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Natural Service Mating with Bulls: Management Guidelines

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Introduction

Three realities concerning bovine reproduction are, 1) reproductive performance is highly important to the economic sustainability of an operation, 2) reproductive performance can be managed to achieve targets that are attainable within the resources and motivation of the operation, 3) reproductive performance is influenced by interactions between fertility of the females, males, and effects of the environment and management, The male –either naturally or artificially – contributes substantially to the reproductive outcome of the breeding herd on a higher magnitude than individual cows. Additionally, the breeding bull is the leading contributor towards genetic change or advancement within the herd. Bull fertility and bull management are therefore paramount issues that influence beef and dairy cattle reproductive success.

Even with the rapid development and adaptations of reproductive technologies, the predominant means of breeding beef cow herds involves the utilization of bulls in natural service. Survey results from the 1997 NAHMS Beef Report stated that over 90% of all beef cow-calf producers utilize bulls in their breeding programs. Even after over 10 years of further advancements that allow more adaptable measures for artificial insemination and estrus synchronization, the use of breeding bulls continues to play a major role in cow-calf reproduction. Surveys report that 55 to 90% of U.S. dairies utilize natural mating in some aspect of breeding management. In most dairy breeding programs, the natural service bull is relegated to secondary roles, such as post-AI service, service for minimal genetic merit (crossbreeding) and maiden heifer mating. In beef operations which utilize estrus synchronization programs, bulls may be utilized for intense natural service or they may play a secondary "clean-up" duty following an AI period. Where natural service mating with bulls is employed, the reproductive capability of a bull assumes great importance. Therefore, the understanding of the dynamics of bull fertility and the management of breeding bulls are necessary for successful beef reproduction programs.

Diverse Natural Mating Expectations for Bulls

The management scenarios that producers use bulls in natural service are diverse. Examples of mating systems utilizing natural bull service, include:

1) Single-sire mating within small herds or groups (1 to 50 females)
2) Single-sire mating of multiple bulls by rotations within a herd for defined mating periods
3) Multiple sire mating at highly variable bull-to-female ratios within a herd

4) Selective multi-sire mating rotations within a herd
5) Single or multi-sire mating of estrus-synchronized females
6) Natural service following artificial insemination programs (clean-up bulls)

Within all of these mating systems, bulls are expected to achieve satisfactory pregnancy rates in a time-efficient manner. However, performance of bulls under natural service is highly variable between bulls and within systems and prediction of fertility has proven to be highly elusive. Management of bulls to meet these expectations plays a major role in achieving high reproductive performance.

Factors Contributing to the Reproductive Performance of Bulls

Fertility is a complex interaction of biological and behavioral characteristics (Chenoweth, 2002). Fertility, or the ability to impregnate cows, requires four essential attributes of the bull during natural service. (Jainudeen and Hafez, 2000)

1. The physical capability and soundness to detect estrus and accomplish mating
2. The innate willingness to mate (libido) and the acquired skill to effectively inseminate (mating ability)
3. The testicular development and health to produce sufficient fertile spermatozoa and testosterone
4. Sufficient and healthy spermatozoa to effectively fertilize and sustain embryo survivability.

These necessary attributes must be in place during the natural mating of an individual female in estrus and then repeated subsequently according to the mating load presented to him. Furthermore, the bull is required to adapt to a social hierarchy within the breeding herd. This involves not only other competing bulls but also the female social order. All these capabilities must come into place under the environmental and management constraints of the breeding season. The successful attainment or development of these attributes, particularly of young, virgin bulls will determine his reproductive performance (Barth, 1997). Clearly, all bulls and specifically, young bulls, do not adequately attain these characteristics and this contributes to a wide biological variation in reproductive performance of natural service bulls. Study data has indicated that 15 to 25% of bulls used in natural service have identifiable fertility problems (Coulter et al.1989). Several breeding trials have shown that the minority of bulls (<30%) often sire the majority of the calves (>65%) (Makarechian et al. 1985, Makarechian et al. 1987, Neville et al, 1987). Holroyd et al. 2002). However, we clearly have expectations that each bull used in natural service will have successful reproductive performance and contribute to the calf crop production of the herd.

Evaluation of fertility under natural mating conditions reveals that the environment and management can play major confounding factors and alter the fertility- potential of bulls previously determined to be potentially satisfactory breeders. This is expressed by the low heritability of fertility due to the high environmental influences (Brinks, 1972). Factors which may contribute to the variability in reproductive performance of bulls, include:

a. Physical faults
   Weak conformation and structural faults, limb and feet abnormalities, vision deficits, inadequate or excessive body condition and fat deposition, body size incompatibilities, poor physical fitness and exhaustion, developmental or acquired defects of reproductive organs
b. Reproductive faults
   Testicular development insufficiency, testicular disease/degeneration, reproductive tract injury/disease, seminal changes in quantity and quality, secondary disease effects on spermatozoa production and function
c. Sexual behavior
   Libido, mating ability, sustained mating behavior
d. Social behavior
   Social hierarchy of females and bull battery, competition for mating, conflicts, adaptability
e. Age
   Inadequate pubertal development, weak sexual maturity, inexperience, juvenile behavior transitions, age-related weaknesses affecting physical and reproductive soundness
f. Environmental influences
   Heat stress, cold stress, seasonal influences, acclimation effects, topographical barriers, movement stressors.
g. Management influences
   Mating load, mating season duration, mating environment
h. Breed-Genotype
   Breed-related pubertal effects, maturation differences, breed-selectivity of females, heterosis-crossbreeding effects
i. Nutritional effects
   Inadequate feed resources and growth, undernourishment, over-conditioning, specific deficiencies (Vitamins A, E, Selenium, Copper, Zinc, others), chronic acidosis and laminitis
j. Diseases and injuries, pyrexia (fever), pain, and physiological stress
k. Toxins, chemicals, drugs, radiation exposure
l. Female factors
   Age and breed differences, size discrepancies, receptivity, fertility, disease

Obviously, to characterize infertility or poor reproductive performance to a single factor is difficult when physical, reproductive, behavioral and environmental variables are all interacting concurrently during natural mating. Thus, the identification of bulls with adequate or sufficient reproductive status prior to mating exposure is an important management practice.

Bull Breeding Soundness Evaluations (BBSE)

The mainstay for evaluation of the reproductive capability for bulls has been the Bull Breeding Soundness Evaluation, as structured and refined through the American Society for Theriogenology (1983). The assessment addresses three of the four essential characteristics deemed necessary for bulls to impregnate cows. The principles and

guidelines are thoroughly detailed in many publications (Barth, 1997, Chenoweth et al. 1994, Chenoweth, 2002). Needless to say, the evaluation of bulls prior to mating seasons proves as an economically sound practice (Chenoweth, 2002).

The limitations of the BBSE are:

1) Results are indicative of the present physical and reproductive status of the bull and diagnostically of the prior health and environmental effects upon the soundness of the bull. The results do not imply any conditional warranty or prognostication of reproductive performance.
2) The procedure identifies faults or weaknesses that would contribute to sub-fertility or infertility at that point in time. The system does not identify any conditional superiority in fertility.
3) Occasionally, the procedure is misapplied or not assessed in its entirety. Therefore, the interpretation of the reproductive potential may be over- or underestimated. Equally so, the expectations of producers toward reproductive outcomes may be erroneously interpreted as some guarantee of reproductive success. Human error in interpretation may play a factor.
4) The evaluation does not routinely assess any sexual behavior traits (libido and mating ability) or social adaptability of bulls within the mating environment.
5) Unless performed additionally, no mandate for testing for infertility diseases are required (Brucellosis, Trichomoniasis, Leptospirosis, BVDV, and other diseases).

Withstanding circumstances or insults that occur on a herd basis, generally it is expected and found that 75% or more of any bull group or population will meet the requirements to be classified as satisfactory potential breeders. Diagnostically, the evaluation can be repeated at intervals to assess changes, both positive and negative, in reproductive soundness. In the case of yearling bull candidates, the breeding soundness evaluation assesses the advancement of pubertal development and sexual maturity (Barth, 1997). Bulls from 12 to 15 months of age that meet the threshold requirements of the BBSE are meeting selection parameters for earlier sexual development and maturity (Arteaga et al. 2001). Testicular development, as measured by scrotal circumference, is a highly desirable selection indicator for fertility in both sires and daughters of those sires (Brinks 1972, Chenoweth et al. 1994). All in all, the bull breeding soundness evaluation, when properly performed and interpreted provides a highly useful management tool and serves to reduce the risk of potential sub-fertility in herd bulls. The yearly assessment of fertility-potential of bulls remains a key management tool to achieve higher reproductive performance.

Sexual Behavior

The routine BBSE does not assess the inherent sexual drive or acquired mating ability of bulls in natural service. Unfortunately, sexual behavior is not related to any of the components of the BBSE (Chenoweth et al. 1984 and 1988), including growth performance or scrotal circumference. Methods are available to test bulls for libido and serving capacity and do have merit, particularly with mature bulls (Blockey, 1976 and 1978, 1989; Boyd et al. 1989; Chenoweth, 1997; Price, 1985). The greatest value of libido/serving capacity tests appears to be the ranking of bulls into high, medium and low categories (Lunstra, 1984). Libido/serving capacity tests have shown positive

correlations with fertility, however high libido ranking was not necessarily associated with higher fertility than medium ranking (Coulter et al. 1989). Inconclusive and poor results have been reported from other studies (Boyd et al.1989; Farin et al. 1989). The procedures are time-consuming, incur risks for animals and humans, require facilities and restrained females, need standard and consistent application and sound interpretation. Therefore, they are generally found unfeasible and impractical to perform under field conditions. With young bulls, specifically yearling bulls, the tests require repeated trials to allow bulls to acquire some degree of mating competency (Boyd et al. 1989, Godfrey et al. 1989). Thus, these tests may not necessarily reflect the true service capacity in their first breeding season or as mature bulls (Boyd et al, 1991). Mating ability definitely has a learning curve and competency is acquired through experience. The most useful information gained from either formal "serving capacity" tests or observed natural service periods is the detection of bulls with severe limitations to sex drive and mating ability. A small percentage of bulls (5-10%) are found to have poor sex drive or faults in mating ability that are intermittent or constantly observed. Most commonly these bulls have physical or structural problems that cause pain, inability to mount and copulate, or penile abnormalities that preclude proper intromission and ejaculation. In lieu of a structured serving capacity/libido test, producers can apply management practices that will often detect these issues. Test mating of bulls, particularly virgin yearling and two-year-old bulls will allow observation for faults. A pre-breeding "sex education" period for young, inexperienced bulls has been suggested to allow for mating experience, tempering of juvenile social behavior and observation for bulls with weak sexual behavior tendencies (Boyd et al. 1991; Ellis et al. 2005). The foremost recommendation is to observe all bulls regularly through the breeding period to observe for pre-existing problems or developed problems. With young bulls, highly frequent observation during the first 5-7 days and at 7 days intervals is recommended to monitor mating activity and capabilities.

Bulls with diminished libido may require rest and then a fresh stimulus with active estrus-females. Bulls with exhausted mating activity often need rest and recuperation. Removal of exhausted or injured bulls and rotations with fresh bulls may be applicable in some breeding herds. Mating competition may be necessary for some young bulls to fully express sexual behavior. Young bulls in single-sire mating schemes may benefit from the addition of another bull to provide the stimulus. All in all, the proven management practices that address deficient libido and mating activity involve regular monitoring of bull activity, observation of services and culling of young bulls with weak mating activity.

Social Behavior

Under natural mating conditions, the social ranking of bulls within the herd hierarchy can influence sexual activity and reproductive performance. Dominance is expressed more strongly in older bulls (i.e. 3 to 4 years of age and older) and is more related to seniority than any other factor (Blockey, 1979). The effects of dominance amongst bulls on herd fertility may be greatest at lower bull-to-female ratios and when there is limited estrus-activity within a herd. Dominant bulls may impregnate more cows and limit the reproductive performance and calf outputs from subordinate bulls. Conversely, dominant

bulls may hinder the estrus-detection and mating of subordinate bulls without impregnating a higher proportion of cows. If dominance is associated with low semen quality or low sex drive, than herd fertility may be compromised (McCosker et al. 1989). These effects occur most frequently when older and younger bulls are combined in the same breeding pastures and occasionally when mixing different bull breed-types together. In multi-sire breeding herds, recommendations are that the bull group be relatively homogenous (age, size, breed-type). General recommendations to minimize the effects of social dominance in multi-sire breeding groups include:

1) Yearling bulls should not be included with older bulls
2) Young bulls (2-3 year-olds) should be the core bull breeding groups
3) Mixed-age, multi-sire groups should be utilized under high mating loads (BFR) to avoid dominance-effects during the early breeding season
4) Bull rotations of mature, senior bulls early in the breeding season followed with young bull groups during the later breeding season

Mating Load or Bull-to-Female Ratios (BFR)

The intensity of bull mating is extremely variable from operation to operation. The 97 Beef Report documented that average mating loads for beef bulls were 1 to 25 females for mature bulls and 1 to 17 females for young bulls. Field reports reveal bulls that are mated to very small, select groups of females (1 to 10) and bulls that are used in intense mating exposures of over 50 females for variable time periods. Traditionally, recommendations for bull mating load have remained at 1:20 to 1:30 cows per mature bull and 1:15 to 1:20 females per yearling bull. Information is available to strongly suggest that bull mating capacity is underestimated at these levels. However, the interactions of reproductive status, sexual behavior, social behavior and environmental constraints, precludes identifying the "super" bull for mating capacity. When bulls were compared in single- and multi-sire systems at BFRs of 1:25, 1:44, and 1:60 (Rupp et al. 1977), fertility, libido and mating ability of the individual sires were most important in determining the reproductive performance of bulls. Studies in Colorado have looked at bull mating capacity in intense, estrus-synchronization breeding systems. Comparison of a variety of single-sire BFRs (1:7 to 1:51) with bulls from 1-7 years of age, found that BFR was not a limiting factor to reproductive performance, even at the higher breeding stress (Pexton et al. 1990). Utilization of sound bull management practices, including yearly bull breeding soundness evaluations and solid breeding season monitoring would allow beef producers to explore the optimal mating loads for their programs. Decreasing the BFR to reduce costs, while maintaining satisfactory herd reproduction, is a worthy management consideration.

Young Bull Management

Further management considerations arising with the use of natural service beef bulls include the age at which bulls are used. For many years now, bulls from 12 to 18 months of age have been developed, selected and successfully used for mating as "yearling" bulls. The one to two-year-old aged bulls are the primary replacement herd additions for beef herds in the U.S. These young bulls have special management requirements that contribute towards their immediate and long-term reproductive performance for the operation (Barth 1997).

Breed differences in development and maturity are recognized between *Bos taurus* and *Bos indicus* genotypes that necessitate management plans to successfully employ these breed types (Chase et al. 1997). Rate of testicular development, puberty onset, and progression of normal sperm production are highly dictated by genotype-environment interactions (Fields et al. 1979). However, a single indicator of pubertal status is attainment of a scrotal circumference (SC) of 26-28cm at 8-9 months of age (Lunstra et al. 1978) and attaining the threshold SC for the BBSE of 30cm by 12-15 months of age. Most definitely, more rapid testicular development and exceeding this threshold is a major selection criteria for early maturity, growth performance and testicular production capacity. The successful categorization of satisfactory potential breeder at 12-15 months for most well-developed *Bos taurus* bulls is testament to early puberty, advanced reproductive development and the potential to successfully impregnate cows or heifers.

Surveys indicate that most yearling bulls are generally given lower mating loads than older bulls (Chenoweth, 2000) and research has supported this finding (Coulter et al. 1989). In breeding trials with synchronized females, yearling bulls achieved lower pregnancy rates than older bulls (Chenoweth, 1984). The constraints on young bull fertility and reproductive performance are multi-factorial. Sperm production – both quantity and quality are highly considered factors related to immaturity. Sexual activity, in regards to the learning curve for mating activity that is documented, is surely a contributing factor. Physical condition and the effects of physiological stress of mating are shown to influence fertility. The excessive activity of medium and high libido bulls, the marked loss of physical condition and testicular mass, and the high rates of injury incurred during short breeding periods all contributed to variable calves-sired per bull in a Nebraska study (Ellis et al. 2005). Young bulls developed on high-performance rations have been shown to have impaired sperm output and semen quality (Coulter et al. 1984) which may influence short and long-term reproductive performance. These factors, in addition to social effects and environmental influences all necessitate the expectations that yearling bulls are not equally capable as mature bulls.

With the information available concerning reproductive capabilities of yearling *Bos taurus* bulls, and in some respects *Bos indicus* bulls selected and raised for early development and puberty, some general guidelines exist.

1. Select yearling bulls for early maturity, testicular growth, satisfactory semen quality and health
2. Properly develop young bulls nutritionally without over-conditioning and excessive growth
3. Proper physical-conditioning of young bulls with exercise
4. Prepare young bulls to changes in environment and nutrition at least 30 days prior to breeding season
5. Test mate young bulls and observe for libido, successful service and allow the acquisition of experience prior to breeding season
6. Utilize accepted BFRs for yearling bulls of 1:20 to 1:25, knowing that individuals may not meet these expectations under the right circumstances

7. When used in multi-sire mating schemes, use yearling bull groups only to avoid dominance effects and reduce injuries incurred during conflicts with older bulls
8. Offer limited breeding exposure (<45 days) to allow young bulls to remain healthy and regain condition and continue growth.

Natural Service with Estrus-Synchronized Females

Most commonly, beef producers associate estrus synchronization of cows/heifers as only a means to manipulate and assist an AI program. The majority of beef operations that AI with or without estrus synchronization use natural service bulls for clean-up activity of cows failing to cycle or conceive. However, in some instances, estrus synchronization can be advantageous, feasible and successful when natural service with bulls is the means of insemination. Some operations lack the time, manpower and facilities to properly utilize AI in their breeding programs. Use of bulls may be an interim means to develop an AI program in following years. The potential advantages of estrus-synchronization and natural service may justify this management option. Research has demonstrated that natural mating can be an effective alternative to AI in estrus synchronization programs (Farin et al. 1982,1989; Pexton et al. 1989).

With synchronization, estrus activity in select groups of cows can be concentrated toward the beginning of the breeding season. This "bunching-up" of breeding serves to increase early calving cows which positively impacts future reproductive performance. The production and economic ramifications of a high proportion of the cowherd calving during the early calving season have been well documented. With heifers, estrus synchronization places a selection pressure on fertility and offers an option for intense, concentrated calving of heifers. These are management options that can enhance overall herd productivity and reproductive performance. With proper selection and use of bulls, natural service can be the means of breeding for synchronized females. Practicing good management and use of fertile, sound bulls should achieve similar pregnancy rates as AI.

Some options that should be considered in use of natural service bulls with estrus synchronized females include the breeding capacity of the bull. This may dictate the synchronization program utilized. Program that have less intense concentration of cycling (5$\pm$2 days) may be preferred over program that concentrate a high number of cycling females into 48-72 hours. A simple program which synchronizes estrus and then bulls are turned in on the subsequent return to estrus is probably the most relaxed plan. With any natural service program on synchronized females, attention to details and bull management will be key and close observation of bull activity and performance is mandatory.

Guidelines to consider when using bulls in natural service and estrus synchronized females:

1. Perform complete breeding soundness evaluations on bulls prior to use
2. Have bulls healthy and in good physical condition: BCS of 5-6, physically fit and sound on feet and legs, adapted to feed rations received by the cows/heifers
3. Ideally, bulls should be experienced breeders as the higher intensity of estrus activity may distract young, virgin bulls from learning successful mating ability

and produce marked variability between bulls in performance. Experienced bulls 2 to 4 years of age have been most successfully used.
4. Use a small pasture or confinement lot to reduce the physical activity of movement amongst the sexually-active groups of females
5. Breeding area should provide sound footing and be free of traps and encumberments.
6. Use a BFR of 1:15 to 1:25 and have extra bulls on hand in case of unsuccessful adaptation of bulls, physical exhaustion or injuries
7. Use single-sire mating if possible to eliminate bull competition and conflicts which distract from effective breeding.
8. If multi-sire mating is used, bulls of like age are recommended and should have a stable social order well before turn out.
9. Bulls may be used for intense 2-5 day breeding periods and then should be rested for 2-3 weeks prior to further breeding use.
10. Bull rotations have been utilized on 48-72 hours intervals depending on the activity of the individual bulls

An example of a successful natural service/estrus synchronization/timed AI system has been reported from Nevada and Oregon. The first protocol involved yearling heifers that were synchronized with the CO-Synch + CIDR system and bulls (1:15 BFR) were used from time of CIDR removal to 48 hours and again at 84 hours. Timed AI breeding occurred at 65-70 hours following CIDR removal. The second protocol used involved the CO-Synch plan without CIDR and bulls (same BFR) were used on day five following the initial GnRH injection (48 hours prior to the prostaglandin injection) up to 48 hours post prostaglandin injection. Timed AI occurred at 68 to 72 hours post-prostaglandin injection. Bulls were reintroduced at 84 hours post prostaglandin injection. The objective of natural service in conjunction with the programs was to service heifers in estrus early and late to the synchronization effects. The results summarized from calving data, suggested an increase in pregnancy rates of as much as 20%. This program looks interesting in incorporating natural service and AI into an intense breeding program (Torell, R. et al. 2007).

Conclusion

Beef bulls in natural service have expectations from producers of achieving satisfactory reproductive performance. This is particularly true when a Bull Breeding Soundness Evaluation classifies them as satisfactory potential breeders and prior breeding exposure yielded acceptable calving rates. However, due to the complex interaction between male reproductive potential, the environment and management, vast variability in performance is recognized between bulls and years. Management decisions and practices that influence a bull's reproductive performance play a large part in this variability. Factors that could determine the success or failure of a bull or bull group include:

1. Mating system the bull is employed
2. Reproductive soundness throughout the breeding season
3. Physical soundness throughout the breeding season
4. Observation and adjustments for faults or changes in libido and mating activity

5. Avoidance of dominance effects and associated herd fertility impacts
6. Mating load expectations and optimization
7. Young bull management for reproductive potential, mating experience and mating load

Although not detailed in this presentation, environmental conditions and nutrition play considerable roles in the present and future breeding potential of bulls. When possible, management should attempt to mitigate these effects to assure satisfactory breeding. Equally, disease and injury during a breeding season are ever common and any preventative measures that could control losses should be explored.

When bulls are placed in breeding situations of the intensity of an estrus synchronization program, higher levels of consideration for these factors must be placed. Any insult or defect in breeding activity may contribute to unsuccessful performance. The key with bulls in normal natural service or intense, short-term breeding service is constant vigil and observation of bull activity, health and viability for sustainable fertility for the duration of his herd reproductive service.

Literature Cited

Arteaga, A., M. Baracaldo, and A.D. Barth (2001)
The proportion of beef bulls in western Canada with mature spermiograms at 11 to 15 months of age. Can. Vet. J. 42:783-787

Barth, A.D. and R.J. Oko (1989)
Abnormal Morphology of Bovine Spermatozoa
Iowa State University Press, Ames, IA

Barth A.D (1997)
Evaluation of potential breeding soundness of the bull
In: Youngquist RS, (ed.) Current Therapy in Large Animal Theriogenology
W.B.Saunders Co., Philadelphia pp.222-236 1997

Blockey M.A.de.B (1976)
Serving capacity – a measure of the serving efficiency of bulls during pasture
Therio 6, pp.393-401

Blockey M.A.de.B. (1978)
The influence of serving capacity of bulls on herd fertility
J Anim Sci 46: pp.589-595

Blockey M.A.de.B. (1989)
Relationship between serving capacity of beef bulls as predicted by the yard test and their fertility during paddock mating
Aust Vet J. 66: pp.348-351

Blockey M.A.de.B (1979)
Observations on group mating of bulls at pasture
Appl Anim Ethol 5: pp.15-34

Boyd G.W. and Corah L.R. (1988)
Effect of sire and sexual experience on serving capacity of yearling beef bulls
Therio 29, p. 779

Boyd G.E., Lunstra, D.D., and Corah, L.R. (1989)
Serving capacity of crossbred yearling beef bulls I. Single-sire mating behavior and fertility during average and heavy mating loads at pasture
J Anim Sci 67, pp.60-71

Boyd G.W., Healy, V.M., Mortimer, R.G. and Piotrowski, J.R. (1991)
Serving capacity tests are unable to predict the fertility of yearling bulls
Therio 36, pp. 1015-1025

Brinks, J.S. (1972)
Heritability of fertility components in beef bulls
In: Proc. Beef Imp.Fed.Res.Symp. and Ann.Mtg. pp.21-28

Chase Jr., C.C., P.J. Chenoweth, R.E. Larsen, et al. (1997)
Growth and reproductive development from weaning through 18-months of age among breeds in sub-tropical Florida Therio, 47:723-745

Chenoweth, P.J., Farin, P.W., Mateos, E.R., Rupp, G.P., and Pexton, J.E. (1984)
Breeding soundness and sex drive by breed and age in beef bulls used for natural mating Therio 22, pp.341-349

Chenoweth, P.J., Farin, P.W., Mateos, E.R., Rupp, G.P., and Pexton J.E. (1988)
Relationships between breeding soundness and sex drive classifications in beef bulls
Therio 30, pp.227-233
Chenoweth, P.J., F.M. Hopkins, J.C. Spitzer, et al. (1994)
New guidelines for the evaluation of bulls for breeding soundness
Proc. Bovine Pract. 27:105-107
Chenoweth, P.J. (1997)
Bull libido/serving capacity
Vet Clinics of NA: Food Animal Practice 13, pp.331-334
Chenoweth, P.J. (2002)
Bull Breeding Soundness Exams and Beyond
Proc: App.Repro Strategies in Beef Cattle Sept. 2002, pp.174-180
Coulter G.H. and Kozub G.C. (1984)
Testicular development, epididymal sperm reserves and semen quality in two-year-old Hereford and Angus bulls: effects of tow levels of dietary energy
J Anim Sci 59, pp. 432-440
Coulter, G.H. and G.C. Kozub (1989)
Efficacy of methods used to test fertility of beef bulls used for multi-sire breeding under range conditions J. Anim. Sci. 67:1757-1766
Ellis, R.W. (2004)
Changes in physical, reproductive and behavioral characteristics of yearling beef bulls during natural service Masters Thesis University of Nebraska – Lincoln
Ellis R.W., G.P.Rupp, P.J.Chenoweth, L.V.Cundiff, and D.D. Lunstra (2005)
Fertility of yearling beef bulls during mating Therio. 64: 657-678
Farin, P.W., Chenoweth, P.J., Mateos, E.R., and Pexton, J.E. (1982)
Beef bulls mated to estrus synchronized heifers: single vs. multi-sire breeding groups
Therio 17, pp. 365-372
Farin, P.W., Chenoweth, P.J., Tomky, D.F. (1989)
Breeding soundness, libido, and performance of beef bulls mated to estrus-synchronized heifers
Therio 32, pp. 717-725
Fields, M.J., W.C. Burns, and A.C. Warnick (1979)
Age, season and breed differences in testicular volume and semen traits in young beef bulls J. Anim. Sci. 48: 1299-1304
Godfrey, T.A., Lunstra, D.D. (1989)
Influence of single or multiple sires and serving capacity on mating behavior of beef bulls J Anim Sci 67, pp. 2897-2903
Healy V.M., Boyd G.W., Gutierrez P.H. et al. (1993)
Investigating optimal bull:heifer ratios required for estrus-synchronized heifers
J Annim Sci 71:pp.291-297
Holroyd, R.G. et al. (2002)
Bull selection and use in northern Australia 4. Calf output and predictors of fertility of bulls in multiple-sire herds Anim. Reprod. Sci. 71:67-79

Jainudeen, M.R and B. Hafez (2000)
Reproductive Failure in Males
In: Reproduction in Farm Animals, Hafez B and Hafez ESE (eds.)
7th Ed. Pp 279-289 2000

Lunstra D.D., Ford, J.J., and Echternkamp, S.E. (1978)
Puberty in beef bulls: hormone concentrations, growth, testicular development, sperm production and sexual aggressiveness in bulls of different breeds
J Anim Sci 46, pp. 1054-1062

Lunstra, D.D. (1984)
Changes in libido-fertility relationships as beef bulls matures
J Anim Sci 59(Supp.1): 351 Abstr.

Makarechian,M.A., A. Farid and R.T.Berg (1985)
The relationship between breeding soundness evaluation and fertility of beef bulls under group mating at pasture Therio. 23: 887-898

Makarechian, M.A., A. Farid and R.T. Berg (1987)
Evaluation of bull fertility in multiple-sire mating at pasture
Can. J. Anim. Sci. 67:27

McCosker T.H., Turner A.F., McCool C.J., et al (1989)
Brahman bull fertility in a North Australian rangeland herd
Therio 32: pp.285-300

Neville, W.E. Jr., K.L. Richardson and P.R. Utley (1987)
Breeding performance of bulls assigned either to 40 cows per bull or 80 cows per bull during the breeding season J.Anim. Sci. 65:872

Pexton, J.E., Farin, P.W., Gerlach, R.A., and Sullins, J.L. (1989)
Efficiency of single-sire mating programs with beef bulls mated to estrus synchronized females Therio 32, pp. 705-716

Pexton, J.E., Farin, P.W., Rupp, G.W., Chenoweth, P.J. (1990)
Factors affecting mating activity and pregnancy rates with beef bulls mated to estrus synchronized females
Therio 34, pp. 1059-1070

Price, E.O (1985)
Sexual behavior of large domestic farm animals: an overview
J Anim Sci 61, pp.62-74

Rupp, G.P., Ball, L., Shoop, M.C., et al. (1977)
Reproductive efficiency of bulls in natural service. Effects of male to female ratio and single vs. multiple sire breeding groups
J Am Vet Med Assoc 171, pp.639-732

Torell R., Geary T., Bohnert D., Ahola, J. (2007)
Utilizing natural service with estrous synchronization in conjunction with timed Artificial insemination
Fact Sheet-07-25 University of Nevada Cooperative Extension

Society of Theriogenology (1983)
Manual for breeding soundness examination of bulls
J. Soc. for Theriogenology XII:1-6

USDA NAHMS Cow/Calf Health and Productivity Audit, Part I: Beef Cow-Calf Management Practices, May 1997