EFFECTS OF CONVENTIONAL OR LOW BULL TO FEMALE RATIO AND UTILIZATION OF REPRODUCTIVE TRACT SCORES IN EXTENSIVELY-MANAGED, NATURAL MATING BREEDING GROUPS

A Thesis

by

RYAN JAMES RATHMANN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2005

Major Subject: Physiology of Reproduction

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Approved by:

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	L. R. Sprott
Committee Members,	Kerry Barling
	Bill Holloway
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ABSTRACT

Effects of Conventional or Low Bull to Female Ratio and Utilization of Reproductive Tract Scores in Extensively-Managed, Natural Mating Breeding Groups.

(December 2005)

Ryan James Rathmann, B.S., Texas A&M University

Co-Chairs of Advisory Committee: Dr. David W. Forrest
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The current study involved two experiments which were conducted at the Texas A&M Agricultural Research and Extension Center in Uvalde (semi-arid environment) from 2002 to 2004. In experiment one, Bonsmara bulls (n = 19; 20-24 mo of age) were joined with multiparous, crossbred females (n =586) for 90 d in 2003 and 2004. Bulls were allotted by selected physical traits, seminal traits, social rank, and serving capacity to one of two bull to female ratio (BFR) treatments: Conventional (1:21-1:29; n = 6 pastures) or Low (1:47-1:52; n = 2 pastures) BFR. Pregnancy rate (P = 0.33), calving rate (P = 0.26), and calving date (P = 0.22) did not differ between Conventional and Low BFR treatments. Post-breeding evaluation of bulls in 2002 (n = 16) indicated that social rank, but not seminal traits, was significantly correlated with pre-breeding values (P < 0.05). The current study demonstrates that Low BFR can be utilized in single- and multi-sire, 90-d breeding pastures of up to 2,090 ha without adversely affecting reproductive performance.

In experiment two, yearling, one-half or three-quarter Bonsmara heifers (n = 106; 11-14 mo of age) were palpated per rectum and assigned a reproductive tract score (RTS) immediately prior to the beginning of the breeding season. Reproductive performance was measured in their two subsequent breeding years in order to estimate the value of the RTS system in extensively-managed, natural mating, 90-d breeding season programs. RTS was positively correlated ($p < 0.01$) with frame score ($r = 0.25$), age ($r = 0.31$), weaning weight ($r = 0.47$), and the weight of the heifer on the day of RTS exam ($r = 0.56$). The RTS means by dam parity also differed ($P < 0.03$). A lower ($P < 0.01$) percentage of females conceived during each of their first two breeding seasons for heifers of RTS 1 and 2 (65.2%) than for heifers of RTS 3, 4, and 5 (91.2%). Females with a RTS of 1 had a lower pregnancy rate over each of their first two breeding seasons, conceived later during their first breeding season, weaned lighter first calves, and remained lighter each year for fall body weight and body condition score than did heifers with RTS of 2 to 5 ($P < 0.05$). Collectively, the results of the current study indicate that heifers with a RTS of 1 immediately prior to a 90-d breeding season should be culled. Consideration should also be given to eliminating RTS 2 heifers, but further studies will be needed to confirm the potential economic advantage of this practice.

DEDICATION

I would like to dedicate this thesis to several people. Foremost, I would like to dedicate it to my biggest supporter, my best friend, and the person who keeps me on task, my beautiful wife, Kayla. Additionally, I would like to dedicate it to a pair of gentleman who helped me understand what Texas A&M is about, who set a masterful example of how to impact students lives, who always gave me irreplaceable advice, and who were good friends of mine; Dr. John McNeill and Dr. Howard Hesby.

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I would like to gratefully thank my committee, Drs. David Forrest, L.R. Sprott, Bill Holloway, and Kerry Barling, for their assistance and guidance through this project. I appreciate your understanding of my commitment coaching the livestock judging team while I pursued my M.S. I would like to thank Dr. Bobby Warrington at the experimental station in Uvalde, TX for his patience and time while helping me assemble data. Certainly, I would like to thank Kevin Curley, my statistician; for his time, intelligence, and lack of frustration with me. Plus, I would like to extend my gratitude towards Drs. Andy Herring, Jason Sawyer, and Jodi Sterle for their advice along the way.

Most importantly, I must thank my wife, Kayla for loving me, and supporting me in my quest to complete my thesis. Additionally, I must thank my families, both mom and dad and my in-laws Norman and Kathy Kohls. Life is about the people you surround yourself with, and I could not have been blessed with better people to support me than my wife and my families.

Being that I dedicated a large portion of my time to my passion, coaching the Texas A&M Livestock Judging Team from 2002 to 2004, I must thank many people in this arena. Foremost, I would like to thank Dr. Chris Skaggs, who is my mentor, and a perfect example of class. Thank you for the opportunities you gave me. I would like to thank the 44 members of my judging teams. I am extremely proud of their work ethic, heart, and character. Although, I'm sure it would be hard to give up the three National Championships we won, I would never trade the memories and stories of the times we

had on the road, or the friendships we now share. The relationships I have acquired with these students and those I have come into contact with at Texas A&M have shaped who I am and will make life's journey a truly special road.

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CHAPTER I

INTRODUCTION

Bull cost per kilogram of calf produced influences profitability of commercial cattle operations. The expense per bull, his fertility level, serving capacity and social dominance rank are factors that ultimately dictate bull cost per calf in multi-sire herds. Additionally, the number of bulls a cattleman must buy also impacts the total cost. Traditionally, the suggested bull to female ratio (BFR) is 1:25. How much benefit would there be in reducing the bull demand by one-half, if calf output could remain the same? Taking into consideration salvage value, bull maintenance, death risk, and interest on purchase price for a $1500 bull, the estimated bull cost per calf is $34.60 (Herman et al., 1994). This is assuming a BFR of 1:25. Obviously, this cost could be reduced to $17.30 per calf if BFR could be reduced to 1:50 given a constant bull price. Not only would a cattleman have to purchase fewer bulls, but he could also afford to upgrade to genetically superior bulls that would ultimately improve the performance of his calf crop.

Calf output distribution per bull has generally been demonstrated to be inefficient in multiple-sire herds at conventional BFR levels (Neville et al., 1989; Holroyd et al., 2002; Whitworth, 2002). Reducing the BFR could lead to increased efficiency of sire use in multiple-sire herds, but the potential adverse affects on reproductive performance must be investigated to validate this management practice. A recent publication has indicated that this theory may be possible in extensively-managed multiple-sire pastures (Fordyce et al., 2002). Investigations into maximum pasture size, minimal stocking rates, and bull

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grouping dynamics are necessary to validate these concepts and give confidence to commercial cattleman for their application. In experiment one we tested the hypothesis that the BFR in single- and multiple-sire breeding groups can be drastically reduced below the traditional level of 1:25 without adversely impacting the reproductive performance of the herd. The objectives of this study were to: (1) quantify the relationship between BFR and pregnancy rate, calving rate, and calving date in extensively-managed herds; (2) confirm that breeding pressure does not skew sex ratios; (3) determine relationships between BFR and change in sperm morphology and bull weight loss during the breeding season; (4) evaluate the repeatability of sperm motility, sperm morphology, and social dominance measurements taken pre- and post-breeding season; and (5) determine the difference in reproductive performance between bull groups with uniform versus extreme variation in social dominance rank in conventional BFR pastures.

It is imperative that replacement heifers reach puberty early, and conceive early in the breeding season, as these females will be more likely to remain in the breeding herd and will produce more kilograms of calf in their lifetime than heifers calving later the first time (Lesmeister et al., 1973). The reproductive tract scoring system is a classification system designed by researchers at Colorado State University to aid producers in management decisions regarding the selection of replacement heifers (Lefever and Odde, 1986). However, application has been minimal as only 1% of beef cattle operations in the United States utilize RTS (Field and Taylor, 2003), and its value has not be quantified in 90-d, natural mating programs. In experiment two, we tested the hypothesis that reproductive tract scores (RTS) are effective in estimating subsequent two-year reproductive performance in 90-d, natural mating breeding systems, and thus is a valuable selection tool for replacement heifers. The objectives of this study were to: (1) determine the influence of age, dam parity, frame score, weaning weight, post-weaning weight gain, and yearling weight on RTS; (2) determine the relationship between RTS and two-year reproductive performance of heifers placed in natural service, multiple-sire breeding groups in an extensively-managed environment; and (3) establish whether RTS can be used to identify heifers that should be culled on the first day of the breeding season, based upon their reproductive performance over their first two breeding years.

CHAPTER II

REVIEW OF LITERATURE

Bull Fertility

The breeding soundness evaluation (BSE) provides a systematic format for identifying problems that could potentially limit bull fertility (Hopkins and Spitzer, 1997). Its intent is to classify bulls as either satisfactory or unsatisfactory for breeding. However, the BSE does not give indication as to which bulls may be the most fertile or most capable of high and efficient rates of calf output. Perry et al. (1989) outlined three categories that exert the greatest influence upon reproductive performance: semen characteristics, sex drive and mating ability, and social interactions between animals in the breeding pasture. Two of these three traits are not evaluated in a standard BSE. These omissions contribute to the variability observed in the relationship between BSE classification and bull fertility (Makarechian and Farid, 1985; Neville et al., 1988). Many authors (Chenoweth, 1980; Perry et al., 1989; Holroyd et al., 2002) agree that no single trait is an accurate predictor of bull fertility, but rather that several variables which do not always act in harmony are influential. Therefore, some researchers have attempted to construct a fertility index that would encompass numerous traits and would predict reproductive performance with greater accuracy (Perry et al., 1989). Perry et al. (1989) used a step-wise regression procedure to select the most suitable combinations of traits that were highly correlated with pregnancy rates in single-sire mating groups. Interestingly, the most important traits incorporated into the fertility indices included testicular volume, induced, circulating LH concentration, libido score, and bodyweight with age and dominance value also being represented. The fertility indices derived were, in general, highly predictive of pregnancy rates with correlations mainly ranging from .66 to .89. A noteworthy exclusion from the model was BSE score. However, the author points out that mating load (bull to female ration) and breeding group (single- vs. multiple-sire) could impact which fertility traits are paramount.

The repeatability of reproductive performance over a bull's lifetime and repeatability of tests which measure bull fertility traits are two major concerns for accurate fertility assessments. Curiously, bulls tested immediately before or after the breeding season failed to yield significant correlations with pregnancy rates, while the correlations were significant when bulls were tested from 2 to 11 months prior to breeding (Perry et al., 1989). Farid et al. (1987) reported that the repeatability estimates of the measures of bull fertility were low, and that the reproductive performance of a 2-year-old bull cannot be accurately predicted from his performance as a yearling.

Holroyd et al. (2002) conducted an intensive study of bull fertility in multiple-sire breeding groups in Australia and suggested that it may be difficult to identify the extremely fertile, "super bulls". However, the authors concluded that a systematic physical and reproductive examination will identify a large number of bulls that will be poor contributors to calf output. The authors further explained that spermatozoa morphology was the only trait included in every predictive model. The authors indicated that once a trait reaches a threshold level, there may be little value in placing further emphasis on selecting bulls above that level in regard to the impact of that trait on calf output in multiple-sire herds.

There are other indirect variables that could be detrimental to bull fertility such as disease, age, injury, weather, and nutritional status (Barth et al., 2002). Nutritional differences can greatly confound BSE results in young growing bulls since nutrition impacts attainment of puberty and scrotal circumference growth (Coulter et al., 1997; Spitzer and Hopkins, 1997). Chenoweth et al. (1996b) conducted two trials with grass-fed bulls whose growth was delayed. The BSE was performed according to 1993 Society for Theriogenology guidelines. In yearling bulls that averaged 314 kg (trial 1) and 263 kg (trial 2), only 16 and 17%, respectively, were classified satisfactory potential breeders. However, at the completion of these two trials, when the bulls were 18 to 22 mo of age, satisfactory BSE scores were achieved by 74 and 59% of the bulls respectively, which then weighed 490 kg (trial 1) and 472 kg (trial 2). Spitzer and Hopkins (1997) suggest that it would be prudent not to conduct a BSE until the rate of bulls achieving the satisfactory potential breeder score is in line with the rate of development of the young bulls being assessed. However, a high plane of nutrition could also compromise male reproductive performance. Coulter and Kozub (1984) compared Hereford and Angus bulls on two different nutritional planes from 12 to 21 mo of age. High energy diets actually had detrimental effects on sperm output of bulls compared to their 100% forage-fed contemporaries. Excess scrotal fat deposition can cause thermoregulation problems which inhibit proper spermatogenesis (Barth, 1997; Kastelic et al., 1997).

Seminal Traits

Numerous procedures and measurements can be employed to quantify seminal traits which may or may not have significant correlations to fertility. Semen sample volume, color, concentration, mass activity, and percentage of live spermatozoa are some traits which have rarely been identified as having significant prediction value of reproductive performance (Hopkins and Spitzer, 1997). However, they can be an indication of sperm motility and morphology. Motility and morphology are the most commonly measured seminal traits, and a standard component of a BSE. A satisfactory sire's semen sample must display 30% or greater progressive forward motility, and 70% or greater normal morphology (Hopkins and Spitzer, 1997). Following these guidelines, a study that assessed 898 extensively-managed bulls in Costa Rica showed that 23.9% failed the BSE due to unsatisfactory sperm morphology (Chacon et al., 1999). Furthermore, sperm abnormalities were more prevalent in bulls less than 2 years of age and were highest in *Bos indicus x Bos taurus* bulls. Likewise, Kennedy et al. (2002) reviewed BSE results on 3,648 yearling bulls from performance test stations in the southeast United States and reported that 4% of bulls were classified as unsatisfactory due to inadequate sperm motility, 7% of bulls were unsatisfactory due to inadequate sperm morphology, and 2.6% of bulls failed due to a combination of both. Results likely vary due to the bias of the evaluator and subjectivity of the measurements.

Motility can be assessed in one of two ways (Hopkins and Spitzer, 1997). Gross motility is the amount of swirling activity present in a semen sample and is rated from very good to poor. The other method of measuring motility estimates individual sperm based on the percentage moving progressively forward. Motility is commonly considered a compensable trait, meaning that problems in motility can be overcome by increasing sperm numbers (Saacke et al., 1994; Saacke et al., 2000). However, Christensen et al. (1999) refutes this argument in a study that analyzed A. I. bulls in Denmark where both sperm motility collected from fresh ejaculates and post-thaw motility were found to be significantly correlated to non-return rates. The authors concluded that motility was not compensable because poor motility indicates other dysfunctions of the population of motile cells.

Whitworth (2002) attempted to include specific independent variables in an ANOVA model which accounted for number of calves sired per bull and reported that one of two experiments yielded the inclusion of motility as being significant. Fitzpatrick et al. (2002) discovered similar inconsistencies in their experiments. Sperm motility was related ($P < .05$) to calf output in 5/8 Brahman bulls but not in Santa Gertrudis and purebred Brahman bulls. Additionally, the authors noted that percentage of sperm motility results were moderately repeatable ($r = .44$) when collections were compared on an annual basis. Coulter and Kozub (1989) reported that, when three collections were taken within 4-d intervals, sperm motility was unchanged and comparisons among 1-, 2-, and 3-year-old bulls were unaffected by age. However, sperm motility is generally reported to be lower in bulls <15 mo of age (Carson and Wenzel, 1997) and in young *Bos indicus* bulls due to their later maturing genotype (Chenoweth et al., 1996a). Chacon et al. (2002) observed that sperm motility was higher during the breeding season than in samples collected at other times (62% versus 52%, respectively).

The evaluation of spermatozoa morphology entails classifying sperm as normal, having primary abnormalities, or having secondary abnormalities (Barth and Oko, 1989). Primary abnormalities are defects of the head and acrosome assumed to occur as a result of abnormal spermatogenesis within the testis. Secondary abnormalities are defects of the midpiece/principal piece as a result of abnormal epididymal function. Secondary abnormalities prevent successful fertilization due to a lack of motility. Some evaluators might also classify tertiary abnormalities, which are tail related defects, but these may or may not actually prevent successful motility. Abnormal spermatogenesis is the result of either genetic or environmental causes (Johnson, 1997). Typically, animals genetically programmed to produce abnormalities of sperm produce these problems on a consistent basis, while environmental effects will cause an animal's sperm morphology to fluctuate (Johnson, 1997).

Scrotal circumference is often linked with seminal characteristics. Coe (1999) reviewed BSE results from 1173 beef bulls ($<$15 mo of age). Among bulls with $\geq$30 cm scrotal circumference (SC) only 27% had $<$70% normal spermatozoa, whereas 70% of the bulls with $<$30 cm scrotal circumference produced $<$70% normal spermatozoa. However, the most accurate regression model based on age and scrotal circumference still explained only 11% of the variation in percentage of morphologically normal spermatozoa. Younger bulls ($\leq$12 mo of age) have been shown to ejaculate a greater prevalence of sperm with proximal and distal droplets, thus limiting their potential to achieve an acceptable percentage of normal spermatozoa (Johnson et al., 1998). Amman et al. (2000) reported that the incidence of proximal droplets decreased as young bulls mature, but their in vitro fertilization rates were severely compromised until the decrease in proximal droplets occurred. Because spermatogenesis is extremely temperature sensitive, Kastelic et al. (2001) hypothesized that ultrasonographic testicular echotexture is associated with seminal quality. Interestingly, the authors discovered a positive linear regression between ventral scrotal surface temperature and incidence of secondary sperm defects, but a negative linear regression with primary sperm defects. Additionally, the authors noted that scrotal circumference was positively related to epididymal sperm reserves.

It has been well illustrated that there is a stronger relationship between sperm morphology and calf output in multiple-sire pastures than motility (Coulter and Kozub, 1989; Fitzpatrick et al., 2002; Whitworth et al., 2002). Whitworth et al. (2002), concluded that bulls with ≤20% abnormal sperm morphology sired calves earlier in the breeding season, and sired more total calves throughout the calving season when compared to bulls with 20-30% or with >30% abnormal sperm morphology. These results are further validated by Australian scientists who conducted similar studies on extensively managed Santa Gertrudis and Brahman bulls (Fitzpatrick et al., 2002). They reported that bulls with <50% normal spermatozoa sired few calves while bulls with the highest calf output possessed >70% normal spermatozoa. Wiltbank and Parrish (1986) compared bull groups selected for ≥80% normal sperm morphology versus a random group of bulls unselected for semen traits. The two-year experiment used BFR of 4% in extremely large, multiple-sire groups on the King Ranch (Kingsville, TX) with 2-year old, Santa Gertrudis bulls. Results from year one yielded pregnancy rates five percentage points higher in the cow group exposed to the ≥80% normal morphology bulls. Year two compared ≥70% normal morphology bull groups to the control while using virgin heifers instead of first-calf cows. Results from year two warranted nearly identical pregnancy results as year one with a six percentage point increase over the unselected bull group. It should be recognized that although the results of this study are in line with that of previously mentioned authors, the number of observations is few because groups are being compared as opposed to individual sires within groups.

Sexual Behavior

Sexual behavior in bulls is associated with both libido and their mating ability. Libido is described as the bull's desire to mate or sexual aggressiveness, while mating ability is defined as the competence of the bull to perform the physical act of breeding (Chenoweth, 1983a). Libido is largely a genetically controlled, highly heritable trait, which is not related to seminal traits, and is not necessarily higher in the faster growing, most masculine bulls (Chenoweth, 1980). As with any behavior, libido is a response to endogenous or exogenous stimuli mediated through a variety of physiological mechanisms, learned experience and motivation (Bryant, 1989). Several researchers have investigated the relationship between levels of sexual behavior and circulating blood concentrations of LH and T but have not confirmed a strong relationship in mature bulls (Chenoweth et al., 1979; Boyd et al., 1988).

A sexual behavior test must be simple, quick, highly repeatable, and predictive of calf output (Chenoweth, 1997). Originally, a scoring system that subjectively ranked bulls from one (low libido) to ten (high libido) dependent upon their degree of sexual interest indicated by chin resting, sniffing, flehmen, mounting, and servicing was utilized (Chenoweth, 1983b). However, copulatory activity can be more accurately assessed by a test known as serving capacity. First proposed by Blockey (1976), serving capacity test designs have varied greatly amongst administrators. Likewise, results can vary greatly between *Bos taurus* and *Bos indicus* bulls (Chenoweth et al., 1996a; Silva-Mena et al., 2000). Earlier test designs focused on restraining females in service crates, and found this method to be more effective than restraint by halter (Blockey, 1981a). Blockey (1978) first concluded that the number of services a bull achieves over a 7.5 hr pasture mating period is predictive of the fertility in the beef herd, but later claimed that the testing period could be reduced to 1 hour (Blockey, 1981b). Wallach and Price (1988) found that restrained non-estrus females were as effective as restrained estrus females during a 20-min test. These findings are consistent with other authors, in that the primary stimulus for mounting is the immobility of the female (Chenoweth, 1980; Blockey, 1981b; Bertram et al., 2002).

Bos Indicus-influenced bulls have actually been shown to exhibit greater copulatory behavior in unrestrained pen tests versus stanchion tests (Hawkins et al., 1988). This could be attributed to variations in behavior (shy performers) or disposition characteristics (more temperamental) amongst *Bos Indicus* breeds compared to *Bos Taurus* breeds (Chenoweth and Osborne, 1975; Chenoweth et al., 1996a; Bertram et al., 2002). It would seem more logical to use an unrestrained group pen test for bulls to be utilized in multiple-sire breeding groups as this would stimulate natural breeding competition within sexually-active groups (Blockey, 1979). The unrestrained pen test involves placing a group of bulls with a group of unrestrained cows in standing estrus (synchronized) for a set time (usually 20 or 30 min). It has been suggested that in restrained female tests with multiple bulls that the BFR be held at 1:1 (Price and Wallach, 1991a), but with unrestrained pen tests BFR have been reported between 5:8 and 6:5 (Carpenter et al., 1992; Whitworth, 2002). The number of mounts (including any intromissions or ejaculations), intromissions (including any ejaculations) and ejaculations are generally recorded (Carpenter et al., 1992; Whitworth et al., 2002). However, some researchers feel there is no value in recording mounts and intromissions because of a lack of correlation with services (Price and Wallach, 1991b). Nonetheless, *Bos indicus* bulls are classified as high if they recorded two or more ejaculations, moderate if they achieved one ejaculation, and low if they did not have an ejaculation within the given time (Carpenter et al., 1992). Serving efficiency can also be calculated as a mount to service ratio (Whitworth, 2002). The author indicated that serving efficiency could be used as a tool to identify bulls of higher fertility, since there was a strong correlation between the ratio and number of calves sired. Boyd et al. (1989a) compared low and high serving capacity, crossbred, yearling bulls at a BFR of 1:25. The low serving capacity bulls had a less efficient mount to service ratio, still had fewer services per cow at pasture, and spent 1.2 hr/d less time grazing. These results indicate that poor serving efficiency could negatively impact the body condition of the bull over the duration of the breeding season.

Pruitt and Corah (1985) have shown that nutrition differences in the development of young bulls have not affected virgin serving capacity outcomes. However, serving capacity results can be greatly affected by age and sexual experience (Chenoweth et al., 1984; Bertram et al., 2002). It has been reported that the sexual behaviors of prepubertal beef bulls are ineffective in predicting adult (18 to 24 mo of age) sexual performance (Boyd et al., 1991; Price and Wallach, 1991c). Apparently, there is a certain learning curve in young virgin bulls, as sexual experience is necessary before serving capacity tests become successful and repeatable (Boyd et al., 1988; Boyd et al., 1989b; Godfrey and Lunstra, 1989). Price and Wallach (1991d) determined that serving capacity scores are underestimated in bulls until 18 mo of age. Repeatability of libido/serving capacity tests was measured by Lunstra (1984) as beef bulls mature. He noted a high correlation (r = .71) between the level of libido of yearling (16 mo) and mature (40 mo) Hereford bulls. In addition, libido was directly related to a bull's natural mating fertility (r = .90) and was retained as the bull matured. However, other authors (Landaeta-Hernadez et al., 2001) that have duplicated serving capacity tests with the same bulls over time have concluded that there is a lack of sufficient repeatability between tests.

Opinions based on individually derived studies appear to be quite diverse as to the value and predictability of a serving capacity test upon calf output. Trials by Christensen et al. (1982) in a tropical environment failed to yield a relationship between a 40-min yard test, and pregnancy rates after 3 or 7 wk of single-sire mating. Blockey (1989) strongly recommends that a minimum of three or more services within a 40-min serving capacity test with restrained females is imperative for optimal reproductive performance. In defense of this, his data showed that bulls with a serving capacity of $\geq$3 impregnated on average 89% of their cows in a 10-wk period, while their contemporaries with a serving capacity score of 1 or 2 only impregnated as high as 66.6% of their cows. Furthermore, the higher serving capacity bulls impregnated a higher percentage of cows on their first estrus. However, these results are based upon single-sire, *Bos taurus* breeding groups at a ratio of approximately one bull to 40 cows.

Godfrey and Lunstra (1989) determined that when observing high against low serving capacity bulls at pasture in single-sire situations there was no difference in breeding activity. However, in multiple-sire situations, the high serving capacity bulls did in fact achieve more services and impregnated more heifers. Using multiple-sire groups and blood typing calves, Coulter and Kozub (1989) determined that the number of services performed was positively correlated to fertility up to only four services, at which point fertility actually diminished with subsequent services. Alternatively, Australian multiple-sire data have shown that serving capacity measurements were not always correlated to calf output (Bertram et al., 2002). The authors concluded that expressions of sexual behavior by bulls in a serving capacity test do not appear to be a consistent predictor of calf output when the bulls are used in a multiple-sire mating group in extensive conditions. It could be hypothesized that serving capacity is not as critical in multiple-sire breeding groups because highly fertile bulls would compensate for subfertile bulls as evidence by the overlapping effect explained by Rupp et al. (1977). However, if a cattleman wanted to decrease the BFR it may be more critical to abide by the suggestion of a minimum serving capacity score of 3 (Blockey, 1989).

Adoption of a serving capacity test seems to be erratic because there is not an established protocol on testing as there is with BSE and there are inconsistent reports upon its effectiveness. Additionally, some bulls are shy performers, and temperament problems can misconstrue results (Bertram et al., 2002). However, the serving capacity test is always valuable to assess whether or not a bull is physically capable of natural service. Interestingly, libido/serving capacity scores do not necessarily work in concert with other traits known to influence bull fertility such as social dominance rank and BSE scores (Chenoweth et al., 1988). Farin et al. (1989) assigned libido and BSE scores to 93 bulls, and joined them with estrus synchronized females. The authors concluded that classification of bulls by libido scores could identify bulls that serviced more estrus synchronized females, but only BSE classifications proved valuable in predicting pregnancy rates.

Social Behavior

Like serving capacity tests, social behavior tests are not normally a standard component of a typical BSE. However, it has been well documented that the social ranking of bulls is correlated to calf output per individual sire when they are mated in multiple-sire groups (Coulter and Kozub, 1989; Fordyce et al., 2002; Whitworth et al., 2002). McCosker et al. (1989) reported this correlation to be 0.51 in multiple sire herds in northern Australia. Social dominance is established through observation. A group of bulls can be ranked subjectively according to their altercations against opposing bulls while competing for a feed source (Carpenter et al., 1990; Whitworth et al., 2002). The duration of observation would extend until the observer could establish the social dominance hierarchy of the group by determining the ratio of wins and losses between bulls. A win is described as one bull yielding to another.

Age and weight have been positively correlated to social dominance rankings (Rupp et al., 1977; Fordyce et al., 2002). It has also been noted that social dominance is not always synonymous with libido, or with BSE components (Chenoweth, 1980; Ologun et al., 1981). If this is true, it implies that the dominant bull in a multi-sire group may actually suppress pregnancy rate if he is subfertile or is deficient in sex drive because he discourages subordinate bulls from servicing. Likewise, the dominant bull may not be the one with superior conformation or production traits, and consequently calf crop genetic value would be depressed because the dominant, inferior bull sired the largest percentage of the calf crop. Blockey (1979) observed that mixed age groups of bulls achieved lower pregnancy rates than did groups of young, similarly aged bulls. Whitworth's (2002) findings are in agreement with these results.

Rupp et al. (1977) demonstrated that dominant bulls marked an estrus female more often, and mated a greater number of estrus females than subordinate bulls in a multiple-sire pasture. This logic supports the findings of Fordyce et al. (2002) in

Northern Australia where dominant bulls spent more time with cows, and sired more calves than did subordinate bulls. Additionally, these authors showed that calf output was more proportional among bulls of disparate social ranking when the BFR was reduced from 6.0% to 2.5%. The authors suggest that, when the work load is increased, bulls spend less time in altercations between each other and more time servicing females in estrus. Ultimately, social ranking is of less importance when the BFR is decreased. Alternatively, Carpenter et al. (1990) rejected the working hypothesis that dominant bulls would consistently sire more calves than subordinate bulls in a study with Braford and Angus bulls that were equivalent for seminal quality and serving capacity. The results indicated that at lower cow numbers dominant bulls sired more calves, but with higher cow numbers the subordinate-paired bull sired more calves. It appeared that the threshold was one bull per approximately 32 cows. However, both authors concluded that the effectiveness of social ranking as a predictor of calf output is largely dependent on the breeding ratio, and that more studies are needed to establish optimal mating ratios where herd dispersion is either very high or very low (Carpenter et al., 1990; Fordyce et al., 2002).

Multiple-Sire Breeding Groups

There are many arguments as to the benefits and potential downfalls of utilizing single- versus multiple-sire breeding groups. Neville et al. (1987) reported that two bulls assigned to 80 cows actually sired calves an average of 3.7 days earlier in the calving period than did single-sire bull arrangements exposed to 40 cows. There was no difference in calving rate except between breeds. This evidence indicates that there is greater sexual activity in multiple-sire groups due to competition among bulls. This is in agreement with observations made by Mattner et al. (1974), which revealed that there were over twice as many services and mounts in multiple- versus single-sire groups. Apparently, bulls from both groups were most sexually active at night, but bulls within multiple-sire breeding groups tended to be more active during daylight. Godfrey and Lunstra (1989) observed similar conclusions when comparing single- and multiple-sire mating behaviors. Additionally, these authors concluded that producers using multiple-sire groups should place priority on serving capacity, and use social dominance as a secondary consideration.

It has been suggested that multiple-sire herds are inefficient. Holroyd et al. (2002) reported that in their trials 58% of the bulls tested, sired 10% or fewer calves within their respective breeding groups. Neville et al. (1989) discovered similar inefficiencies in their experiments. Using twenty-six, two-sire groups the average proportion of calves sired by the high bulls was .64 versus .36 for the low bulls, with a range of .51 to .86 for the bulls with the highest proportion of calves. From this information, it is possible that reducing the BFR could result in a more uniform calf distribution among bulls in multiple-sire pastures. However, the paramount dilemma with improving the efficiency of multiple-sire herds is identifying bulls with superior reproductive capacity to ensure that calf output levels are sustained. Unfortunately, no single measurement has consistent predictive value upon calf output (Coulter and Kozub, 1989; Holroyd et al, 2002; Whitworth, 2002). Coulter and Kozub (1989) found that a linear regression model including scrotal circumference, seminal quality, backfat thickness, and libido only accounted for 29% of the total variation in fertility of 277 bulls used under extensive range conditions in multiple-sire herds.

There is disagreement regarding the influence of breeding overlap on fertility. Farin et al. (1982) indicated that there was an increase in first service pregnancy rate due to extra services. However, Rupp et al. (1977) claimed that an increase in the number of bulls that mated an estrus female did not increase the average conception rate of these females. It is quite possible that social dominance and serving capacity differences could have confounded results. Lunstra and Laster (1982) designed a study in Nebraska to minimize such factors. When three different sires each mated heifers once, conception rates were 11 percentage points higher than when each heifer was mated only once, or were mated three times by the same bull. This evidence would infer that a potential advantage of multiple-sire breeding groups would be that fertile bulls will compensate for sterile or sub-fertile bulls. Nelson et al. (1975) supports this concept through studies where semen from several, normal fertility sires was mixed and then inseminated artificially. Pregnancy rates were typically higher when compared to when semen from a single bull was used, but fertilization rates never exceeded that of the most fertile bull alone.

Bull to Female Ratio

Traditionally, cattlemen use a bull to female ratio (BFR) of 1:25. However, several researchers have challenged this notion. Neville et al. (1979) demonstrated that there was no statistical difference in percent calf crop between bulls placed with 25 cows versus 40 cows in a single-sire mating group. Rupp et al. (1977) demonstrated that overall pregnancy rates could still be maintained when the BFR was increased from 1:25 to 1:44 and even 1:60. Furthermore, Rupp et al. (1977) claimed that the fertility, libido, and mating ability of each bull were more important than the BFR or multi- vs. single sire situation, when based on conception rates. An Australian study showed that bulls with high serving capacity and a scrotal circumference of >33.5, achieved pregnancy rates of 52% to 63% in 20 days at a BFR of 1:75 (Blockey, 1989).

One potential limitation in decreasing BFRs could be the ability of the bull to detect all cows in estrus. Beerwinkle (1974) presented data that mounting rates declined from 95% at a BFR of 1:30, to 64% at 1:60, and then 51% at 1:100. However, serving capacity and libido differences could likely have confounded results. Due to the attraction of cattle coming into estrus to sexually active groups (SAG), it is unlikely that estrus would go undetected, even if BFR were reduced (Rupp et al., 1977). Rupp et al. (1977) reported estrus detection was equally good at BFR of 1:25, 1:44, and 1:60. Additionally, the number of bulls per pasture did not affect the number of heifers in which estrus was detected.

Fordyce et al. (2002) claimed that herd dispersion is a critical variable in the effectiveness of potentially reducing the BFR. Dispersion differences could be attributed to the size of the pasture, the number and location of watering points, the topography, tree or brush density, forage quality, and weather extremes (Fordyce et al., 2002). However, a study done on large ranches in Northwest Colorado in which the terrain ranges from arid flatland to mountainous showed no differences in pregnancy rates amongst increases in BFR from 1:16 to 1:24 and from 1:25 to 1:37 (Boyd et al., 1992). Interestingly, Fordyce et al. (2002) discovered that in their multiple-sire Australian study, bulls with the least amount of observed range movement tended to sire a greater proportion of the calves. This indicates that estrus females come to the bull as opposed to the bull constantly seeking estrus females. The authors also noted that a BFR greater than 3.5% tended to result in more instances of broken fences due to bulls seeking estrus females or antagonistic social behavior against neighboring bulls.

Sperm production could potentially be a rate limiting factor in reducing the BFR. Senger (2003) reports that after eight to ten successive ejaculates over several hours that sperm in the ejaculate can be reduced to nearly zero. Additionally, he suggests that when bulls are exposed to several females in estrus there is a strong likelihood that he will select one female and inseminate her numerous times. This could deplete the bull's extragonadal reserves and jeopardize successful pregnancies of other estrus females. However, Chenoweth (1983a) claimed in his review that bull mating potential is not limited by sperm production, as another fertile ejaculate may be produced within several minutes. Ghallab et al. (1987) collected six successive ejaculates, 15 min apart, from 19 bulls, and found no difference in total sperm abnormalities between ejaculates.

Boyd et al. (1989a) exposed yearling bulls, individually to 25 naturally cyclic cows for 3 d (average mating load), and subsequently to 9 estrus-synchronized cows for 1 d (heavy mating load). They discovered that body temperature was .7 to 1.2° C higher ($P < 0.05$) when bulls were engaged in heavy mating activity, which resulted in an average body temperature of 39.4° C for bulls under average mating loads and 39.5° C for bulls under heavy mating loads. The authors proposed that this fluctuation and increase in body temperature could be detrimental to reproductive performance of young bulls, but they did not have evidence to prove this hypothesis. Additionally, this study yielded similar averages for grazing time between the average and heavy mating load experiments despite the fact that the bulls obviously spent more time in mating activity while under increased pressure. Raadsma et al. (1983) monitored the grazing activity of single-sire mated, mature bulls during the breeding season and found that grazing activity did not differ from the first 3 wk of the season (heavy mating activity) to the end of the breeding season (low mating activity). Thus, it appears that mating activity has no effect on grazing time in either study. This evidence helps support the concept of decreasing the BFR, because bulls would still have similar nutritional planes in order to uphold body condition and help sustain reproductive function throughout the breeding season.

Reproductive Tract Score

The reproductive efficiency of a cowherd is largely dependent upon replacement heifer management and selection. Researchers at Colorado State University (LeFever and Odde, 1986; Anderson et al., 1991) designed a 5-point scoring system to measure the pubertal status of virgin beef heifers prior to the start of the breeding season. This subjective assessment is based upon palpation for rectum of the uterine horns, ovaries, and ovarian structures. Transrectal ultrasonography has been utilized to show that marked growth of the reproductive tract in heifer calves occurs during the first few months of age, and prior to first ovulation. Prepubertal development of the reproductive tract is concomitant with phases of increased ovarian follicle numbers and size (Honaramooz et al., 2004). The RTS system is recommended as a selection tool for replacement heifer candidates, because of its potential to predict their subsequent reproductive performance. The system holds potential value in estimating pregnancy rates, the timing of conception during the breeding season, and the likelihood of subsequent conception as a first-calf heifer. A RTS classification of 1 is described as having no uterine tone, and no palpable ovarian structures. A RTS of 2 is characterized by a 20 to 25 mm uterine horn diameter without tone and ovarian follicles of less than 8 mm in diameter. RTS 3 heifers have uterine horn diameter of 25 to 30 mm, slight uterine tone, and 8 to 10 mm diameter ovarian follicles. RTS 4 heifers have a 30 mm uterine horn diameter with good tone, ovarian follicles with a diameter greater that 10 mm, and a possible corpus luteum (CL). Finally, RTS 5 heifers have greater than a 30 mm uterine horn diameter, and the presence of a palpable CL. Heifers with a RTS of 1 to 3 are considered prepubertal, while heifers with a RTS of 4 and 5 are considered postpubertal (LeFever and Odde, 1986).

Due to the subjective nature of the RTS system, the repeatability and accuracy of the examinations outcome is a concern. RTS examinations (n=174) were performed over a 3-mo period on 29 heifers by two veterinarians, one with 22 years of experience and the other a recent graduate (Rosenkrans and Hardin, 2003). Heifers were examined in the morning and then were randomized and reexamined in the afternoon. Multicategory Kappa agreement was substantial within veterinarians (0.64), moderate between veterinarians (.46), and fair when compared against ultrasound (.35). Rosenkrans and Hardin (2003) concluded that their study did validate the RTS system as a repeatable and accurate screening test to assess the pubertal status of heifer groups prior to the onset of the breeding season. However, due to an 18% false negative rate (heifers classified as prepubertal that were actually pubertal) the authors do not recommend the system be used to cull individual animals. Since it is typically suggested that only RTS 1 heifers should be culled, it would appear that the most critical identification is to accurately determine the females in the RTS 1 classification rather than determining which females are prepubertal.

The timing of the RTS exam is critical to its utilization in management decisions. Heifers exhibit higher conception rates on their third estrus (78%) compared to their first-service (57%) or pubertal estrus (Byerley et al., 1987). The probability of heifers conceiving during their pubertal estrus increased with age, while age was not a factor on their third estrus. Therefore, heifers should reach puberty one to three months prior to breeding to ensure that a high percentage of heifers are cycling and that the effects of lowered potential fertility at first estrus are minimized (Patterson et al., 2005). It is normally inferred that RTS exams should be administered 30 to 60 days prior to the proposed start of the breeding season or synchronization treatment or when half of the heifers are thought to be cycling (Torell et al., 1996). There does not appear to be any published data on the effectiveness of RTS exams given immediately before the breeding season or its effectiveness in predicting reproductive performance of heifers placed in natural service, multiple-sire breeding groups. From a management perspective, RTS scores could be utilized in culling decisions, to determine when to start a synchronization program or to determine that an adjustment needs to be made in the nutritional plane of the heifers prior to the breeding season to increase pregnancy rate (Torrel et al., 1996; Patterson et al., 2005).

The RTS values have proven to be predictive of reproductive performance in yearling heifers used in synchronization programs and at the end of the breeding season. In a review by Williams (2001), he averaged the results from five studies relating RTS to pregnancy outcomes in synchronization/AI programs, which were followed by a 45-day natural service breeding season. The RTS 1 heifers achieved only a 2.6% pregnancy rate from synchronized breeding and only a 28.2% pregnancy rate by the end of the breeding season. The RTS 2 heifers had a 22.6% pregnancy rate from synchronized breeding and 74.2% pregnancy rate at the conclusion of the breeding season. The RTS 3 heifers had a synchronized breeding pregnancy rate of 39.5% but were still comparable to RTS 2 heifers by the end of the season at a pregnancy rate of 76.8%. RTS 4 and 5 heifers were the most successful with comparable pregnancy rates of 54.6% and 55%, respectively, from synchronized breeding, and 94.1% and 85% pregnancy rates, respectively, by the end of the breeding season. Furthermore, the RTS 1 heifers conceived an average of 19 days later than the RTS 5 heifers. Based on this evidence, it would appear logical to cull the RTS 1 heifers. Another study evaluated the relationship between RTS and reproductive performance in 1017 heifers during a 5-year period (Pence and BreDahl, 1999). An RTS exam was performed between 30 and 60 d prior to breeding, estrus cycles were synchronized and heifers were mated by AI 12 hr after they were observed in standing estrus. Heifers with an RTS of 1 were culled prior to breeding. There was a positive correlation between reproductive tract score and pregnancy to AI. The data revealed that in each of the years studied, AI pregnancy rate generally increased as the RTS increased: RTS 2 - 50% pregnant; RTS 3 - 40% pregnant; RTS 4 – 54% pregnant; RTS 5 – 62% pregnant. In addition, final pregnancy rate (including pregnancy to AI and natural service) was increased as the RTS increased: RTS 2 – 75% pregnant; RTS 3 – 86% pregnant; RTS 4 – 87% pregnant; RTS 5 – 93% pregnant.

RTS is believed to be moderately heritable at 0.32 (Pence and BreDahl, 1999). Age and weight at puberty are moderately to highly heritable traits (Dhuyvetter and Lardy, 1999). This could lead one to speculate that age and weight could be used indirectly as selection tools to influence RTS.

CHAPTER III

EFFECTS OF CONVENTIONAL OR LOW BULL TO FEMALE RATIO IN EXTENSIVELY-MANAGED, NATURAL MATING BREEDING GROUPS

Materials and Methods

This study was conducted at the Texas A&M Agricultural Research and Extension Center in Uvalde, TX. Range conditions at the ranch (6,780 ha) are extensive and the environment is semi-arid. The current study involved three 90-d breeding seasons (April to July) from 2002 to 2004 and the information on the resulting calf crops. Bonsmara bulls (n = 16 for 2002; n = 11 for 2003; n = 14 for 2004; 20-24 mo of age) were obtained from George Chapman in McClean, TX at least 2 wk prior to the beginning of each breeding season. Upon arrival, bulls received *ad libitum* water and sorghum hay until partitioned into respective breeding groups. Breeding soundness evaluations (BSE) were performed and social dominance rankings were determined both pre- and post- breeding season. Serving capacity tests were administered only pre-breeding season due to availability of non-pregnant females for synchronization of estrus. Pre-breeding evaluations were performed the day before the start of the season, and post-breeding evaluations were performed from 2 to 4 wk after the conclusion of the season. Based on the results of these tests, bulls were allotted to multiple-sire pastures (with the exception of one pasture) with BFR ranging from 1:16 to 1:53. Sixty to 75 days following the conclusion of the breeding season, females were palpated per rectum to determine pregnancy status. Three measures of reproductive performance were evaluated for each breeding group: pregnancy rate, calving rate, and calving date.

Bull Allotment. Over the course of three breeding seasons, Bonsmara bulls (n = 41) were assigned to fourteen different breeding pastures. Bulls were joined with crossbred females of varying percentages of Bonsmara, Tuli, Angus, Brahman, and Hereford. In 2002, three mature cow breeding groups (n = 203; 2-12 yr of age) and one heifer group (n = 110; 11-14 mo of age) were utilized at BFR that ranged from 1:16 to 1:22. In 2003, four mature female breeding groups (n = 308; 2-12 yr of age) and one heifer group (n = 106; 11-14 mo of age) were utilized at BFR that ranged from 1:24 to 1:53. In 2004, four mature female breeding groups (n = 278; 3-12 yr of age) and one heifer group (n = 193; 11-26 mo of age) were utilized at BFR that ranged from 1:21 and 1:48. The composition of females in each pasture was similar across years in order to facilitate cross year comparisons. Bulls were assigned to each breeding pasture based on the average motility, serving capacity (number of ejaculates), and social dominance of the group. The average values for the aforementioned characteristics were similar for bull groups across pastures.

BSE. Standards employed to determine if a bull was a satisfactory potential breeder followed the Society for Theriogenology's guidelines (Hopkins and Spitzer, 1997). However, sperm morphology was not assessed prior to identifying bulls which would be utilized in the study. Additionally, the 2003 pre-breeding BSE was performed prior to bulls being transported to Uvalde, TX. Physical traits measured included body weight (BW), scrotal circumference (SC), body condition score (BCS) and frame score (FS). Body condition score was based on a scale of one to nine, with one being emaciated and nine being obese (BIF, 2002). Frame score was based on a scale of one to nine, with one being the smallest and nine being the largest (BIF, 2002). Physical data were unavailable for the 2004 post-breeding season evaluation.

Semen samples were collected by electroejaculation (Electrojac II, Chicago, IL). A sample of each collection was immediately placed upon a slide, covered with a cover slip, and observed at 400 X magnification with a light microscope to assess if the ejaculate contained enough sperm to warrant a successful evaluation. If the sample was deemed adequate, then the percentage of progressively motile spermatozoa was estimated in increments of 10 percentage points. A drop of semen was placed on a slide, subsequently mixed with a commercially available eosin-nigrosin stain (Semen Analysis Kit, A.J.P. Scientific, Inc., Clifton, NJ), and smeared. Each slide was allowed to air dry and then transported to a lab at Texas A&M University (College Station, TX) for morphological assessment at a latter date. Percentage of normal sperm morphology, percentage of primary abnormalities and percentage of secondary sperm abnormalities were classified according to the standards set by Barth and Oko (1989).

Social Dominance. Social ranking was determined by observation. Bulls were randomly allotted into groups (n = 5 to 8 bulls) and allowed to compete for a feed source. Each encounter between bulls was recorded as a win, loss, or tie (Carpenter et al., 1990). A win was defined as one bull yielding to another. Once initial social ranking was determined the bulls were categorized as either high or low (based upon median social rank within group) and redistributed into like groups. A second social rank was determined among bulls within contemporary groups. Final social rank was based upon the social dominance hierarchy within the entire group of bulls. Post-breeding season social dominance ranking was only available in 2002.

Serving Capacity. Twelve days prior to serving capacity tests (d 0), females (n = 25) were administered a Syncro-Mate B implant (SMB; Rhone Merieux, Inc., Athens, GA) that contained 6 mg norgestomet. Implants were removed at 1700 on d 10, and an injection of estradiol benzoate (1 mg) was administered at 0800 on d 11. The next morning from 0700 to 0730 females in standing estrus were identified. Bulls were placed with estrus females at a ratio of .75-1.4 for 30 min. The BFR depended upon availability of estrus females. Copulatory behavior was then assessed by recording the number of mounts (M), intromissions (I), and ejaculations (E). Determination of ejaculation was based on whether a bull displayed pelvic thrust. Serving capacity scores were based on total number of E, and classified as low (2 or fewer E), medium (3 E), and high (4 or more E). Serving efficiency (SE) was calculated ((M +I+E) / E).

Conventional vs Low Bull to Female Ratio. Breeding groups were allotted to either a Conventional BFR (ranged from 1:21 to1:29) or a Low BFR (ranged from 1:47 to 1:52). A total of six conventional and two low BFR groups in 2003 and 2004 were compared for differences in pregnancy rate, calving rate, and calving date. Only mature female groups were analyzed statistically. In addition, heifer groups from all three years were averaged and reported (one Conventional and two Low BFR groups). Progeny sex ratios were recorded per pasture, and totaled within Conventional and Low BFR groups. Allotment of bulls to BFR treatment group was based upon physical, reproductive, and behavioral traits. Mean values for BW, BCS, FS, SC, spermatozoa motility, normal sperm morphology, serving capacity, serving efficiency, and social rank did not differ ($P > 0.05$) between Conventional and Low groups (Table 1). To account for variability in number of bulls each year, social dominance rankings were converted into percentages and reported on a scale of one to ten.

Table 1. Means for physical, reproductive, and behavioral traits of bulls allotted to either Conventional or Low bull to female ratio (BFR) groups

	BFR		Pooled	
	Conventional	Low	SEM	P-Value
Weight (kg)	595.4	586.3	13.28	0.793
Body condition score	5.5	5.5	0.13	0.967
Frame score	5.9	6.5	0.13	0.962
Scrotal circumference (cm)	37.8	37.8	0.73	0.968
Spermatozoal motility (%)	67.2	75.0	4.34	0.500
Normal morphology (%)	77.3	90.0	2.08	0.051
Serving capacity	2.3	2.5	0.20	0.684
Serving efficiency	5.11	3.99	0.34	0.235
Social rank[a]	5.7	5.1	0.60	0.527

[a] Adjusted to a scale of 1 to 10

Statistical Analysis. The SAS program (SAS Inst. Inc., Cary, NC) was utilized to analyze all data. Least square (LS) means by BFR group were derived by the GLM procedure to determine treatment differences for pregnancy rate, calving rate, and calving date. Because pregnancy rate and calving rate were recorded as a percentage of the total, these data were adjusted to fit a normal, independent distribution by an arcsine transformation for the purpose of statistical analysis. Additionally, progeny gender ratio by BFR group was analyzed using chi-square distribution frequency analyses. The GLM procedure was used to compare LS means for physical, reproductive, and behavioral traits of bulls allotted to either Conventional or Low BFR groups. Once again, because spermatozoal motility, and normal morphology data were recorded as a percentage of the total, these data were adjusted to fit a normal, independent distribution by an arcsine transformation for the purpose of statistical analysis.

Repeatability of and Relationships among Physical and Reproductive Traits of Bulls. The repeatability of BW, BCS, FS, SC, percentage of motile spermatozoa, percentage of normal spermatozoal morphology, percentage of primary sperm abnormalities, percentage of secondary sperm abnormalities, and social rank was determined from pre- to post-breeding season in 2002 (n = 16). Bulls from 2002 and 2003 were analyzed for relationships between change in percentage of normal spermatozoal morphology and changes in bull weight and BCS from pre- to post-breeding season (n = 27). Finally, bulls from all three years were evaluated for relationships between breeding pressure (Conventional vs Low BFR group) and change in percentage of normal morphology (n = 41).

Statistical Analysis. Pearson correlation coefficients were utilized to determine the repeatability between pre- and post- breeding season bull fertility traits and the relationship between change in sperm morphology and change in weight or BCS. Change in percentage of normal sperm morphology, and change in weight or BCS between Conventional and Low BFR groups was analyzed by LS mean differences using the GLM procedure. Once again, data reported as a percentage of a total were adjusted to fit a normal, independent distribution by an arcsine transformation for the purpose of statistical analysis.

Uniform vs Extreme Variation in Social Arrangement in Conventional BFR Groups. Conventional BFR breeding groups comprised of mature cows from 2002, 2003, and 2004 were utilized to determine differences in pregnancy rates among pastures assigned bulls with uniform (n = 5) versus extreme variation (n = 4) in social rank. Each year social dominance was ranked pre-breeding season within the entire group of bulls. The total group ranking was then divided into three equal subgroups and designated as dominant, moderate, or submissive. If a dominant bull was paired with a submissive bull in the same breeding pasture then the group was deemed extreme. If there were no dominant and submissive bulls paired together in the same pasture then these groups were deemed uniform.

Statistical Analysis. Least square (LS) means were derived by the GLM procedure of SAS to determine differences in pregnancy rates between uniform and extreme social rank groups. Once again, pregnancy rate data were adjusted to fit a normal, independent distribution by an arcsine transformation for the purpose of statistical analysis.

Results

Conventional vs Low Bull to Female Ratio. The breeding groups were allotted to either Conventional or Low BFR treatments. Pregnancy rate, calving rate, and mean calving date did not differ between (P > 0.20) between BFR treatments (Table 2). Although, the Low BFR groups tended to have an advantage in pregnancy rate (94.78 vs. 90.68%), the Conventional BFR groups conceived an average of eight days earlier in the breeding season. Weaning weights were only available for 2003, and calves averaged 35.77 kg heavier at weaning for the Conventional than for Low BFR groups (P = 0.20). Pregnancy rate ranged from 87.50 to 98.25% for Conventional BFR groups, while the two Low BFR groups recorded 91.49 and 98.06% pregnancy rates, respectively.

Table 2. Reproductive performance of mature female groups assigned to Conventional or Low bull to female ratio (BFR) groups

	BFR		Pooled	
	Conventional	Low	SEM	P-Value
Pregnancy rate (%)	90.68	94.78	0.56	0.33
Calving rate (%)	90.39	94.78	0.56	0.26
Calving date[a] (d)	308	316	3.41	0.22

[a] Interval from start of breeding until calving

Table 3 represents averages from breeding groups which contained only virgin heifers, or virgin heifers and first-calf heifers. The effects of BFR were not statistically analyzed since there was only one heifer group allotted to the Conventional BFR treatment. Obviously, reproductive performance expectations are not as high for heifers as for mature cows. Management reasons prevented the mixture of females for the sake of the current study. The two Low BFR heifer groups achieved 79.79 and 85.85% pregnancy rates, respectively, compared to 81.99% by the Conventional BFR heifer group. The trend for an earlier calving date for heifers allotted to Low BFR than for Conventional BFR groups was opposite of the trend found with the mature female groups.

Table 3. Reproductive performance of heifer groups assigned to Conventional or Low bull to female ratio (BFR) groups

	BFR			
	Conventional[a]	Number of heifers	Low[b]	Number of heifers
Pregnancy Rate (%)	81.99	111	82.82	299
Calving Rate (%)	81.99	111	82.82	299
Calving Date[c] (d)	330	91	324.5	245

[a] Mean calculated within one breeding group
[b] Mean calculated between two breeding groups
[c] Interval from start of breeding until calving

Chi-square frequency analyses were used to evaluate variations in the calf sex ratio between Conventional and Low BFR groups. No differences ($P > 0.10$) were found in gender distribution compared to the expected 50:50 ratio (Table 4).

Table 4. Sex ratio of progeny by bull to female ratio (BFR) treatment group

	Number of progeny			
BFR	Male	Female	χ^2	P-Value
Conventional	161	144	0.4734	> 0.10
Low	90	100	0.2633	> 0.10
Total (%)	251 (50.7%)	244 (49.3%)		

Repeatability of and Relationships among Physical and Reproductive Traits of Bulls. The repeatability of bull fertility traits before and after the 90-d breeding season was analyzed by Pearson Correlation Coefficient (n = 16). Only bull weight (r = 0.66), scrotal circumference (r = 0.81), and social rank (r = 0.55) were significantly repeatable (Table 5). Body condition score, sperm motility, sperm morphology, primary abnormalities, and secondary abnormalities before the breeding season were not significantly correlated with their respective values after the breeding season.

Table 5. Repeatability of physical and reproductive traits of bulls pre- and post- breeding season

	Body			Spermatozoa %		% Primary	%Secondary	Social
	Weight	BCS[a]	SC[b]	Motile	Normal	Abnorm.	Abnorm.	Rank
r	0.66**	0.18	0.81***	0.12	0.35	0.36	0.25	0.55*

*** P < 0.001
** P < 0.01
* P < 0.05
[a] Body condition score
[b] Scrotal circumference

The 2002 and 2003 bulls were analyzed by Pearson Correlation Coefficients for relationships between percentage normal sperm morphology change, and BW or BCS change between pre- and post-breeding season (n = 27). The percentage normal sperm morphology change was not associated with BW change (r = 0.31, P = 0.1098) or BCS change (r = 0.01, P = 0.97). Data from the heifer groups were included with data from mature cows for 2003 and 2004 to determine differences between bulls assigned to Conventional or Low BFR groups in percentage normal sperm morphology change from pre- to post-breeding season. In 2003, bulls assigned to Conventional BFR groups had a change of -19.7±7.7%, and bulls allotted to Low BFR groups had a change of -27.0±8.4% in normal spermatozoa (P = 0.54). In 2004, bulls assigned to Conventional BFR groups had a change of 9.0± 5.4%, and bulls in the Low BFR groups had a change of 6.5± 8.0% in normal spermatozoa (P = 0.80). Once again, data from the heifer groups were included, but only the 2003 bulls (n = 11) were analyzed to determine differences between bulls assigned to Conventional or Low BFR groups for BW and BCS from pre- to post-breeding season. Bulls allotted to Conventional BFR groups had a change of -12.2±14.9 kg, and bulls in the Low BFR groups had a change of -4.1±16.3 kg in BW (P = 0.73). Bulls allotted to Conventional BFR groups had a change of -0.3±0.4 kg, and bulls in the Low BFR groups had a change of 0±0.4 kg change in BW (P = 0.56).

Uniform vs Extreme Variation in Social Arrangement in Conventional BFR Groups. Each multiple-sire breeding group was classified as either Uniform or Extreme in their social arrangement. Only the Conventional BFR groups comprised of mature cows from 2002, 2003, and 2004 were analyzed (n = 9). Table 6 displays reproductive performance outcomes between Uniform and Extreme social arrangement bull groups. Social arrangement had no affect on pregnancy rate (P = 0.72), calving rate (P = 0.72), or calving date (P = 0.84).

Table 6. Reproductive performance of mature female groups assigned to Uniform or Extreme social arrangement bull groups

	Social Arrangement		Pooled	
	Uniform	Extreme	SEM	P-Value
Pregnancy rate (%)	92.80	91.44	2.60	0.72
Calving rate (%)	92.28	91.09	2.28	0.72
Calving date[a] (d)	312	311	3.61	0.84

[a] Interval from start of breeding until calving

Discussion

In single-sire mating groups, Neville et al. (1979) demonstrated that lowering the BFR from 1:25 to 1:40 had no adverse affects on pregnancy rates, and Rupp et al. (1977) reported a similar conclusion when BFR was lowered to 1:44 or 1:60. In extensive, multiple-sire pastures, the BFR can be reduced to 2.5% (1:40) without detrimental effects upon calf output (Fordyce et al., 2002). The findings in our study are in agreement with these authors for both single- and multiple-sire breeding groups. However, caution should be exercised in the application of reduced BFR breeding groups. Since each pasture is an observation, it is difficult to conduct a study which yields a large data set. However, results from the current study and from the aforementioned studies demonstrate that it is possible to reduce BFR under the conditions tested in these studies.

The criteria that are necessary to achieve success with a reduced BFR must be defined. Bull groups used in the current study were in moderate body condition, classified as satisfactory by a BSE and averaged a moderate serving capacity classification. Likewise, a manager must weigh the potential upside cost savings against the downside risk for his/her particular operation. The potential advantages of reducing the BFR would include: a decrease in bull cost per calf, each absent bull can be replaced in the breeding herd with females, an operation will have more capital to purchase bulls of superior genetics, and in turn it is likely that greater genetic merit will be represented by increased performance in the calf crop. The potential disadvantages of reducing BFR would include: an increased risk of a low pregnancy rate if a bull is injured during the breeding season, average calving date (conception date) may be slightly delayed (current study), and bulls may be thinner after the breeding season and require a higher plane of nutrition and/or recovery time.

There are numerous variables which could potentially impact the success or failure of reducing BFR below conventional levels. It is possible, that in this study and in the Australian study (Fordyce et al., 2002), that not all females were cycling at the beginning of the breeding season and thus estrus frequency and mating demand would have been diluted over a longer span of time. Investigations into optimal BFR for estrus-synchronized females exposed to multiple-sires lend insight into possible limitations of a reduced BFR if all females are cycling at the beginning of the breeding season. Healy et al. (1993) determined that the optimal BFR level is 1:25 with estrus-synchronized females (83% pregnancy rate during a 28-d breeding season). The authors reported a 6% decrease in pregnancy rate when BFR was increased to 1:50. Although pregnancy rates were comparable for females subjected to a BFR of 1:16, the females calved three days sooner than females in the BFR treatment of 1:25, but an economic analysis indicated that the BFR group of 1:25 yielded the highest return (Healy et al., 1993). It is likely that strict serving capacity standards must be employed for bull candidates utilized in low

BFR groups. In the current study, all bulls used in Low BFR treatments had serving capacity scores of ≥ 2.

Calving dates were not significantly different between Conventional versus Low BFR treatments. However, the Low BFR groups of mature females in both years did calve and average of 8 d later, but a lack of observations likely prevented a true reflection of whether or not Low BFR treatments affect conception date. It could be hypothesized that due to greater breeding demands in either single- or multiple-sire groups, ideal service times were compromised in some females. On the other hand, there would be a greater chance of heterospermic insemination in multiple-sire groups with less breeding pressure which would result in higher fertilization rates due to innate differences between males, or a more appropriate interval from natural service insemination to ovulation when inseminations are not simultaneous (Dziuk, 1996). Further studies will be needed to investigate the affects of low BFR levels on the timing of service and resulting calving dates. Timing of insemination relative to ovulation may influence the gender ratio of progeny (Baublits et al., 2003). The gender ratio of progeny did not differ between Low and Conventional BFR groups in the current study.

The ability of bulls to detect all females in estrus is a potential concern of low BFR groups. Beerwinkle (1974) indicated that estrus detection rate was 95% at a BFR of 1:30, but only 64% at a BFR of 1:60. In contrast, Rupp et al. (1977) reported that estrus detection was equally adequate at BFR of 1:25, 1:44, or 1:60. The attraction of estrus females to sexually active groups helps negate the inability of bulls to seek out all females in estrus. In fact, bulls with the least range of movement sire the greatest proportion of calves (Fordyce et al., 2002). This could suggest that sexually active groups of females attract bulls, and the social behavior of bulls that have limited range of movement results in them siring more calves. However, a potential obstacle to the formation of these sexually active groups could be pastures with high herd dispersion due to extensive stocking rates. The current study involved two Low BFR pastures of 2,090 ha and 1,049 ha, respectively. The Australian study utilized low BFR paddocks up to 6,000 ha size (Fordyce et al., 2002). Neither study found adverse calf output effects in extensive pastures at Low BFR.

Fordyce et al. (2002) claimed that herd dispersion is a critical variable in the effectiveness of potentially reducing the BFR. Dispersion differences could be attributed to the size of the pasture, the number and location of watering points, the topography, tree or brush density, forage quality, and weather extremes. The analysis of range use with GPS technology in the Edwards Plateau and Rio Grande Plains region in Texas indicated that all ranches had uneven grazing distribution problems (Lyons et al., 2005). On the ranches in the Edwards Plateau, areas with increased slope, rock, and brush density deterred cattle from even dispersion, and on the Rio Grande ranch, brush cover and brush density were the major barriers to grazing. The authors did demonstrate that controlling water access could improve grazing distribution by attracting animals to less-preferred areas. Once cattle become accustomed to liquid protein supplements, the supplements can be utililized to attract cattle to under-grazed areas within pastures in south Texas (Warrington et al., 2004). However, the authors did note that rainfall and watering points tended to have the greatest influence on cattle movement in large pastures. Warrington et al. (2004) reported that grazing patterns indicated skewed distribution in the Prairie pasture (1,088.06 ha) which was one of the pastures utilized in the current study. In future studies, placement of GPS transponders on both bulls and females could be utilized in large pastures of varying sizes with low BFR to elucidate relationships between herd dispersion and pregnancy rate. Additionally, if cyclicity was determined in the females with transrectal ultrasonography prior to bull exposure and the bulls were fitted with chin-ball markers with different colored paint during the first 21 days of the breeding season, then observations could be made upon estrus detection and first service pregnancy rates relative to BFR in pastures with variation in herd dispersion.

The current study failed to find a relationship between BFR treatment and change in sperm morphology. In addition, sperm morphology was not correlated to a change in BW or BCS. Furthermore, there were no significant relationships between BFR treatment and changes in BW or BCS during the breeding season. These data are in agreement with results from an Australian study (Fordyce et al., 2002). The authors determined that the “harder working” bulls (bulls that sired the greatest proportion of calves) had no relationship with body condition loss. Additionally, the bulls in low BFR pastures (1:40) maintained body condition, while bull attrition occurred in conventional BFR pastures. The authors attributed the attrition to heightened agonistic behavior between bulls with a higher ratio of bulls to females. Multiple grazing-time studies have concluded that breeding pressure does not affect daily grazing length (Raadsma et al., 1983; Boyd et al., 1989a). Collectively, these results support the theory that weight and body condition losses during the breeding season are not limiting factors to reducing the BFR below conventional levels.

Although it has been demonstrated that social dominance is highly related to the proportion of calves sired per individual bull in multiple-sire groups (Coulter and Kozub, 1989; Fordyce et al., 2002; Whitworth et al., 2002), the effect of variations in social arrangement between groups on total pregnancy rate has not been reported. In the current study, uniform versus extreme variation in social behavior groupings yielded no difference in pregnancy rate when comparing Conventional BFR groups. Likewise, variation in social behavior between bulls in the multiple-sire Low BFR group was uniform and successful pregnancy rates were obtained (98.06%). We did not determine the influence of extreme social arrangement of bulls in the Low BFR groups in the current study. Social variations among bulls within the same breeding group are of less significance with regard to pregnancy rate when BFR is lowered (Carpenter et al., 1990). However, it appears that despite the breeding pressure social arrangement is insignificant in relation to total pregnancy rate for the group.

There is limited information regarding the repeatability of social dominance tests amongst bulls. The current study indicates that social ranking is repeatable before and after a 90-d breeding season (r = .55). Sperm motility has been shown to be moderately repeatable on an annual basis (r = .44) (Fitzpatrick et al., 2002), and unchanged during 4-d intervals (Coulter and Kozub, 1989). Sperm motility can also be higher after mating activity (Chacon et al., 2002). This could explain why spermatozoal motility repeatability was not significant in the current study. Spermatozoal morphology, primary abnormalities, and secondary abnormalities were also not repeatable. As stated before, there was no relationship between breeding pressures upon changes in spermatozoal morphology. Seasonal effects could have accounted for the lack of correlation between a late spring, pre-mating seminal evaluation and a mid-summer post-evaluation. Environmental effects will cause fluctuations in sperm morphology (Johnson, 1997).

CHAPTER IV

UTILIZATION OF REPRODUCTIVE TRACT SCORES IN EXTENSIVELY-MANAGED, NATURAL MATING BREEDING GROUPS

Materials and Methods

This study was conducted at the Texas A&M Agricultural Research and Extension Center in Uvalde, TX. Range conditions at the ranch (6,780 ha) are extensive and the environment is semi-arid. The current study involved the development of replacement heifers (n = 106) and the information on their resulting reproductive productivity through 3.5 yr of age. The Bonsmara-sired heifers were born at the ranch between January 21 and May 2, 2002. A portion of the heifer calves (n = 26) were produced from first-calf heifer dams, and their breed composition was three-quarter Bonsmara and one-quarter Brahman, Tuli, or Angus or crosses thereof. The remaining heifer calves (n = 80) were produced from mature cow dams and their breed composition was one-half Bonsmara and one-half Brahman, Tuli, or Angus or crosses thereof. The heifer calves were not creep-fed while on their dam. After weaning at approximately 7 mo of age heifer calves were retained in a dry lot for 30 d and fed 3.6 kg per day of an 11% CP commercial feed. Additionally, they received *ad libitum* sorghum hay and water. At the beginning of the 30-d dry lot period, an anthelmintic pour-on was administered, and calves were immunized with an injection of a 7-way blackleg and of CattleMaster® GOLD™ (BVD Type 1 & 2, IBR, BRSV, PI_3) by Pfizer. After the 30-d dry lot period, the heifer calves were grazed on native range pasture until December 10, 2002 at which time they were placed on oat pasture until the following June, 2003.

During both the native range and oat grazing periods, the heifers were supplemented 5.45 kg of 20% CP cottonseed cake $hd^{-1}wk^{-1}$.

Prior to the start of their virgin breeding season, records were kept for age, age of dam (Dam), frame score (FS), weaning weight (WWhfr), weight on the first day of the virgin breeding season (RTSwt), and weight gain from weaning until the first day of the breeding season (PostWW). Heifers were palpated per rectum on the first day of their virgin breeding season and assigned a reproductive tract score (RTS) according to the description outlined by LeFever and Odde (1986). Table 7 identifies these guidelines.

Table 7. Description of reproductive tract scores (RTS)

		Ovaries			
		Approximate Size			
RTS	Uterine Horns	Length (mm)	Height (mm)	Width (mm)	Follicle Diameter
1	Immature <20 mm diameter - no tone	15	10	8	<8 mm
2	20 - 25 mm diameter - no tone	18	12	10	8 mm
3	25 - 30 mm diameter - good tone	22	15	10	8 - 10 mm
4	30 mm diameter - good tone - erect	30	16	12	>10 mm CL[a] possible
5	>30 mm diameter - good tone - erect	>30	16	12	>10 mm CL[a] present

[a] corpus luteum

The experimental group was left intact during 90-d breeding seasons both years within a 973.9 hec multiple-sire pasture. They were placed with Bonsmara bulls, described in the previous experiments (20-24 mo of age), at a BFR of 1:53 during year 1 and 1:48 during year 2. Sixty days following the conclusion of the breeding season females were palpated per rectum to determine pregnancy status. At this time, BCS and weights was assessed and measured on the females during both years. At calving time, birth weight (BW) and a subjective calving score was recorded during year one. A calving score of one denotes that the female calved unassisted with no signs of dystocia, a calving score of two denotes that the female was assisted but delivery was easy and pulled by hand, a calving score of three denotes that the female was assisted and that it was a hard pull, and finally a calving score of four denotes that there was severe dystocia and it resulted in a dead calf. Estimated conception dates were determined by subtracting 282 days from each female's calving date; this information was recorded during both years. Actual calf weaning weights (WWcalf) were recorded during year one and kgs of calf weaned per exposed female was calculated.

Statistical Analysis. The statistical program SAS (SAS Inst. Inc., Cary, NC) was utilized to analyze all data. Initially, Pearson Correlation Coefficients were determined between RTS and the traits measured prior to the beginning of the virgin breeding season (Age, Dam, FS, WW, PostWW, and RTSwt) by using the Corr procedure of SAS. Next, LS means by RTS classifications were derived by the GLM procedure to and differences were determined by an ANOVA table. Then, the independent variables with the lowest F-values were sequentially deleted from an ANOVA model until a model which best predicted the dependent variable, RTS was derived. After this point, RTS was then used as the independent variable. To assess the predictive value of RTS, GLM procedures were used to compare differences between two year pregnancy status' relative to RTS. Two RTS groups (RTS group) were also analyzed by combining RTS 1 and 2, and comparing them against RTS 3, 4, and 5 for two year pregnancy status'. Both RTS and RTS group were used as main effects in GLM procedures to determine differences in conception date, calf weaning weight, calf birth weight, calving score, BCS, fall cow weight, and kg of calf weaned per exposed female. Pearson's Chi-Square test was used to determine differences in the percentage of heifers that conceived during each 30-d interval of the breeding season. Additionally, another ANOVA model was run with the independent variables (Age, RTSwt, and RTS) to attempt to fit a model that could predict pregnancy status over both years.

Results

The heifer's frame score, age, weaning weight, and weight at the time of the RTS exam are all positively correlated with RTS (Table 8). There is only mild correlation strength in frame score (r = 0.25) and age (r = 0.31), while there is a more moderate correlation found in both weaning weight (r = 0.47), and weight at the time of the RTS exam (r = 0.56). No correlation was found between RTS and post-weaning weight gain. More specifically, heifers that received an RTS of 1 were lower in weaning weight from all other RTS scores (Table 9). The same holds true for the weight of the heifer the day the RTS exam was administered. Age only differed between RTS 1 and RTS 3, thus RTS 1 heifers were younger than RTS 3 heifers. Frame score was smaller for RTS 1 versus RTS 2 and 3 heifers.

Table 8. Correlations between reproductive tract score (RTS) and prebreeding measurements[a]

	Age[b]	WW[c]	FS[d]	RTS wt[e]
RTS	r = 0.31	r = 0.47	r = 0.25	r = 0.56

[a] $P < 0.008$; n = 106
[b] Age of heifer when the RTS exam was administered
[c] Weaning weight
[d] Frame score
[e] Weight of heifer when the RTS exam was administered

Table 9. Least square (LS) mean age, weight, and frame score measurements of heifers by reproductive tract score (RTS)

		LS means				
RTS	Number of heifers (%)	WW[a] (kg)	Post WW[b] (kg)	RTS wt[c] (kg)	Age[d] (d)	Frame score
1	49 (46.2%)	217.7[e]	65.8	282.9[g]	406[g]	5.06[g]
2	23 (21.7%)	251.8[f]	67.4	319.2[h]	414	5.82[h]
3	24 (22.6%)	261.6[f]	66.8	328.3[h]	421[h]	5.83[h]
4	6 (5.7%)	276.1[f]	59.4	335.6[h]	421	5.50
5	4 (3.8%)	258.0[f]	62.5	320.5[h]	418	5.75
Pooled SEM		7.79	6.31	5.67	4.17	0.22

[a] Weaning weight
[b] Post weaning weight gain until the day the RTS exam was administered
[c] Weight the day the RTS exam was administered
[d] Age when the RTS exam was administered
[e,f] Means with unlike superscripts within column differ ($P = 0.03$)
[g,h] Means with unlike superscripts within column differ ($P < 0.01$)

The categorical variable, dam, was also analyzed for its relationship with RTS. The RTS means differed (P = 0.03) between heifers by first-calf heifer dams and heifers by mature cow dams. However, when either the WW of the heifers or the RTS weight of the heifers was included in the ANOVA model, dam parity was not predictive of RTS. A full model predicting RTS with the independent variables (dam parity, age, WW, post WW gain, RTS weight, and FS) was analyzed (R^2 = .25). Analysis of the full model indicated that age (P = .01) and RTS weight (P = < 0.01) were the two most predictive factors of RTS. These two variables were combined to yield the reduced model, RTS = -8.12 + .0116 Age + .0174 RTS weight (R^2 = .35).

Table 10. Pregnancy rate during year 1 and year 2 by reproductive tract score (RTS) (n = 106)

	Pregnancy rate (%)	
RTS	Year 1	Year 2
1	79.5	73.5
2	87.0	78.3
3	91.7	87.5
4	100.0	100.0
5	100.0	100.0

Table 10 displays pregnancy rate by RTS for the female's virgin breeding season (Year 1), and their second breeding season (Year 2). Although pregnancy rate did not differ (P >0.10) by RTS, the pregnancy rate distribution across RTS classification was consistent between years. When comparing RTS to the female's pregnancy status over their first two years (Table 11), it is interesting to note the downward pattern in the percentage of females that were deemed pregnant both years. 100% of both the RTS 4 and 5 females bred both years, 87.5% of the RTS 3 females, 65.2% of the RTS 2 females, and only 61.2% of the heifers given a RTS of 1 were pregnant both years. However, statistically only RTS 1 heifers differed from RTS 3 (P < 0.01), and RTS 4 (P < 0.04) females. Although, 100% of the RTS 5 heifers were pregnant both years a lack of observations (n = 4) prevented it from being significantly different from RTS 1 (P = .09).

Table 11. Two-year pregnancy outcomes
by reproductive tract score (RTS)

	Two-year pregnancy status totals (%)				
RTS	PP[a]	PN[b]	NP[c]	NN[d]	Total
1	30 (61.2%)[e]	9 (18.4%)	6 (12.2%)	4 (8.2%)	49
2	15 (65.2%)	5 (21.7%)	3 (13.0%)	0 (0.0%)	23
3	21 (87.5%)[f]	1 (4.2%)	0 (0.0%)	2 (8.3%)	24
4	6 (100.0%)[f]	0 (0.0%)	0 (0.0%)	0 (0.0%)	6
5	4 (100.0%)[g]	0 (0.0%)	0 (0.0%)	0 (0.0%)	4
Total	76	15	9	6	106

[a] Pregnant both year 1 and year 2
[b] Pregnant year 1, but non-pregnant year 2
[c] Non-pregnant year 1, but pregnant year 2
[d] Non-pregnant both year 1 and year 2
[e,f] Values with unlike superscripts differ (P < 0.05)
[e,g] Values with unlike superscripts differ (P < 0.10)

Data were also analyzed by assigning females to two RTS groups (RTS group). RTS 1 and RTS 2 females were designated as RTS group 1, and RTS 3, RTS 4, and RTS 5 were designated as RTS group 2. There were trends that RTS group 1 had lower first year pregnancy rates (81.9%) versus RTS group 2 (94.1%; $P < 0.10$). However, there was actually a difference between RTS group 1 (75.0%) and RTS group 2 (91.2%) for year two pregnancy status ($P < 0.05$). Additionally, RTS group 1 (62.5%) differed from RTS group 2 (91.2%) for being diagnosed pregnant both years as opposed to being non-pregnant either year or both years ($P < 0.01$).

There were trends between breeding date means associated with RTS during year 1 ($P = 0.07$), but not year 2. Numerically, as RTS increases the average days into the breeding season in which a heifer conceived decreased (Table 12). Heifers with a RTS of 1 conceived later in the first breeding season than RTS 4 heifers ($P = 0.04$). RTS 1 heifers conceived later than RTS 3 and 5 heifers ($P = 0.06$). Using a simple linear regression model, RTS did predict date of conception ($P = 0.004$), however only 9% of the variation was explained ($R^2 = 0.09$). Logically, RTS was also predictive of the conception date when grouped by 30 d segments during the breeding season ($P = 0.02$; Table 13). Heifers that were given an RTS of 1 were less likely to breed within the first 30 d of the breeding season compared to RTS 3, 4, and 5 heifers ($P < 0.05$).

Table 12. Least square (LS) mean conception date and calf weaning weight relative to reproductive tract score (RTS)

RTS	LS means					
	Conception date[a]				Calf WW[b]	
	Year 1 (d)	n	Year 2 (d)	n	Year 1 (kg)	n
1	41.3[e]	39	53.9	23	181.0[e]	35
2	37.5	20	30.0	5	185.8	16
3	30.6[g]	22	45.8	12	197.2[f]	21
4	22.0[f]	6	44.3	3	209.6[f]	5
5	20.5[g]	4	28.0	2	204.6	4
Pooled SEM	4.92	91	8.30	45	7.48	81

[a] Day in the breeding season the heifer conceived
[b] Calf weaning weight
[e,f] Means with unlike superscripts within column differ (P < 0.05)
[e,g] Means with unlike superscripts within column differ (P = 0.06)

Table 13. Percentage of heifers that conceived within 30-d intervals during the virgin breeding season by reproductive tract score (RTS)

		Heifers that conceived by 30-d intervals (%)			Heifers that failed to conceive
RTS	n	Day 0-30	Day 31-60	Day 61-90	(%)
1	49	26.5[a]	34.7	16.3	20.4
2	23	30.4	52.2	4.3	13.0
3	24	50.0[b]	41.7	0.0	8.3
4	6	83.3[c]	16.7	0.0	0.0
5	4	75.0[b]	25.0	0.0	0.0

[a,b] Values with unlike superscripts within column differ (P < 0.05)
[a,c] Values with unlike superscripts within column differ (P < 0.01)

Calf weaning weight during year 1 was influenced by RTS ($P = 0.12$). As RTS decreased, calf weaning weight decreased (Table 12). RTS 1 heifers weaned lighter calves than did RTS 3 and 4 heifers ($P = 0.05$). RTS did not significantly affect kg of calf weaned per exposed female by RTS. This was due to the fact that one RTS 4 and one RTS 5 heifer lost a calf due to dystocia. Furthermore, analysis of calf birthweight and calving score by RTS yielded no significant differences.

During the assessment of pregnancy status during the fall of each year, the heifers were weighed and evaluated for BCS (Table 14). Fall weights differed by RTS for both year 1 ($P < 0.01$), and year 2 ($P < 0.04$). The BCS of the females also differed by RTS for both year 1 ($P < 0.01$) and year 2 ($P < 0.03$). Year 1 fall weight was lighter for RTS 1 females versus all other RTS classifications ($P < 0.02$). During year 2, fall weight was lighter for RTS 1 than for RTS 2 and 3 ($P < 0.05$). In year 1, RTS 1 heifers had lower BCS compared to RTS 3, 4, and 5 ($P < 0.02$), and RTS 2 heifers had lower BCS than RTS 5 heifers ($P < 0.04$). In year 2, RTS 1 females had lower BCS compared to RTS 3 and 5 females ($P < 0.02$), and RTS 2 females had lower BCS than RTS 5 females ($P < 0.04$).

Table 14. Least square (LS) mean fall weight and body condition score (BCS) by reproductive tract score (RTS)

	Fall weight[a]				Fall BCS[b]			
	Year 1		Year 2		Year 1		Year 2	
RTS	kg	n	kg	n	BCS	N	BCS	n
1	350.8[c]	48	401.3[e]	49	4.9[c]	47	4.1[c]	35
2	388.8[d]	23	443.8[f]	23	5.2[g]	22	4.3[g]	16
3	391.8[d]	24	431.3[f]	24	5.5[d]	24	4.8[d]	22
4	416.8[d]	5	443.6	6	5.6[d]	5	4.4	5
5	383.5[d]	4	442.6	4	6.0[d,h]	3	5.7[d,h]	3
Pooled SEM	5.86		13.00		0.13		0.25	

[a] Weight recorded 75 d after the conclusion of each breeding season
[b] BCS evaluated 75 d after the conclusion of each breeding season
[c,d] Means with unlike superscripts within column differ ($P < 0.02$)
[e,f] Means with unlike superscripts within column differ ($P < 0.05$)
[g,h] Means with unlike superscripts within column differ ($P < 0.04$)

Discussion

This may be the first study evaluating the aspects of the relationship between various prebreeding measurements of heifers and RTS. If RTS is accepted as being a valuable selection tool for replacement heifers, as demonstrated in the current study, then it is helpful to understand which traits ultimately affect the outcome of the RTS exam. From a management perspective, these traits could be more critically monitored to facilitate an early decision on which females to retain and develop for replacements after weaning. The data suggest that the weaning weight of the heifers moderately affected the eventual RTS outcome. Weaning weight had higher predictive value than did age, although both were linked to RTS. Interestingly, frame score also affected RTS but to a lesser degree. It is understood that smaller-framed cattle are earlier maturing, and thus should generally attain puberty at a younger age. However, our results show a positive correlation between RTS and frame score, rather than a negative correlation. This apparent discrepancy could be due to the fact that in this study the heifers were subjectively assessed for frame score by an evaluator instead of by hip height and age (BIF, 2002). The evaluator did not know ages during the evaluation, and thus it is likely that there was a tendency to evaluate all cattle as though they were equal in age. Furthermore, it is likely that plane of nutrition under these extensive conditions could have limited both growth (weight and height) and pubertal development, thus explaining the relationships found in this study.

The final ANOVA model encompassing prebreeding traits only explained a modest percentage of the variation in RTS ($R^2 = 0.35$). This model included age and the weight of the heifers on the day that the RTS exam was given. To reduce the error term we could have measured other environmental and genetic factors. For example, there is a known relationship between the sire’s scrotal circumference and the age at which puberty is obtained in his daughters (Smith et al., 1989). In the current study sire information was unavailable because the heifers were produced in multiple-sire pastures.

Some researchers have quantified the link between RTS and subsequent pregnancy status during the first breeding season for synchronization/AI programs, followed by a 60-d single-sire natural service system (LeFever and Odde, 1986; Pence and BreDahl, 1999; Williams, 2001). However, there is no literature regarding extensively-managed replacement heifers which are allotted to natural service, multiple-sire breeding pastures, for 90-d breeding seasons. Likewise, there are no studies that have looked at the utility of implementing the RTS system as a selection tool at the beginning of the breeding season, instead of 30 to 60 d before the start of breeding. Furthermore, there is no literature which has looked at the relationship between RTS and dystocia, calf weaning weight, second-year pregnancy status, or cow weight and BCS patterns during subsequent years. This study validates the value of the RTS system as a selection tool when making management decisions regarding replacement heifers immediately before the start of a natural service, 90-d breeding season. However, future studies encompassing additional variables will be necessary in order to more accurately explain lifetime reproductive performance based upon replacement heifer traits. Lesmeister et al. (1973) presented data which indicated that heifers calving earlier the first time produce more kilograms of calf in their lifetime than heifers calving later the first time. Furthermore, the authors claimed that most of the difference in average annual lifetime production was associated with increased production at the first calving.

It has been recommended that more than 50% of the heifers should be cycling (RTS 4 and 5) 30 d prior to the beginning of a synchronization program to ensure that a large portion of females will show estrus (Torrel et al., 1996). In the current study, only 9.4% of the heifers were deemed pubertal and thus cycling on the first day of the breeding season, yet 85.5% of the entire group of heifers became pregnant during their virgin, 90-d breeding season. This illustrates that, in fact, reasonable pregnancy results can be achieved in a natural mating, 90-d breeding season even if the majority of the heifers are not cycling at the start of breeding. At the end of the breeding season, females ranged from 14 to 17 mo of age. However, a closer look at the individual RTS scores reveals that RTS 1 heifers were less likely to become pregnant both as heifers and as first-calf heifers. The RTS 1 heifers conceived later in the breeding season and had lighter calves at weaning. Additionally, RTS 1 heifers had lighter body weight at 2 yr of age and a lower body condition score at the time of pregnancy determination during each fall than heifers with RTS > 1 which further jeopardized the ability of these females to rebreed in subsequent years. Consequently, the evidence supports the claim that heifers who receive a RTS of 1 should be culled from the breeding herd. If sold as a short-yearling, these immature heifers would likely be treated as other feeder cattle and should not receive price discounts versus retention of a heifer that fails to reproduce and is later culled. Additionally, this would spare the owner additional expenses associated with heifer development and breeding.

When data for RTS 1 and 2 heifers were pooled, lower pregnancy rates were found during year 1 (81.9%), year 2 (75.0%), and both years combined (62.5%) when compared with RTS 3, 4, and % heifers. If traditional culling standards were practiced, (e.g., any non-pregnant female after the breeding season would be culled) these culling rates would clearly not be acceptable. However, in the current study pregnancy rate, breeding date, and calf weaning weight for RTS 2 heifers were not significantly lower than for RTS 3, 4, and 5 heifers. Future studies are needed to ascertain the potential value of retaining or culling heifers with an RTS of 2 under these conditions.

CHAPTER V

CONCLUSIONS

Effects of Conventional or Low Bull to Female Ratio in Extensively-Managed, Natural Mating Breeding Groups

The results from the current study demonstrate that the BFR can be reduced to unconventional levels (1:47 to 1:52) in extensive pastures with a 90-day breeding season without adversely affecting pregnancy and calving rates. Selection pressure for bulls with adequate fertility must be utilized to ensure a high reproductive rate. Variation in social dominance arrangement did not affect total pregnancy rates in conventional BFR (1:25) pastures. Social rank was repeatable when measured before breeding and again after the 90-d breeding season. Increasing breeding pressure on bulls was not associated with a greater decrease in body weight, BCS, or percentage normal sperm, which further supports the reduction in BFR to less conventional levels. However, caution should be exercised in the application of unconventional BFR dependent upon the number of females cycling at the beginning of the breeding season and until further studies quantify the relationship between BFR and the interval from start of breeding until conception.

Utilization of Reproductive Tract Scores in Extensively-Managed, Natural Mating Breeding Groups

The value of the RTS system in estimating two year reproductive performance for replacement heifers utilized in a 90-d, natural mating breeding season has been validated in the current study. The weight of the heifers on the day of RTS assignment, weaning weight, age, frame score, and dam parity affected the ultimate RTS outcome of yearling heifers. RTS 1 heifers were less likely to conceive in both years, they conceived later the first year, and they weaned lighter calves their first year. Plus, the RTS 1 females had lighter body weight as 2-yr-olds and lower BCS after each of the first two breeding seasons which would further jeopardize their long term rebreeding potential. These results indicate that heifers that receive a RTS of 1 on the first day of a 90-d, natural mating breeding season should be culled from the breeding herd. Consideration should also be given to eliminating RTS 2 heifers, but further studies will be needed to confirm the potential economic advantage of this practice.

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APPENDIX

Appendix Table 1. Number of bulls, number of females, bull to female ratio (BFR), and BFR treatment by pasture

Female Composition	Pasture/ Year ID	Number of Bulls	Number of Females	BFR	BFR[a] Treatment
Mature					
	BS03	2	48	1:24	C
	P03	2	48	1:24	C
	H03	2	57	1:29	C
	H04	2	57	1:29	C
	P04	2	42	1:21	C
	YB04	5	132	1:26	C
	YB03	3	155	1:52	L
	BS04	1	47	1:47	L
Heifer					
	H02	5	111	1:22	C
	VC03	2	106	1:53	L
	VC04	4	193	1:48	L

[a] C = conventional; L = low

Appendix Table 2. Mean pregnancy rate, calving rate, weaning rate, calving date, and calf weaning weight (WW) by pasture

Female Composition	Pasture/ Year ID	BFR[a] Treatment	Pregnancy Rate (%)	Calving Rate (%)	Weaning Rate (%)	Calving Date (d)	Calf WW (kg)
Mature							
	BS03	C	87.5	87.5	87.5	307	270.4
	P03	C	87.5	87.5	77.1	299	281.5
	H03	C	98.3	96.5	93.0	302	249.1
	H04	C	87.7	87.7	N/A	316	N/A
	P04	C	95.2	95.2	N/A	313	N/A
	YB04	C	87.9	87.9	N/A	316	N/A
	YB03	L	98.1	98.1	94.8	314	231.2
	BS04	L	91.5	91.5	N/A	319	N/A
Heifer							
	H02	C	82.0	82.0	81.1	330	231.6
	VC03	L	85.9	85.9	76.4	317	188.5
	VC04	L	79.8	79.8	N/A	332	N/A

[a] C = conventional; L = low

Appendix Table 3. Pre-breeding mean physical, seminal, and behavioral bull traits by pasture

Female Composition	Pasture/ Year ID	BFR[a] Treatment	Body Weight (kg)	SC[b] (cm)	BCS[c]	FS[d]	Spermatozoa Motile (%)	Spermatozoa Normal Morphology (%)	Serving Capacity	Serving Efficiency	Social Rank	Social Group[e]
Mature												
	BS03	C	622.6	39.0	5.5	6.0	80.0	80.0	3.5	4.8	5.5	E
	P03	C	613.5	39.5	5.0	6.0	80.0	80.0	2.0	4.3	4.5	U
	H03	C	639.6	40.5	5.5	5.5	70.0	80.0	2.0	6.3	6.3	E
	H04	C	563.6	35.8	6.0	6.0	60.0	63.0	2.0	6.2	5	E
	P04	C	570.4	35.4	5.5	5.5	55.0	81.0	2.0	5.7	5.4	E
	YB04	C	562.9	36.4	5.4	6.2	58.0	79.8	2.2	3.6	7.6	U
	YB03	L	632.8	39.7	5.0	6.0	90.0	90.0	3.0	4.5	6.6	U
	BS04	L	539.8	36.0	6.0	7.0	60.0	90.0	2.0	3.5	3.6	
Heifer												
	H02	C	543.4	36.5	4.8	5.2	56.0	68.4	2.4	3.6	4.5	E
	VC03	L	654.3	39.5	5.5	6.0	90.0	90.0	3.0	3.5	3.6	U
	VC04	L	564.7	35.6	5.5	6.3	35.0	79.5	2.5	5.3	3.2	U

[a] C = conventional; L = low
[b] Scrotal Circumference
[c] Body condition score
[d] Frame score
[e] E = extreme; U = uniform

Appendix Table 4. 2002 pre- and post- breeding physical, seminal, and behavioral bull traits

Bull ID	Body weight (kg)		Scrotal Circumference (cm)		BCS[c]		Sperm Motility (%)		Sperm Normal Morphology (%)		Primary Abnorm. (%)		Secondary Abnorm. (%)		Social Rank	
	1[a]	2[b]	1	2	1	2	1	2	1	2	1	2	1	2	1	2
30	595.5	634.1	39.3	40.0	7	5	40	70	40	77	19	4	41	19	5	6
47	554.5	552.3	36.5	37.3	5	5	70	40	46	78	12	2	42	20	10	11
79	527.3	545.5	34.0	35.0	6	5	30	20	85	90	0	0	15	10	6	4
88	534.1	556.8	36.0	36.5	5	5	80	30	77	80	5	2	18	18	9	7
96	579.5	606.8	34.3	37.0	4	6	80	50	56	90	2	1	42	9	4	8
99	536.4	518.2	35.0	35.0	4	5	70	70	66	66	6	2	28	32	16	10
105	529.5	559.1	36.5	38.3	6	5	50	30	74	80	1	2	25	18	14	9
109	518.2	525.0	38.0	39.3	6	5	50	80	70	85	0	5	30	15	12	3
112	572.7	613.6	36.3	38.5	6	6	40	20	80	80	3	0	17	20	15	15
115	531.8	588.6	36.0	37.5	5	5	70	40	68	64	4	2	28	34	2	2
122	563.6	609.1	37.5	37.8	5	5	60	40	70	63	2	2	28	35	3	12
125	554.5	561.4	35.0	37.3	6	5	50	70	35	61	1	3	64	36	11	16
129	511.4	568.2	36.3	37.0	5	5	60	60	77	47	1	3	22	50	8	13
133	581.8	565.9	37.3	37.0	6	5	90	70	93	86	0	1	7	13	7	5
140	506.8	561.4	34.5	36.3	5	5	30	60	60	73	0	3	40	24	13	14
153	525.0	570.5	37.5	38.0	5	5	20	50	80	87	1	2	19	11	1	1

[a] Pre-breeding value
[b] Post-breeding value
[c] Body condition score

Appendix Table 5. Pre- to post-breeding change in percentage normal spermatozoa morphology by bull to female ratio (BFR) treatment

	Year	Bull ID	BFR[a] Treatment	Sperm Normal Morphology Change (%)
	2003	4	C	-9.0
		32	C	-6.0
		103	C	-17.0
		113	C	-50.0
		122	C	-40.0
		139	C	4.0
LS mean				-19.7[b]
		19	L	-20.0
		36	L	-9.0
		40	L	-48.0
		94	L	-20.0
		135	L	-38.0
LS mean				-27.0[c]
	2004	34	C	11.0
		35	C	-10.0
		44	C	15.0
		47	C	46.0
		65	C	4.0
		73	C	15.0
		85	C	18.0
		94	C	-3.0
		126	C	-15.0
LS mean				9.0[d]
		71	L	6.0
		91	L	19.0
		100	L	3.0
		118	L	-2.0
LS mean				6.5[e]

[a] C = conventional; L = low

[b,c] Unlike superscripts within column do not differ (P = 0.54)

[d,e] Unlike superscripts within column do not differ (P = 0.80)

Appendix Table 6. Pre- to post-breeding change in 2003 bull body weight, and body condition score (BCS) by bull to female ratio (BFR) treatment

	Bull ID	BFR[a] Treatment	Body Weight Change (kg)	BCS[b] Change
	4	C	-20.5	-1
	32	C	29.5	1
	103	C	4.5	0
	113	C	-13.6	-1
	122	C	-61.4	-1
	139	C	-11.4	0
LS mean			-12.2[c]	-0.3[e]
	19	L	-68.2	-1
	36	L	2.3	0
	40	L	34.1	1
	94	L	34.1	1
	135	L	-22.7	-1
LS mean			-4.1[d]	0[f]

[a] C= conventional; L = low
[b] Body condition score
[c,d] Unlike superscripts within column do not differ (P = 0.73)
[e,f] Unlike superscripts within column do not differ (P = 0.56)

VITA

Ryan James Rathmann was born in Austin, TX on May 20, 1980 to James and Janet Rathmann. He grew up in the Central Texas town of Bastrop on his family's cattle ranch. He earned an Associate degree in May 2000 from Connors State College in Warner, OK, and a B.S. degree in Animal Science from Texas A&M University in May 2002. He then coached the Texas A&M Livestock Judging Team to three-consecutive National Championships from 2002 to 2004 while being named the National Collegiate Coach of the Year in both 2003 and 2004, respectively. He married Kayla Kohls on December 13, 2003. In January of 2005, he went to work for Cargill Animal Nutrition as a Sales Consultant until August of 2005, when he came back to school to complete his thesis and teach ANSC 107 (Introduction to Animal Science) in the fall of 2005. He earned a M.S. in Physiology of Reproduction from Texas A&M University in December 2005.

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