AN ECONOMIC COMPARISON OF BREEDING PERFORMANCE
OF YEARLING AND TWO-YEAR-OLD BULLS

by

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A thesis submitted in partial fulfillment
of the requirements for the degree
of
Master of Science
in
Applied Economics

MONTANA STATE UNIVERSITY
Bozeman, Montana

December 1990
APPROVAL

of a thesis submitted by

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ACKNOWLEDGEMENTS

I would like to thank the members of my committee for their time, guidance and suggestions during the writing of this thesis: Drs. R. Clyde Greer, M. Steve Stauber, James Johnson and Mark Peterson. I also thank Rudy Suta for his assistance in preparing the graphs for this thesis, Dr. Mike Frank for his suggestions, and Wanda Myers for her typing and editing.

A special thanks goes to my wife Sharon for her patience, support and editing.

Finally, I pay tribute to my friends and family for their encouragement to complete my graduate degree.
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ABSTRACT

An important decision a rancher makes is the age at which a bull will first be used for breeding. While yearling bulls are used by many ranchers in the Great Plains States, there is concern that lack of maturity among yearling bulls leads to lower breeding performance.

To compare the breeding performance of yearling and two-year-old bulls Line One Hereford bulls in single sire breeding herds at Fort Keogh Livestock and Range Research Laboratory (LARRL) were analyzed. Tests for differences in pregnancy rates, calving dates, calf birth weight, and calf average daily gain were conducted.

The physical attribute distributions were converted to a returns distribution for each age of bull. The distributions were then compared in a stochastic dominance framework. From the results it was concluded that the alternative "use the bull first as a two-year-old" dominated the alternative "use the bull first as a yearling" in the first order stochastic sense.

While ranchers are using yearling bulls, the expected income is higher and the dispersion of observed income smaller from herds bred to two-year-old bulls. Ranchers may be deriving other benefits from the use of yearling bulls such as decreased intervals for introducing special genetic traits. Ranchers may be using yearlings in multiple sire settings which may diminish the downside risk of using yearling bulls as compared to using yearling bulls in single sire settings.
CHAPTER 1

INTRODUCTION

The environment in which cattle producers make their business decisions is stochastic due to prices, weather, and genetic variability. One particularly important decision a producer makes is whether a bull should first be used in natural service mating as a yearling or as a two-year-old. Since a yearling bull may not be mature, there may be increased uncertainty with respect to breeding performance. Decreased breeding performance could decrease profits. Thus, it is critical to analyze the potential effects of the age at which a bull is first used in natural service mating on the profitability of the cattle operation.

Historically, bulls were two years of age when first used for breeding. At this age, potential herd sires were almost certain to have reached puberty, and assessment of prospective herd sires could be based on conformation, growth traits, and disposition. Over the last several years, however, yearlings have been used in increasing numbers in the range states of the United States (Linton, 1979). For instance, between 1969 and 1977 only 8 of 40 novice herd sires, bulls having no prior breeding experience, in natural service matings at Fort Keogh Livestock and Range Research Laboratory (LARRL) were yearlings. Between 1978 and 1984, however, 22 of 30 novice herd sires at LARRL were yearlings. While LARRL is not a commercial operation, it is
managed to reflect operations of representative local commercial producers.

The increase in use of yearling bulls may be the result of industry-wide selection of early maturing individuals. Application of improved nutritional information may also have contributed to earlier maturity in cattle. Faster maturing cattle and better fed cattle are physically capable of successful breeding at younger ages than in the past. Emphasis on use of yearling bulls has been perpetuated by the concept that quicker injection of desirable traits is aided by reducing generation interval. For instance, the time required for a son of a genetically superior sire to be used for breeding is about two years shorter if both bulls and heifers are bred as yearlings rather than as two-year-olds.

Makarechian, Berg and Farid (1983) examined breeding performance of yearling and two-year-old bulls in herds ranging from 15 to 29 cows per bull. They found conception rates and calving dates for yearling bulls and two-year-old bulls were not significantly different (P<.05). If these results could be generalized, a producer might use yearling sires in order to more quickly introduce certain desirable genetic traits into a herd without reducing overall pregnancy rates or affecting weaning weights.

In another study, Makarechian and Farid (1984) found that while pregnancy rates were similar for yearling and two-year-old bulls, the cows mated to two-year-old bulls had more calves during the first six weeks of the calving season. With a higher percentage of calves born later in the calving season, the calves sired by yearlings would be
lighter at weaning if the calves' daily rate of gain is constant. Assuming that there are no cost savings or price premiums for lighter calves, the use of yearling sires would decrease profitability. If profitability is of interest for the decision maker, the effects of age of sire on the net revenue function should be considered.

Specific Objectives and Outline

This thesis extends previous research on the choice of sire age in two ways. First, the inherent risk of this decision is modeled using stochastic dominance (SD) analysis. The SD approach has been used in assessing risky alternatives and specifically addresses the stochastic nature of the environment (Anderson, Dillon, and Hardaker, 1977). In particular, the outcome of the choice is treated as a random variable. Second, rather than emphasize herd pregnancy as the relevant outcome, expected revenue is used as the measure of relative performance between yearling bulls and novice two-year-olds.

To empirically evaluate bull commencement breeding age in this framework, the cumulative probability distribution of net revenue for both age groups must be determined and compared. Specific objectives of this study include:

1. Estimate the expected revenue for both yearling and novice two-year-old bulls from data on Line 1 Hereford cattle at Fort Keogh Livestock and Range Research Laboratory (LARRL) at Miles City, Montana; and
2. Conduct a SD analysis of the distributions of revenues for yearling and novice two-year-old bulls to determine whether one of the alternatives is preferred.

The remainder of this thesis is organized as follows. A review of literature, with particular emphasis on research conducted by animal scientists, is given in Chapter 2. A brief discussion of the theoretical model is offered in Chapter 3. The implicit experimental design and data sample are discussed in Chapter 4. The empirical results are presented and discussed in Chapter 5. The thesis is concluded with a summary and suggestions for further research in Chapter 6.
CHAPTER 2

A REVIEW OF PREVIOUS RESEARCH

Much of the research in cattle reproduction has focused on the physical aspects of production. Further, more attention appears to be given to female reproductive performance, with particular emphasis on the effect of nutritional plane on the individual. In general, it has been shown that factors such as dry matter intake during pre-calving and post-calving (Dunn, 1969), previous calving date (Makarechian and Farid, 1984) and (Makarechian, Farid and Berg, 1985) and age of cow (Greer et al., 1988) all affect the reproductive performance of the female.

Wiltbank (1970) suggested that more emphasis be placed on the sire in cattle reproduction because a single bull will have a greater impact on herd performance than an individual cow. He concluded that herd reproduction performance could be improved by (1) increasing the proportion of cows bred during the first 21 days of the breeding season, (2) increasing the conception rate at first service and (3) decreasing losses at or near birth.

Chenoweth (1975) suggested that inadequate attention to behavioral factors such as libido and mating ability in estimating potential sire performance resulted in economic losses. However, no attempt was made to explicitly measure such losses, nor was it clear whether the loss pertained to gross or net revenues. His main point was that factors
other than semen quality should be examined to assure a satisfactory breeding program.

Makarechian and Berg (1982) found scrotal circumference had a significant positive correlation with the ratio of number of calves per bull and a significant negative correlation with the average calving date. More recently, Makarechian, Mahone and Maynard (1983) examined the relationships between certain physical and environmental characteristics of bulls to semen production for yearling and two-year-old bulls. The characteristics considered included body weight, scrotal circumference, libido scores, breeding soundness evaluation and multiple sire settings. In general, it was found that there was considerable variation among individuals and that no single trait was a reliable indicator of bull fertility.

Neville, Smith, and McCormick (1979) studied the reproductive performance of two-year-old and three-year-old bulls assigned 25 and 40 cows during a 90 day breeding season in single sire setting. They found no statistically significant difference in the percentage of calves born among the groups. However, the authors recognized that as individual producers manage to attain satisfactory breeding performance the number of cows per bull may vary due to differences in pasture area, climatic conditions, terrain and other factors.

Makarechian, Farid, and Berg (1983) examined the relationships among testicular size, firmness of testicular tissue (consistency), libido score, and semen quality with bull age. They found scrotal circumference to be highly associated with preweaning growth. In particular, scrotal circumferences tended to be larger in faster...
growing bulls. They concluded that selection on scrotal circumference as a single trait would only reduce the selection intensity on the important economic traits under consideration. However, they did recommend bulls with abnormally small testes be culled.

Makarechian and Farid (1985) investigated the effects of testes consistency and breeding soundness in both yearling and two-year-old bulls. They found that while the means of these measurements were similar for each age of bull, the ranges of the measurements were wider for yearling bulls than for two-year-old bulls. In particular, mean testes consistency was 16.4 cm for yearlings and 16.0 cm for two-year-olds, and the means for overall breeding soundness on a scale of 100 were 80.4 for yearlings and 75.6 for two-year-olds. Testes consistency ranged from 7.0 cm to 21.0 cm for yearlings and from 10.0 cm to 18.0 cm for two-year-olds, while breeding soundness ranged from 31.0 to 98.0 among yearlings and from 66.0 to 84.0 among two-year-olds.

If breeding soundness and testes consistency are indicators of breeding performance, these results suggest that an average yearling may perform comparably with an average two-year-old. However, there may be greater risks in using yearlings, as the ranges of testes consistency and breeding soundness for yearlings are wider than the ranges for two-year-olds.

While the previous studies have found various relationships between physical and environmental characteristics on breeding performance, little has been offered with regard to the economic aspects of breeding performance. Torrell, Speth and Ching (1982) used linear programming to determine the effects of various levels of weaned
The authors found that high percentages of calves weaned are not necessarily the most preferred. They concluded that ranchers should consider the added costs of achieving a higher calf crop percentage and compare them to the associated added revenue. While this study did examine the monetary importance of different levels of calf crop, the only source of variation in calf crop was dam’s plane of nutrition.

Previous research suggests that present tests are unable to accurately predict either a yearling or a two-year-old bull’s ability to produce offspring. Certain desirable genetic characteristics may be introduced more quickly into a herd by using yearling bulls without a significant decrease in calf crop. However, given that less is known about a yearling and that the performance of a yearling has greater variance, the decision to use yearling bulls may be costly. In particular, the distribution of net returns could be different between yearling and two-year-old bulls.
The choice made by a producer among risky alternatives should explicitly take into account the distribution of the outcomes. Further, some measure to evaluate the potential outcomes must be devised. Economists often assume that the rational producer chooses among alternatives so that expected utility is maximized.

The theory of producer behavior under risk in agriculture is well documented (Anderson, Dillon and Hardaker, 1977). More recently, Antle (1983) presented an extension of the analysis of analyzing risk in agriculture. His approach considers profit with dynamic production. The resulting profit function is a function of random variables such as price and output. Antle (1983) suggests that some consideration of risk should always be included in an analysis of producer behavior in agricultural production. Further, the producer need not be risk averse in order to benefit from the risk information.

Historically, several approaches to analyzing choice among risky alternatives have been proposed. Several of the more common approaches are mean-variance (EV) analysis (Hanoch and Levy, 1969), stochastic dominance (SD) analysis (Quirk and Saposnik, 1962), higher moments analysis (Antle, 1983), lower partial moments (Atwood, 1985) and safety first (Roy, 1952). Due to their simplicity and overall popularity, only EV and SD will be discussed.
Mean-Variance Analysis

An EV analysis uses familiar statistical concepts. In particular, only means, variances and possibly covariances are used to model the distribution of the outcomes. Producers are assumed willing to accept an increase in the variance of returns in order to attain higher mean returns. Such a result appears reasonable in that an outcome with greater variance must have a larger expected return before the producer would be willing to choose it. However, an EV analysis embodies one serious shortcoming in that both positive and negative deviations in returns are assumed to be equally undesirable to the producer. In other words, a choice based on variance as a measure of risk eliminates both favorable and unfavorable extremes (Markowitz, 1959). A producer, however, may well view an "upside risk" differently than a "downside risk."

In EV analysis the implicit utility function assumes that the distribution of the prospect outcomes is fully characterized by the first two moments; the mean and variance. Utility is assumed to be ordinal so that a utility function which is strictly quasi-concave, monotonically increasing and unique up to any monotonic transformation represents preferences. This assumption allows preferences to be represented by a family of indifference or isouility curves in two dimensional space (Variance, Expected Return) as illustrated in Figure 1.
Figure 1. A Family of Indifference Curves for Expected Return and Variance. The level of utility rises as we move from the curve labeled $u^1$ to that labeled $u^2$, and so on.

The shapes of the indifference curves illustrate two important properties of the preference function assumed in EV analysis. First, along each indifference curve a producer trades alternatives, groups of assets which generate income, so that an alternative with greater variance also has greater expected return. Second, the rate at which a producer must be compensated for accepting more risk (greater variance) increases as the variance increases. The latter property illustrates the concept of risk aversion (Feldstein, 1969).
The EV approach was made more applicable with the development of EV efficiency which allows the set of all risky alternatives to be separated into two disjoint subsets, one composed of efficient alternatives and another composed of inefficient alternatives. An alternative is said to be efficient if no other alternative with the same (or smaller) variance has a larger expected return and no other alternative with the same (or larger) expected return has a smaller variance (Porter and Gaumnitz, 1972).

While EV analysis has some practical applications there are many times when the underlying distributions are not known a priori. If the distributions are not fully characterized by the expected return and variance, EV analysis is not an appropriate method for discerning the most favorable outcome. It was this weakness in EV analysis that prompted development of other analytical methods.

**Stochastic Dominance**

The concept of stochastic dominance was introduced in the early 1960's by Quirk and Saposnik (1962). A risky prospect is said to dominate another if the consequences of the prospect are preferred for at least one state and as preferred for all other states (Anderson et al. 1977). Stochastic dominance is based on the following concepts. Two probability density functions $f(r)$ and $g(r)$ are defined only when $r$ does not take values outside the interval $[a,b]$. In addition, $r$ is assumed continuous over the range $[a,b]$, which requires continuous density functions. The cumulative distribution functions (CDF) are defined in equations (1) and (2).
These cumulative distribution functions define the area under their respective probability density functions. If $F_1$ is less than or equal to $G_1$ for all possible $R$ in the range $[a,b]$ with at least a strict inequality (i.e., the $<$ holds for at least one value of $R$), then $F$ is said to dominate $G$ in the sense of first-degree stochastic dominance (FSD). The economic implication of FSD regarding risk preference is that more is preferred to less. Those distributions which are not eliminated by FSD are said to be first order stochastic efficient (FSE).

Distributions which are FSE become candidates for second order stochastic efficiency (SSE) which provides a basis for eliminating those distributions which are dominated in the sense of second order stochastic dominance (SSD). The area under the cumulative distribution functions can be found as shown in equations (3) and (4).

\[
F_2(R) = \int_a^R F_1(r) \, dr \quad \text{where } R \text{ is an element of } [a,b]
\]

\[
G_2(R) = \int_a^R G_1(r) \, dr \quad \text{where } R \text{ is an element of } [a,b]
\]

If $F_2$ is less than or equal to $G_2$ for all possible $R$ in the range $[a,b]$ with at least a strict inequality (i.e., the $<$ holds for at least one value of $R$), then $F$ is said to dominate $G$ in the sense of SSD. The economic implication of SSD regarding risk preference is that the decision maker is risk averse. The distributions which are not eliminated by SSD are said to be second order stochastic efficient (SSE).
Distributions which are SSE become candidates for third order stochastic efficiency (TSE) which provides a basis for eliminating those distributions which are dominated in the sense of third order stochastic dominance (TSD). Development of TSD is similar to the procedures used in developing FSD and SSD.

\[ F_3(R) = \int_a^R F_2(r) \, dr \quad \text{where } R \text{ is an element of } [a,b] \]  
\[ G_3(R) = \int_a^R G_2(r) \, dr \quad \text{where } R \text{ is an element of } [a,b] \]

If \( F_3 \) is less than or equal to \( G_3 \) for all possible \( R \) in the range \([a,b]\) with at least a strict inequality (i.e., the \(<\) holds for at least one value of \( R \)), then \( F \) is said to dominate \( G \) in the sense of third-degree stochastic dominance (TSD). The economic behavioral implication of TSD, that as people become wealthier they become less risk averse, is not as widely accepted as the implications of FSD and SSD. The remaining set of distributions which are not dominated in the TSD sense are said to be third order stochastic efficient (TSE).

If preferences cannot be directly identified, assumptions can be made on which to base stochastic dominance analysis. The assumptions are based on the characteristics of a monotonically increasing utility function, \( U \), with the respective first, second, and third derivatives of \( U \) denoted \( U', U'', \) and \( U''' \). If the utility function exhibits specific characteristics, inferences about the decision maker's attitudes toward risk and returns can be made. (1) If \( U' \) is strictly positive, \( U'>0 \), the implication is that more is preferred to less. (2) If \( U' \) is strictly positive and \( U'' \) is strictly negative, \( U'>0 \) and
U''<0, the decision maker is said to be risk averse. (3) If U' is
strictly positive, U'' is strictly negative, and U''' is strictly
positive, U'>0, U''<0, and U'''>0, the implication is that as people
become wealthier they become decreasingly averse to risk. First-
degree stochastic dominance (FSD) satisfies the first assumption.
Second-degree stochastic dominance (SSD) satisfies the first and the
second assumption. Third-degree stochastic dominance (TSD) satisfies
the first, second and third assumption (Anderson et al., 1977).

The definitions of FSE, SSE and TSE suggest a method of ordering
risky prospects. To illustrate the concepts of FSE and SSE simple
linear functions of R may be used. It is recognized that linear
cumulative distribution functions (CDFs) represent a limited family of
functions; however, calculations of the areas under linear CDFs do not
require any rigorous integration and serve quite adequately to
demonstrate the concept of stochastic efficiency. Suppose the CDFs of
outcomes for alternative F, alternative G, and alternative H are given by

\[
F_t(R_t) = \begin{cases} 
-1.2 + .4R_t & \text{when } R_t < 3 \\
0 & \text{when } R_t = 3 \\
1 & \text{when } R_t > 5.5
\end{cases}
\]

\[
G_t(R_t) = \begin{cases} 
1/6R_t & \text{when } R_t < 0 \\
0 & \text{when } R_t = 0 \\
1 & \text{when } R_t > 6
\end{cases}
\]

\[
H_t(R_t) = \begin{cases} 
-2/3 + 1/6R_t & \text{when } R_t < 4 \\
0 & \text{when } R_t = 4 \\
1 & \text{when } R_t > 10
\end{cases}
\]

These functions are shown graphically in Figure 2. From visual
inspection of Figure 2, G and H are parallel lines, through the ranges
of increasing values with G always above and to the left of H,
Figure 2. Probability Versus Returns for Distributions F, G, and H.
therefore $H$ dominates $G$ in the first order stochastic sense. For each probability the corresponding $R$ is greater with distribution $H$ than with distribution $G$. For example, at $P=.5$ the corresponding $R$ for distribution $H$ is 7 while the $R$ for distribution $G$ is 3. To state the comparison yet another way, for any $R$ the probability of a larger $R$, a more favorable outcome, is greater with the $H$ distribution than with the $G$ distribution. By inspection, distribution $H$ also dominates distribution $F$ in the first order stochastic dominance sense.

Comparing distributions $F$ and $G$, however, leads to a different conclusion. Because the CDFs for distributions $F$ and $G$ intersect, neither dominates the other in the FSD sense, therefore they are examples of FSE distributions. To rank the alternatives the next step in stochastic dominance analysis must be taken; calculate the area under the CDFs to determine if either distribution is second order stochastically dominant (SSD). Recall, the distribution having the smaller area under the CDF is said to dominate the other distribution stochastically in the second degree.

The areas under the respective prospect CDFs for the range $R$ equal 0 to 10 are given in Table 1. Over the range 0 to 10 $H$ has the smallest area under the CDF and thus dominates both $F$ and $G$ in the second degree, which of course is an expected result since $H$ was determined to be FSD. Comparing $F_2$ and $G_2$ it is found that distribution $F$ dominates distribution $G$ in the second degree; the values of $F_2$ are less than those of $G_2$. If the next step were completed it would be found that the TSD ranking of the prospective alternatives would be $H$, $F$, $G$, from most to least preferred.
Table 1. Areas Under CDFs at Various Values of R.

<table>
<thead>
<tr>
<th>R</th>
<th>$F_2(R_i)$</th>
<th>$G_2(R_i)$</th>
<th>$H_2(R_i)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>.33</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>.20</td>
<td>1.33</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>1.75</td>
<td>3.00</td>
<td>.33</td>
</tr>
<tr>
<td>8</td>
<td>3.75</td>
<td>5.00</td>
<td>1.33</td>
</tr>
<tr>
<td>10</td>
<td>5.75</td>
<td>7.00</td>
<td>3.00</td>
</tr>
</tbody>
</table>

As a practical matter FSD does not eliminate many alternatives and is inconclusive as to which alternative is best. Results using SSD and TSD will vary only if there is skewness in the parent distributions. The set of distributions which can be ordered by TSD is in general larger than that which can be ordered with SSD (Whitmore, 1970).

Although the ordering strength of TSD exceeds that of SSD, there remain many practical situations where the preference between two uncertain alternatives cannot be established. For instance, the following situation arises frequently in practice. An alternative, J(R), appears attractive relative to a second alternative, K(R), except that one (or several) outcome of J(R) falls below all the possible outcomes of K(R). Regardless of how attractive J(R) is and how small the probability of the adverse outcome of J(R) is (provided it is not zero), the rule for third-degree stochastic dominance will not rank J(R) at least as preferred as K(R) (Whitmore, 1970). When this inherit
weakness of stochastic dominance does not prescribe an alternative, the
decision maker must rely on some other method for choice selection.

Comparison of EV and SD

In general, SD analysis requires fewer assumptions than EV
analysis. Both approaches require that preferences are adequately
defined by a utility function. However, the actual form of the utility
function need not be known for SD analysis. In contrast, for EV
analysis the utility function must be quadratic so that only the first
two moments fully characterize preferences. The restriction precludes
analysis of the effects of the third (or higher) moments of the
distribution of outcomes. If the distributions of outcome are
symmetric, EV and SD yield similar results.

As a practical matter, SD tends to eliminate from consideration
the low return, low variance outcomes. However, for cases of strong
risk aversion, both second and third degree stochastic rules are more
consistent with the maximization of expected utility than is the mean
variance rule (Porter and Gaumnitz, 1972). The basic shortcoming of SD
is that the method often produces only a set of stochastically
efficient solutions, thus the decision maker's choice cannot be
predicted from SD analysis results.

While both EV and SD procedures analyze the distribution of
outcomes by making use of the first and second moments of the parent
distribution, stochastic dominance extends the analysis to include
consideration of the third moment of the parent distribution. The use
of stochastic dominance rules appears to yield more robust solutions
than those obtained from mean-variance analysis (Anderson, 1974). Thus for this thesis stochastic dominance was selected to compare the distributions of monetary returns from first using a bull as either a yearling or a two-year-old.
CHAPTER 4

EXPERIMENTAL DESIGN AND DATA DESCRIPTION

The data used in this analysis were taken from production records for 1968–1984 of novice Line 1 Hereford bulls at Fort Keogh Livestock and Range Research Laboratory (LARRL) near Miles City, Montana. Line 1 Herefords are a registered herd which began in 1934 with 40 females and 2 males (Advance Domino 20th and Advance Domino 54th) and has been a closed line since that time (Brinks and Knapp, 1975).

Annual production records are kept on all cattle at LARRL. Each year cows are assigned to breeding herds with a specific sire. At birth each calf is ear tagged by a rider who records the identification numbers of the dam, calf and breeding herd along with birth date, birth weight and sex of the calf. A calving difficulty score is also recorded by the rider. The information is transferred from the rider’s book to the permanent herd sheets and to the cow’s individual record card.

Implicit Experimental Design

Miles City is located in the semi-arid northern great plains. Average annual rainfall is approximately 11.50 inches per year. Elevation is 2360 feet above sea level. The growing season is approximately 160 days. The range land is typical of eastern Montana and the Northern Great Plains. The native vegetation is largely a
mixture of short-grass, mid-grass and browse species. Winter feed in the form of alfalfa hay and corn for silage is grown on bottoms irrigated with water from the Yellowstone River. Temperatures range from over 100° Fahrenheit in the summer to −40° Fahrenheit in the winter with an average of 14.5° F for January and 72.9° F for July (Urick et al., 1966).

While LARRL simulates a commercial operation as much as possible, it is a research center where experiments are conducted on a wide variety of topics with an emphasis on range forage and beef cattle. The Line 1 Hereford cattle are kept separate from other cattle during most of the year; however, they receive the same care as the other herds kept at LARRL. In general, cattle are fed a minimum of supplemental winter feed and are expected to thrive in a somewhat natural setting. The breeding season begins approximately June 15 and continues for 45 days ending near August 1. All calves are weaned around October 15. After weaning, some calves are sold, some are fed in the feedlot at LARRL as part of cattle performance and ration testing experiments, and some are kept for replacement stock.

Within such an implicit design replication of experiments involving breeding performance of novice bulls is impossible, as there is only one breeding season in which a bull will have no prior breeding experience. Climatic conditions also inevitably vary from year to year, making replications of a particular experiment unachievable. Thus, particular emphasis should be placed on accounting for the effects of the uncontrolled factors on the measured outcome.
For this study the measured outcome of interest was bull breeding performance. Factors which were initially considered as possible explicit measures of bull breeding performance were calving date and pregnancy rate. All other factors which affect net revenue to the herd were considered fixed as they were independent of the selection of the age at which a bull is first used in natural service mating.

Statistical tests were done to determine if differences in breeding performance were attributable to differences in the breeding herds assigned to the different age bulls. Before suggesting some steps to derive a revenue function, a description of the data is presented.

Data Description

Definitions and descriptions of the variables included in the data sample collected for this study are given in the appendix. During 1968-1984, records were kept on 1517 individual cows exposed to either 30 yearling bulls or 39 novice two-year-olds at LARRL. However, 190 of these observations were not usable in an analysis of breeding performance because (1) the cow was bred by a bull other than the assigned herd bull, (2) the calf was from a multiple birth and raised by a cow other than its dam, (3) the cow had not been pregnancy tested, or (4) the cow had tested pregnant but did not calve. For these observations either the sire could not be identified or the testing procedure was inadequate to measure bull breeding performance. Rather than giving the assigned herd bull credit for another bull's calf,
observations where a specific sire could not be identified were omitted.

The data were not collected from an experiment designed explicitly to test breeding performance difference between yearling and two-year-old bulls, therefore, potential differences were analyzed before comparisons were made. In general the two-year-old bulls were used in the early years of the study and the yearling bulls in the later years of the study. Two-year-old bulls were assigned herds with mixed aged cows. Yearlings, while usually assigned to herds of mixed aged cows were occasionally assigned to herds of predominately yearling heifers.

A summary of selected characteristics of the 1327 usable observations is presented in Table 2. Notice that birth weights averaged 80.29 pounds but varied substantially among calves, ranging from 34 to 114 pounds. The calf weaning weight mean was almost 405 pounds with a range from 175 pounds to 580 pounds. Calving date mean on the Julian calendar where days are numbered 1 to 365 was day 106 and ranged from day 56 to day 152. The age of calf at weaning mean was 184 days and varied from 109 days to 241 days. The age of cow mean was 3.35 years with cow age ranging from 1 year to 12 years. Age of cow was measured at time of breeding, so 1-year-old cows were heifers less than 24 months of age.

Table 3 contains data on important determinants of bull performance and contrasts and tests for differences between yearling and two-year-old bulls. T-tests were done to determine if there were significant statistical differences between these attributes of yearling and two-year-old bulls.
Table 2. Summary Statistics of All Observations.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calf Birth Weight</td>
<td>80.29</td>
<td>11.28</td>
<td>34.00</td>
<td>114.00</td>
</tr>
<tr>
<td>Calf Weaning Weight</td>
<td>404.76</td>
<td>68.21</td>
<td>175.00</td>
<td>580.00</td>
</tr>
<tr>
<td>Calving Date</td>
<td>106.24</td>
<td>15.68</td>
<td>56.00</td>
<td>152.00</td>
</tr>
<tr>
<td>Calf Weaning Age</td>
<td>184.14</td>
<td>15.90</td>
<td>109.00</td>
<td>241.00</td>
</tr>
<tr>
<td>Cow Age</td>
<td>3.35</td>
<td>2.13</td>
<td>1.00</td>
<td>12.00</td>
</tr>
</tbody>
</table>

A brief overview of the data presented in Table 3 will precede the discussion of the statistical results. The number of observations for the different attributes varies due to the differences in the time of year in which the different attributes were measured. For example, due to deaths during the spring and summer, the number of calves available to calculate the average daily gain was not the same as the number of calves available to calculate the calf birth weight. A substantial number of cows were sold after pregnancy testing and prior to calving which yielded a different number of cows for the calving date comparisons versus the pregnancy rate comparisons. In addition, only the cows which were actually pregnant show up in the calving date comparisons.

Table 3 contains data on important determinants of bull performance and contrasts and tests for differences between yearling and two-year-old bulls. T-tests were done to determine if there were
Table 3. The Effects of Hereford Bulls by Age.

**Calf Average Daily Gain (pound/day):**

<table>
<thead>
<tr>
<th>Age of Bull</th>
<th>Number of Calves</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>324</td>
<td>1.75</td>
<td>.35</td>
</tr>
<tr>
<td>2</td>
<td>557</td>
<td>1.77</td>
<td>.30</td>
</tr>
</tbody>
</table>

Ho: 1.75 = 1.77, Ha: 1.75 ≠ 1.77, t = -.87, therefore do not reject Ho at .01 level t = 2.326.

**Birth Weight of Calf (pounds):**

<table>
<thead>
<tr>
<th>Age of Bull</th>
<th>Number of Calves</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>381</td>
<td>78.21</td>
<td>12.45</td>
</tr>
<tr>
<td>2</td>
<td>671</td>
<td>80.63</td>
<td>11.74</td>
</tr>
</tbody>
</table>

Ho: 78.21 = 80.63, Ha: 78.21 ≠ 80.63, t = 3.14, therefore reject Ho at .01 level t = 2.326.

**Age of Cow at Weaning (years):**

<table>
<thead>
<tr>
<th>Age of Bull</th>
<th>Number of Cows</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>324</td>
<td>2.76</td>
<td>2.00</td>
</tr>
<tr>
<td>2</td>
<td>557</td>
<td>3.74</td>
<td>2.10</td>
</tr>
</tbody>
</table>

Ho: 2.76 = 3.74, Ha: 2.76 ≠ 3.74, t = 6.80, therefore reject Ho at .01 level t = 2.326.

**Pregnancy Rate:**

<table>
<thead>
<tr>
<th>Age of Bull</th>
<th>Number of Cows</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>582</td>
<td>.768</td>
<td>.422</td>
</tr>
<tr>
<td>2</td>
<td>910</td>
<td>.844</td>
<td>.363</td>
</tr>
</tbody>
</table>

Ho: .768 = .844, Ha: .768 ≠ .844, t = 3.70, therefore reject Ho at .01 level t = 2.326.

**Calving Date (Julian day):**

<table>
<thead>
<tr>
<th>Age of Bull</th>
<th>Number of Cows</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>381</td>
<td>106.77</td>
<td>17.66</td>
</tr>
<tr>
<td>2</td>
<td>671</td>
<td>105.81</td>
<td>14.19</td>
</tr>
</tbody>
</table>

Ho: 106.77 = 105.81, Ha: 106.77 ≠ 105.81, t = .906, therefore do not reject Ho at .01 level t = 2.326.
significant statistical differences between these attributes of yearling and two-year-old bulls.

From the results presented in Table 3 it was inferred that the 0.02 difference in average daily gain (ADG) for calves sired by yearlings and two-year-old bulls was not significantly different. Tests were also completed to determine if there was a difference in ADG attributable to differences in age of the cow. Cows were identified as heifers, young, or old. There were differences in ADG among cow age groups; however, ADG for each age of bull was not different within the cow age groups.

Birth weight of calves was different between age of bull groups; however, birth weight was also affected by the age of cow. Within each age of cow group the calf birth weight was not significantly different between bull ages; therefore, differences in cow age rather than bull age was considered the causal factor to observed differences in birth weight between ages of bull. Actual calf birth weight variance was likely attributable to a number of factors in addition to age of cow. Climatic conditions (which may affect condition of cow) may have contributed to differences in birth weight for this data set.

Pregnancy rate achieved by different ages of bulls was significantly different. Due to the significant difference in cow age, conception rate for different ages of cows was also examined. There did not appear to be a significant difference in the conception rate for different aged cows if the breeding herd consisted of various ages of cows. There was an unexplainable difference in conception rates for yearling heifers when a majority of the breeding herd consisted of
yearling heifers and the bull was a yearling with a good gain ratio. Using the same data base as this thesis, discussion of this notion is documented more completely in Greer et al. (1988).

Of the cows bred, there was not a significant difference in time of conception in season. For all ages of cows the mean calving date for those bred by yearlings was Julian day 106.8, while the mean for those bred by two year olds was 105.8. These means are not significantly different (P<.1).

The herd sizes varied from 7 to 38 head of cows. There did not seem to be a pattern in the number of cows assigned to a herd based on age of bull. The capability to perform when compared among herd sizes varied widely. In the smallest herds of seven and ten cows, two-year-old bulls achieved 100% conception rates, while one two-year-old achieved 77% conception rate in a herd of 13 cows. The two-year-old assigned the largest herd attained 82% pregnancy for 38 females. The lowest pregnancy percentages attained by yearling bulls were 22% of 27 cows and 16% of 19 cows, yet there were yearling bulls that attained 88% pregnancy rate in a herd of 25 cows and 81% with 26 cows. Within the sample available to this study differences in herd size was not found to be a significant factor affecting pregnancy rate.

Pregnancy rate achieved by yearling bulls with yearling heifers was 77.0%, which was only slightly better than the 76.4% pregnancy rate for yearling bulls with older cows. Two-year-old bulls achieved 84.0% pregnancy rate with yearling heifers and 84.5% for older cows. Pregnancy rate differences among cow ages were not significantly different (P<.1) for either age of bull.
The calving date performance of yearlings bulls varied with the age-of-cow. Calving date within season was significantly earlier for heifers bred to yearlings than for older cows bred to yearlings 103.0 to 109.6 ($t = 3.68$) ($F = 1.12$, with 165 and 214 degrees of freedom). This difference was attributed to the management practice of placing yearling bulls with yearling heifers earlier than yearling bulls were placed with older cows.

Calving date was not affected by age of cow for two-year-old bulls. The mean calving dates of heifers, 106.7, and older cows, 105.5, bred to two-year-old bulls were not significantly different ($P<.1$).

**Data Adjustments**

Since the data were collected over several years an attempt was made to reconstruct the data as if it were all collected in one year. This was done to remove year to year differences in moisture and temperature which could have played a role in the calves' weaning weights rather than the time of the year in which the calf was born. The observed average daily rate of gain for all calves was approximately 1.75 pounds per day, so 1.75 pounds was selected as the average daily gain from birth to weaning for all calves. This rate of gain constant removes variability attributable to different ages of cows, as calves raised by young cows were found to be significantly lighter at weaning than calves raised by older cows.

The calf birth weight selected for all calves for the revenue function was 80 pounds. Observed calf birth weights varied from 34
pounds to 114 pounds. The 80 pound birth weight selected was near the 80.29 pound mean for all calves. The yearling and two-year-old bulls were assumed to be genetically similar and therefore the birth weight of a calf would not be affected by the age of its sire.

There were different observed herd sizes; however, herd size was not found to affect conception rate. Therefore, the average herd size for this data set, 23 head, was selected as the number of cows each bull was assigned.

Since the calving date distributions for the calves that were born were not significantly different, it was assumed that if a cow was pregnant, she would calve on day 106. With the calving date fixed, it was assumed that all calves were weaned on October 15, Julian day 288. These assumptions eliminate any possible weaning age differences that may have been attributable to year to year management changes, such as actual weaning dates and/or dates in which the bulls were turned out.

After the data base was adjusted to take into account the factors previously discussed, an income calculation was done to estimate the gross income for calves sired by yearling and two-year-old bulls. The income function for each bull was derived by multiplying the pregnancy rate achieved by each bull times the number of cows in the herd times the calculated weaning weight in pounds by $0.75 per pound. The $0.75 per pound is close to the five year average feeder calf price between 1979 and 1984, $.7438.
CHAPTER 5

EMPIRICAL RESULTS

Stochastic dominance was selected as the procedure for comparing the breeding performance of yearling and two-year-old Hereford bulls. Some assumptions were made to account for differences in the sample data that were not directly attributable the age of bull. By converting the physical attributes of the data set to monetary attributes, an economic evaluation of the breeding performance of bulls at different ages can be made.

For this data set the return functions became transformations of the pregnancy rate distributions since the calving date distributions were found to be "not different." In calculating returns for this analysis the following assumptions were made:

1. The cows bred to yearling and two-year-old bulls received the same care and treatment.
2. The price per pound received was the same for all calves.
3. All calves had the same birth weight.
4. All calves gained weight at the same rate per day.
5. All calves were born on the same day.
6. All calves were weaned on the same day each year.
7. Cost of caring for bred cows and non-pregnant cows was equal.

The time period considered for this analysis was the immediate present, where all costs are fixed and assumed to be independent of the decision
variable being examined. For each cow herd the probability of the cow being pregnant was the pregnancy rate achieved by the bull for that particular cow herd. The return for each bull was derived by multiplying the pregnancy rate achieved by each bull times the number of cows in the herd times the calculated weaning weight in pounds by a price per pound.

The return for each bull was calculated as follows:
First a weaning weight was calculated.

\[ ADJCWW = ADJCBW + [(ADJWNDATE-ADJBDATE) \times ADG] \]

where

- **ADJCWW** = Adjusted calf weaning weight
- **ADJCBW** = Assumed calf birth weight, 80 #
- **WNDATE** = Weaning date for all calves, day 288
- **ADJBDATE** = Assumed birth date for individual calf, day 106
- **ADG** = Assumed average daily rate of gain, 1.75 #/day

The calculated weaning weight was then multiplied by the assumed price per pound to arrive at a value for each calf.

\[ CLFVAL = ADJCWW \times CPPP \]

where

- **CLFVAL** = Dollar value of individual calf
- **CPPP** = Calf price per pound, $ 0.75

The final return per herd per bull was calculated by multiplying the value per calf times the number of cows times the observed pregnancy rate for each bull's herd.
HRDRTN = CLFVAL * HRDSIZE * HDPGRT

where

HRDRTN = Dollar return for the bull's herd
HRDSIZE = Number of cows in the herd, 23
HDPGRT = Herd Pregnancy rate for each bull

It is acknowledged that steer and heifer calves bring a different price per pound at market. However, if the assumption holds that sex of calf is not affected by the age of the bull, then a constant price per pound for all calves would not affect the final outcome of the analysis. The $0.75 per pound used in this analysis is close to the five year average feeder calf price from 1980 to 1984 of $0.74.

Table 4 lists cumulative proportions for each age of bull with the corresponding percent pregnant and the calculated return. Since there were 30 yearling bulls, each observation is weighted 0.0333, while each of the 39 two-year-old bull observations were weighted 0.0256. There were 23 pregnancy rate levels for the yearling bulls and 19 pregnancy rate levels for the two-year-old bulls. There were no two-year-olds with less than 56 percent pregnant. In contrast, for yearlings there is a .13 probability that the percent pregnant would be 56 percent or less. For the yearlings there was a .46 probability of an 80 percent pregnancy rate or less, while the two year olds had a .28 probability of 80 percent pregnancy or less. The probability of attaining a 90 percent pregnancy or less level was .83 for yearlings and .79 for two-year-olds.
Table 4. Cumulative Probability Distributions of Percent Pregnancy and Returns for Yearling and Two-Year-Old Bulls.

<table>
<thead>
<tr>
<th>Percent Pregnant</th>
<th>Returns</th>
<th>Yearling</th>
<th>Two-Year-Old</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>1099.86</td>
<td>.0333</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>1512.31</td>
<td>.0667</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>3643.29</td>
<td>.1000</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>3849.51</td>
<td>.1333</td>
<td>.0256</td>
</tr>
<tr>
<td>60</td>
<td>4124.48</td>
<td>.1667</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>4468.18</td>
<td>.2000</td>
<td></td>
</tr>
<tr>
<td>69</td>
<td>4743.15</td>
<td>.2333</td>
<td>.0513</td>
</tr>
<tr>
<td>70</td>
<td>4811.89</td>
<td>.2667</td>
<td>.0769</td>
</tr>
<tr>
<td>71</td>
<td>4880.63</td>
<td>.3000</td>
<td>.1026</td>
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<td>72</td>
<td>4949.37</td>
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<td>.1333</td>
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<td>74</td>
<td>5086.85</td>
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<td>.1538</td>
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<tr>
<td>75</td>
<td>5155.59</td>
<td>.3667</td>
<td>.1795</td>
</tr>
<tr>
<td>76</td>
<td>5224.34</td>
<td>.4000</td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>5293.08</td>
<td></td>
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</tr>
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<td>79</td>
<td>5430.56</td>
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<td>80</td>
<td>5499.30</td>
<td>.4667</td>
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<td>81</td>
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<td>.3590</td>
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<td>.5333</td>
<td>.4615</td>
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<td>83</td>
<td>5705.52</td>
<td>.5667</td>
<td>.5128</td>
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<tr>
<td>84</td>
<td>5774.27</td>
<td>.6000</td>
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<td>85</td>
<td>5843.01</td>
<td>.6333</td>
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<td>86</td>
<td>5911.75</td>
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<td></td>
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</tr>
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<td>88</td>
<td>6049.23</td>
<td>.7000</td>
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<td>6530.42</td>
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<tr>
<td>100</td>
<td>6874.13</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>
Figures 3 and 4 were generated from the observed distributions in Table 4. In Figure 3 the solid line representing yearlings plots column 3, cumulative proportion, along the y axis versus column 1, percent pregnant, along the x axis. The dashed line representing two-year-olds plots column 4, cumulative proportion, along the y axis versus column 1, percent pregnant, along the x axis. The distribution for the yearlings, with the exception of 100 percent pregnancy, is everywhere to the left of the distribution for the two-year-olds. Therefore, the yearling distribution is dominated by the two-year-old distribution in the first order stochastic sense (FSD).

Figure 4 plots the cumulative distribution functions of returns for each age of bull from the information in Table 4. The solid line is the returns CDF for yearlings, while the dashed line is the returns CDF for two-year-olds. For yearlings column 3, cumulative proportion, is plotted along the y axis, while column 2, cumulative returns, is along the x axis. For two-year-olds column 4, cumulative proportion, is plotted along the y axis, while column 2, cumulative returns, is along the x axis. The graph is similar to Figure 3 as the distribution for the yearlings is everywhere to the left of the distribution for the two-year-olds. Therefore, the yearling alternative is dominated by the two-year-old alternative in the first order stochastic sense (FSD).

Because the yearling distributions for this data set were dominated by the two-year-old distribution in the first order stochastic sense, visual inspection of the CDFs was sufficient to determine which choice was preferred. If the CDFs had intersected
Figure 3. Cumulative Distribution Functions of Percent Pregnant for Bulls First Used as Yearlings and Two-Year-Olds.
Figure 4. Cumulative Distribution Functions of Returns for Bulls First Used as Yearlings and Two-Year-Olds.
more rigorous analysis would have been required to search for second and possibly third order dominance.

Given the observed distributions of herd pregnancy rates for yearling and two-year-old bulls, visual inspection of the respective CDFs orders choices. However, quantitative differences in the choices are not measured. In other words, the analysis here determines which choice is preferable but is unable to elicit how much difference there is between the choices. The inability to quantitatively differentiate choices is an inherent weakness of SD analysis.

The application of stochastic dominance to the topic of this thesis focuses on graphic plottings of cumulative distribution functions. Figures 3 and 4 depict how two-year-old bulls dominate yearling bulls in the first order stochastic sense much like the example in Figure 2 where distribution H dominated distribution G. Since two-year-old bulls dominate yearling bulls in the FSD sense, the final conclusion drawn from this analysis is that not only is the expected income derived from two-year-old bulls greater than the expected income derived from yearling bulls, there is greater variability in the distribution of income generated when bulls are first used as yearlings. This conclusion supports the work done at the University of Alberta by M. Makarechian which indicated that yearling bulls have a greater variability in their performance than two-year-old bulls.
CHAPTER 6

SUMMARY AND SUGGESTIONS FOR FURTHER RESEARCH

After extensive testing of the data the only significant difference in the breeding performance of yearling and two-year-old bulls was a difference in pregnancy rates. The difference in pregnancy rate was transformed into a difference in returns to the producer. In reviewing this data set, the less favorable results for yearlings can be attributed primarily to two bulls. The data from these bulls cannot be discarded, however, as they were selected under the same criteria as the bulls which had relatively successful breeding performance. The selection criteria included visual libido and breeding soundness examinations, but did not include semen evaluation tests.

It is recognized that there may be factors other than net returns which influence a producer's choice for age of bull at initial breeding. For instance, this analysis did not consider possible desired changes in the genetic makeup of the breeding herd that can be achieved more quickly by reducing the generation interval with yearling bulls. The decision maker would have to be able to weigh possible trade-offs between the increased income that could be realized from more calves in the near future versus more valuable calves later. The ability to predict the value of a genetic change in the future is beyond the scope of this analysis.
Suggestions for Further Research

Any study of yearling and two-year-old bulls' breeding performance should begin with tests to determine whether or not there are factors other than pregnancy rate which affect the expected return to the producer. It would be erroneous to assume that for all data sets the calving dates for offspring of yearling and two-year-old bulls are the same. It is possible that in other data sets differences in calving date distributions may be found. For those herds where calving date distributions are different there may be a trade-off between having a higher pregnancy rate and having a greater number of late calves. If in addition to having a lower pregnancy rate yearling bulls also sire a greater proportion of late calves, the outcome would be even more favorable towards using a bull first as a two-year-old. If, however, the yearling bulls sired their calves early in the breeding season then became physically exhausted, the advantage of the early calves may outweigh any possible adverse effects of a lower pregnancy rate. The data set examined in this thesis covered a relatively short breeding period which directly led to a relatively short calving period.

Further study appears warranted in the area of development of reliable indicators of a bull's breeding performance. While age is an easily measurable characteristic, the favorable performance of some younger bulls would indicate that if the non-performing bulls could be selectively excluded, there would be obvious benefits to the producer. An accurate selection mechanism would be beneficial to cattle producers
regardless of the age at which a bull is first used in natural service mating.

Another topic which may warrant future research is the differences between novice two-year-old bulls and two-year-old bulls which had been used for breeding as yearlings. Such an analysis could measure the impact of breeding experience on breeding performance.


Chenoweth, P.J., "Bull Behavior and Management," Proceedings, the Range Beef Cow A Symposium on Production IV, December 1975, Denver, Colorado


VARIABLES IN DATA SET

YEAR- is used to help locate a particular breeding season. It may include some weather information that could be calculated in heavier or lighter wean weights depending on the available precipitation and growing conditions (temperature). Year may also contain general trends in cattle size or fertility.

BULL NUMBER- is the identification number of the sire for the breeding season.

AGE OF BULL- identifies the age of the bull at the time of the breeding season. May indicate to some degree the physical and thus sexual maturity of the bull.

% INBRED OF THE BULL- a score of how much the bull is inbred. There have been studies that indicate at high inbred levels there is loss of fertility and may also be reduced growth levels.

HERD SIZE- may be important as breeding performance may decline at high cow to bull ratios. Pregnancy rate and calving date could both be affected.

COW NUMBER- is the identification number of the cow.

COW AGE- indicates the age of the cow at the time of the breeding season. Studies indicate there are differences in weaning weights due to cow age with lighter weights for cows of two to four years of age. There are also indications of improved fertility with age as culling eliminates nonfertile cows when they are young.

LINE- indicates the line breeding of the cows. Most of the cows in this study are of line one breeding. There are a few line one crosses and other crosses. The line breeding should indicate similarity in genotype.

PREGNANCY- a score to indicate the pregnancy status at the end of the breeding season. There are some inaccuracies in palpation as some corrections were made in the data set to adjust the cows called open that did calve.

WET- a score indicating whether the cow had a calf at her side during the breeding season. This may be correlated with the ability of the cow to breed back as the nursing calf does put a drain on the cow's body condition and therefore may not breed back as quickly. In this
data set a wet cow does have in her favor by being wet she has already displayed some fertility. Dry cows with normal reproductive tracts should breed back quicker than wet cows. Dry cows may be lacking fertility to begin with and is thought that excess fat in the cow interferes with the reproductive tract.

BIRTH WEIGHT- the birth weight of the calf. It is proposed that the heavier the birth weight the heavier the weaning weight will be. There may be some correlation to calving date as a heavier calf may have a longer gestation period. For this to be studied the breeding date as well as the calving date would have to be observed.

SEX- sex of the calf. Male calves are heavier at weaning than females this is partially due to heavier birth weights for males and partially to larger average daily gains.

WEAN WEIGHT- is a measure of the weight of the calf at weaning. Calculated by adding birth weight to average daily gain times age at weaning.  \[\text{wean weight}=\text{bw}+(\text{adg*wnage})\]

WEAN AGE- is the age of the calf at weaning in days. \[\text{wean age}=\text{weaning date}-\text{calving date}\]

PREVIOUS CALVING DATE- Julian date that the cow calved on in the previous year. Previous calving date is expected to have some influence on when a cow calves in the current year which would emphasize the importance of keeping a cow calving "early".

PREVIOUS CALVING DIFFICULTY- indicates the degree of difficulty the cow had in giving birth in the previous year. Cows with a difficult birth delivery may suffer damage to their reproductive tract and therefore may not breed back as quickly as cows that deliver normally.

SPECIAL CODE- identifies some of the unusual features of a particular observation.

PG RATE- is the pregnancy rate achieved by the bull for the herd of interest.

BULL BIRTH WEIGHT- birth weight of the bull. Should be a factor in the birth weight of the calf.

NR- is the nursing ratio of the bull. It is evaluation of how the bull did in comparison to his herd mates in a 205 day adjusted weight.

GR- is the gain ratio of the bull. It is an evaluation of how the bull did in comparison to his herd mates on the feeding test after weaning.

YR- is the yearling ratio of the bull. It is an evaluation of how the bull did in comparison to his herd mates in a 365 day adjusted weight.