounted for in that male calves at birth are heavier in both bone and muscle structure (Burfening, 1991). Anabolic effects of testosterone may be the causative factor resulting in increased muscle mass during gestation as well as the increase in male birth weights (Holland and Odde, 1992). It is also theorized that lower blood and urinary estrogen levels in the dam prior to parturition may influence an increase in the frequency of dystocia for male calves (Burfening, 1991).

Of the variables relating to the dam within the AN and PH females, yearling hip height was identified as the most important measure associated with calving difficulty. However, yearling pelvic height and width were of equal importance to yearling hip height in the PH breed. Within the Angus breed, models containing nonpelvic prebreeding

variables were more efficient than those models containing yearling pelvic measures in explaining the variation within calving difficulty scores, which is in agreement with (Holland and Odde, 1992). When yearling pelvic height, width and area were included in the PH model along with calf sex and calf birth month, a significant increase in the explanation of dystocia resulted over that of models containing only nonpelvic information. The differences between the models of the AN and PH data sets can possibly be explained by breed differences (Laster et al., 1973), significantly fewer number of observations contained in the PH data set and finally that calf birth weight was significantly larger for PH calves compared to AN calves while no significant differences were seen between breeds in pelvic dimensions.

In examination of postbreeding dam related variables and their influences upon calving difficulty for the AN females, precalving weight and gain were the most important variable and this again differed for the PH females with precalving pelvic height and width being the most important in agreement with Johnson et al. (1988). However, caution should be used in interpretation because of the lack of sufficient precalving observations within the PH data set.

Results of the sire related variable analysis tend to follow that of Holland and Odde (1992) in that a highly significant effect of sire upon calf birth weight did exist both within and across breed. Of the sire variables studied in this research data set, individual sire differences ranked as the most important for both AN and PH, while sire EPD for birth weight ranked second in importance.

Birth weight and dystocia are antagonistic economically. With increased selection

on weaning and yearling performance, an increase in calving difficulty due to heavier calves at birth is likely to occur. Furthermore, calves extremely small at birth are more susceptible to cold stress and pathogens due to lack of vigor hindering their ability to obtain colostrum within the desired time frame. This data set supports the conclusion of Bellows et al. (1996) showing a trend of a nonlinear or quadratic relationship between calf birth weight and dystocia score. These data infer that calf birth weights above or below an optimum birth weight will increase the incidence of dystocia. In addition, this quadratic relationship held within all categories of pelvic area (25%, 25-75% and 75%+) for the AN females and within the (25-75% and 75%+) categories of PH females. A possible explanation of this nonlinear relationship may be associated with premature calves of extremely small calves failing to attain normal birth position.

Findings through the correlation between heifer yearling pelvic area with weaning and yearling hip height, weight and frame score agree with the findings of Gaines et al. (1993) that pelvic area of the heifer is probably reliant upon frame size and weight of the heifer.

In contrast to Johnson et al. (1988) and Deutscher (1989), prediction of calving difficulty within these data excluded all precalving variables. Precalving variables only lend toward the treatment or culling of the problem; whereas, prebreeding selection would result in a more economical and practical situation enabling producers the opportunity to market predicted problem calvers as feeder calves or open yearlings.

Through stepwise discriminant analysis, sire birth weight EPD, dam birth weight, weaning hip height and yearling hip height were selected as the most effective predictors

of dystocia within the Angus breed. These results are similar to the conclusion of Cook et al. (1993) in that heifer growth measures were better indicators of dystocia than yearling pelvic measures. Likewise, within the PH breed, sire birth weight EPD was identified as the most important variable associated with identifying problem calvers. Again, agreeing with Cook et al. (1993) that selectively mating first-calf heifers to sires with low to moderate birth weight EPD is a more effective means of controlling dystocia than selection of heifers based upon yearling pelvic measurements (Donkersgoed et al., 1990; Donkersgoed et al., 1993). The resulting analysis of prediction did show that nonpelvic prebreeding growth measures were a more useful means of identifying problem calvers than were measures of yearling pelvic dimension. However, the predictive value of this model is extremely poor for both breeds of dam. Nonetheless, this application does perform better than simple guess work and provides practical information on which variables should receive the strongest selection pressure in order to reduce the number and severity of problem calvings.

Interpretation based upon the results of both the Angus and Polled Hereford data lead to a number of conclusions. One, results from stepwise discriminant analysis illustrate that nonpelvic size measures of the replacement heifers are more useful than those of yearling pelvic height, width and area. Two, variables contained within these data sets could not be used to accurately predict dystocia in first-calf heifers. Three, selection of replacement females that are larger as weanlings and yearlings and followed by mating to a sire with low to moderate birth weight EPDs should aid in the prevention of dystocia.

LITERATURE CITED

- Andersen, K. J., J. S. Brinks, D. G. LeFever, and K. G. Odde. 1993. The factors associated with dystocia in cattle. *Vet. Med.* 88:764-776.
- Basarab, J. A., L. M. Rutter, and P. A. Day. 1993. The efficacy of predicting dystocia in yearling beef heifers: I. Using ratios of pelvic area to birth weight or pelvic area to heifer weight. *J. Anim. Sci.* 71:1359-1471.
- Bellows, R. A., R. E. Short, D. C. Anderson, B. W. Knapp, and O. F. Pahnish. 1971. Cause and effect relationships associated with calving difficulty and calf birth weight. *J. Anim. Sci.* 33:407-415.
- Bellows, R. A., D. J. Patterson, P. J. Burfening, and D. A. Phelps. 1987. Occurrence of neonatal and postnatal mortality in range beef cattle. II. Factors contributing to calf death. *Theriogenology* 28:573-586.
- Bellows, R. A. 1984. Calving Management. *Proceeding of the Annual Fall Conference for the Society for Theriogenology.* pp.145-157.
- Bellows, R. A., P. C. Genho, S. A. Moore, and C. C. Chase Jr. 1996. Factors affecting dystocia in Brahman-cross heifers in subtropical southeastern United States. *J. Anim. Sci.* 74:1451-1456.
- Brinks, J. S., J. E. Olson, and E. J. Carroll. 1973. Calving difficulty and its association with subsequent productivity in Herefords. *J. Anim. Sci.* 36:11-17.
- Burfening, P. J. 1991. Factors affecting calving difficulty and implications to breeding and management. In: *Proc. Int. Beef Symp.*, Great Falls MT. pp.59-72.
- Cook, B. R., M. W. Tess, and D. D. Kress. 1993. Effects of selection strategies using heifer pelvic area and sire birth weight expected progeny difference on dystocia in first-calf heifers. *J. Anim. Sci.* 71:602-607.
- Deutscher, G. H. 1988. Pelvic measurements for reducing calving difficulty. *NebGuide* G88-895. Institute of Agriculture and Natural Resources, Univ. of Nebraska, Lincoln. December 1988: B-15.
- Deutscher, G. H. 1989. Pelvic measurements of heifers and bulls for reducing dystocia. *Proc. Beef Improvement Federation.* Nashville, TN pp.22-30.
- Donkersgoed, J. V., C. S. Ribble, H. G. G. Townsend, and E. D. Janzan. 1990. The usefulness of pelvic area measurements as an on-farm test for predicting calving difficulty in beef heifers. *Can. Vet. J.* 31:190-193.

- Donkersgoed, J. V., C. S. Ribble, C. W. Booker, D. McCartney, and E. D. Janzen. 1993. The predictive value of pelvimetry in beef cattle. *Can. J. Vet. Res.* 57:170-175.
- Ellis, G. F., T. C. Cartwright and W. E. Kruse. 1965. Heterosis for birth weight in Brahman - Hereford crosses. *J. Anim. Sci.* 24:93-96.
- Gaines, J. D., D. Peschel, R. G. Kauffman, D. M. Schaefer, G. Badtram, J. Kumi-Diaka, M. K. Clayton and G. Milliken. 1993. Pelvic growth, calf birth weight and dystocia in Holstein x Hereford heifers. *Theriogenology* 40:33-41.
- Gregor, K. E., L. A. Swinger, R. M. Koch, L. J. Sumption, W. W. Rowden, and J. E. Ingalls. 1965. Heterosis in preweaning traits of beef cattle. *J. Anim. Sci.* 24:21-28.
- Holland, M. D., and K. G. Odde. 1992. Factors affecting calf birth weight: A review. *Theriogenology* 38:769-798.
- Johnson, S. K., G. H. Deutscher, and A. Parkhurst. 1988. Relationships of pelvic structure, body measurements, pelvic are and calving difficulty. *J. Anim. Sci.* 66:1081-1088.
- Kriese, L. A., L. D. Van Vleck, K. E. Gregory, K. G. Boldman, L. V. Cundiff and, R. M. Koch. 1994. Estimates of genetic parameters for 320-day pelvic measurements of males and females and calving ease of 2-year-old females. *J. Anim. Sci.* 72:1954-1963.
- Laster, D. B., H. A. Glimp, L. V. Cundiff, and K. E. Gregory. 1973. Factors affecting dystocia and the effects of dystocia on subsequent reproduction in beef cattle. *J. Anim. Sci.* 36:695-705.
- Meirjering, A. 1984. Dystocia and stillbirth in cattle - A review of causes, relations and implications. *Livest. Prod. Sci.* 11:143-177.
- Naazie, A., M. M. Makarechian, and R. T. Berg. 1989. Factors influencing calving difficulty in beef heifers. *J. Anim. Sci.* 67:3243-3249.
- Patterson, D. J., R. A. Bellows, P. J. Burfening, and J. B. Carr. 1987. Occurrence of neonatal and postnatal mortality in range beef cattle. I. Calf loss incidence from birth to weaning, backward and breech presentations and effects of calf loss on subsequent pregnancy rate of dams. *Theriogenology* 28:557-571.

- Peltz, J. M., J. C. Spitzer, L. W. Grimes, G. L. Burns and B. B. Plyler. 1997 . A retrospective analysis of factors contributing to malpresentation at birth, calf mortality and dystocia in beef cattle. J. Anim. Sci. (In Press).
- Price, T. D. and J. N. Wiltbank. 1978a. Dystocia in cattle: A review and implications. Theriogenology 9:195-219.
- Price, T. D. and J. N. Wiltbank. 1978b. Predicting dystocia in heifers. Theriogenology 9:221- 233.
- Rutter, L. M., D. E. Ray, and C. B. Roudicek. 1983. Factors affecting and prediction of dystocia in Charolais heifers. J. Anim. Sci. 57:1077-1083.
- SAS Institute. 1996. SAS/STAT Software changes and enhancments through release 6.11. Cary, NC.
- SAS Institute. 1989. SAS/STAT User's Guide, version 6. Cary, NC.
- Taylor, R. E. 1994. Beef Production and Management Decisions. (2nd edition) MacMillan Publ. Co., New York, pp.223-238.
- Willham R. L. 1973. Beef Cattle Science Handbook - Beef breeding programs. v.10 pp.193-199.

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