Calving distributions of individual bulls in multiple-sire pastures

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Abstract

The objective of this project was to quantify patterns in the calving rate of sires in multiple-sire pastures over seven years at a large-scale cow-calf operation. Data consisted of reproductive and genomic records from multiple-sire breeding pastures (n=33) at the United States Meat Animal Research Center (USMARC) from 2007 to 2013. Calving intervals were analyzed in 21-day periods. A ranking system for each bull was developed based on the calving rate per pasture over the breeding season, with Rank 1 = the bull with greatest calving rate, Rank 3 = the bull with the least calving rate, and Rank 2 = all other bulls. A total of 179 bulls and 3,703 calves were successfully genotyped over seven years. A uniform distribution described the expected percentage of calves sired per rank within pasture. Rank 1 bulls sired 113% greater calves than the expected pasture-average, Rank 2 bulls sired 6% less than expected, and Rank 3 bulls sired 81% less than expected. A rank by calving interval interaction [effect](#) was identified ($P < 0.05$). A Rank 1 bull in calving interval 1 produced a greater average percent of the total calf crop over the entire season, compared to a Rank 2 and Rank 3 bull. The calving rate for individual sires is not homogeneous and there is a large difference between bulls siring the greatest and least number of calves. More research is needed to determine how rank changes over multiple breeding years and its association with dominance, libido, and fertility.

Keywords

calving distribution, multiple-sire pasture, progeny, genotyping, beef bulls

1. Introduction

In commercial cow-calf operations in the United States, multiple bulls are utilized within individual breeding pastures. On average there are 24 cows per mature bull and 17 cows per yearling bull [1]. Bulls are expected to impregnate a high number of cows in a relatively short breeding season. Reproductive performance of bulls relies on the ability to detect cows in estrus, effectively mate cows, and successfully fertilize the oocyte to produce a viable fetus. The theory and practice of breeding soundness examinations is to screen bulls prior to the breeding season to assess some factors that impact reproductive success, such as sperm cell morphology and motility and musculoskeletal conformation [2, 3]. The desire of a bull to actively seek cows in estrous in order to mate is described as libido [4]. The number of estrous cows successfully mated is thought to be influenced not only by libido, but also by other bulls within the hierarchical nature of the herd, more commonly known as social dominance [5, 6]. Understanding and quantifying social dominance has been attempted, with little success to accurately predict reproductive performance based on social dominance [5, 7, 8]. Although commercial cow-calf managers do not have simple methods to identify bulls with high libido or high social dominance, there may be genetic and economic benefits for identifying these bulls.

Variability in the number of offspring born per bull exists between sires in multiple-sire pastures. The reasons for the variability are currently unknown, but have been speculated to be due to differences in libido, social dominance, or conception success among bulls [7, 9]. If variability of reproductive success between bulls in multiple-sire pastures is due to libido or

social dominance, an accurate understanding of bull behavior is needed. Serving capacity, as a proxy for libido, has been shown to be correlated with proportion of estrous cows mated by a bull in a single-sire pasture [10]. The effect of serving capacity on the number of offspring sired in a multiple-sire pasture may be mediated by the bull's hierarchical social ranking. If the number of cows in estrous is three or less, Blockey (1979) observed that a dominant bull is able to successfully prevent mating by other bulls, presumably regardless of competing bulls' libido [5]. If libido and social dominance rank are unrelated behavioral traits, then bulls with high libido and low social dominance or bulls with low libido and high social dominance are likely to negatively impact the number of calves sired by bulls with these characteristics in a multiple-sire pasture. Analyzing overall calving success by bull and patterns of calving success by 21-day intervals are necessary to investigate reasons for variability in progeny data. The objective of this study was to quantify patterns in the number of calves sired by bulls in multiple-sire pastures over multiple years at a large-scale cow-calf operation. We hypothesized that patterns of calving success by 21-day intervals during the calving season would show that bulls siring the greatest number of calves had different calving patterns than other bulls within that pasture.

2. Materials and methods

1. Herd description

Retrospective reproductive data were collected from cowherds housed at the United States Meat Animal Research Center (USMARC). Data consisted of reproductive and genomic

records from multiple-sire breeding pastures (n=33) from 2007 to 2013. The breeding began in June for each year analyzed and lasted for 63 days, and only one breeding season per year per bull was considered. Pastures consisted of cool and warm season grasses and ranged from 24.3 to 48.6 hectares in size. Rotational grazing was utilized to insure adequate nutrition. Each breeding pasture contained 23 to 243 cows with an average of 16 cows per bull (range 8 to 26). Bulls within each pasture were the same age. Breed of cows and bulls consisted of purebred as well as composites of approximately 16 breeds (ranging from 100% to 6.25% of any given breed). Breed within each breeding pasture was selected to produce the desired breeds and sire lines for genetic evaluation projects unrelated to this project. Breeding lifetimes averaged two years for bulls at USMARC, with a range of one to six years. A bull was culled during or after a breeding season based on injuries, reproductive performance, and/or genetic selection purposes. If a bull was removed during the breeding year, the length of total days the bull was in the breeding year was recorded.

2. Genotyping

All cows, bulls, and calves were genotyped using the animal's blood or semen with the Bovine SNP50 BeadChip to determine parentage [11]. Genotyping was confirmed by pedigree as previously described [12, 13]. Only sires with successfully genotyped calves were included in the dataset. If a calf was not successfully genotyped, the calf was removed from the analysis.

3. Calving intervals, rank classification, calving distributions

Calving intervals were analyzed in 21-day periods within the calving season; interval 1 consisted of days 0 to 21, interval 2 consisted of days 22 to 43, and interval 3 consisted of days 44 to 63. An individual bull's reproductive performance as measured by calving rate was calculated as number of calves sired divided by the days the bull was in the pasture for the breeding year. For example, if a bull sired 10 calves and was in the breeding pasture the entire 63 days, then the calving rate would be calculated as $10 \text{ calves} / 63 \text{ days} = 0.159 \text{ calves per breeding-day}$. If a bull was in the breeding pasture for less than 63 days, this number was used to determine the calving rate. For example, if a bull sired 7 calves, and was in the breeding pasture for 27 days, the calving rate would be calculated as $7 \text{ calves} / 27 \text{ days} = 0.259 \text{ calves per breeding-day}$. Based on this calving rate, a ranking system for each bull over the entire breeding season was developed, with Rank 1 = the bull with greatest calving rate, Rank 3 = the bull with the least calving rate, and Rank 2 = all other bulls. If two bulls had the same greatest calving rate, both those bulls received a "Rank 1" as their rank score. If two bulls had the same least calving rate, those bulls received a "Rank 3" as their rank score.

A uniform distribution was used to describe the expected percentage of calves sired per rank within a pasture. Observed percentage of calves sired was determined based on total calves sired by individual bull rank per pasture. The standardized rate between the observed and expected percentage of calves sired for each rank for all breeding seasons was calculated by the following formula [14]:

4. Statistical analysis

All descriptive analytics were performed in Excel (Microsoft Office Excel 2010, Microsoft Corporation, Redmond, WA). Statistical analysis was conducted to evaluate the overall calving distribution based on calving percent in each 21-day interval in each pasture, each year. The model [included effects for repeated measures on pasture within year. was ran with the PROC GLIMMIX procedure \(SAS Institute Inc., Version 9.4, Cary, NC, USA\) and included the 21-day interval as a fixed effect and a random intercept term to account for clustering within pasture within year.](#) Statistical analysis was conducted to evaluate differences between individual bull rankings within intervals of the total calving percent [using a generalized linear mixed model with the PROC GLIMMIX procedure \(SAS Institute Inc., Version 9.4, Cary, NC, USA\).](#) The model included [random effects for pasture within year and repeated measures for each sire fixed effects for rank, interval, and a rank by interval interaction, a random intercept term was included to account for clustering within pasture within year, and a random residual term with compound symmetry covariance structure was included to account for repeated measures for each sire.](#)

3. Results

3.1 Reproductive performance and calving distribution

A total of 3,703 calves were successfully genotyped, and a total of 179 bulls were individually analyzed. Average calving success (calves born per cow exposed for breeding) between the 33 breeding pastures was 89% (range of 67 to 100%) over all 7 years. **Fig. 1** shows the calving distribution of the calving percent per 21-day interval for all individual bulls within pastures. The percentage of calves born per 21-day period decreased as the days in the breeding season progressed.

3.2 Sire rankings

The results on the observed percentage of calves sired for Rank 1 bulls and the expected percentage of calves sired if there was a uniform distribution between the percentages of calves sired between bulls per pasture is shown in **Table 1**. The standardized rate between the observed and expected percentage of calves sired for each rank indicates that Rank 1 bulls sired 113% greater calves than expected on average, Rank 2 bulls sired 6% less than expected, and Rank 3 bulls sired 81% less than expected.

The results of the calving percent difference between individual bulls by rank in 21-day intervals are shown in **Fig. 2**. A calving interval by bull rank interaction was present, $P < 0.05$. A Rank 1 bull in interval 1 produced on average 13% of the total calf crop, a Rank 2 bull produced on average 6% of the total calf crop in interval 1, and a Rank 3 bull produced 2% of the total calf crop in interval 1. The differences between the ranks of individual bulls within interval 1 were statistically significant, as were the differences between ranks within intervals 2 and 3. Overall,

individual Rank 1 bulls sired the greatest percentage of calves in interval 1, 2, and 3, compared to Rank 2 and Rank 3 in the same intervals.

Rank changes between years for individual bulls based on the number of breeding years bulls are used are shown in **Table 2**. Breeding years ranged from one to six years, with a majority of the bulls being utilized for two breeding years. Only 19 bulls had a change in rank over breeding years. There were a total of 21 rank changes from all bulls because two of the 19 bulls had two rank changes over their breeding years. Most rank changes occurred for bulls used for 4 breeding years, and the rank change that occurred most commonly was a change from Rank 2 to Rank 1. There was one bull that had a rank change from a Rank 3 to Rank 1. There were 11 bulls which increased rank, and there were 10 bulls which decreased rank over the breeding seasons evaluated.

4. Discussion

The current study shows a reliable way to classify bulls with successfully genotyped calves in order to describe bulls in multiple-bull pastures with the greatest calving rate. This dataset was consistent with other reports demonstrating the variability in reproductive performance between bulls in multiple-sire breeding pastures [15-17]. One study of a breeding pasture with 27 herd sires found that five bulls produced greater than half of all viable offspring, and 10 bulls did not sire any calves [18]. Variability in bull reproductive success has also been demonstrated at a breeding farm in Northern Australia where 235 bulls were exposed to cows

that sired 4,251 calves; of which, 14% of the bulls sired greater than 30% of the calves, and 6% of the bulls did not sire any calves [16]. Some studies have shown that social dominance and scrotal circumference are highly heritable and related to herd fertility [19, 20]. Whereas, other research has shown no difference between social dominance and calf output, as well as between social dominance and libido [8, 17, 21]. Therefore, there is a need for technology (e.g. genotyping, GPS) to aid in understanding what is happening in breeding pastures before management strategies can be improved.

Factors, such as social dominance and libido, are evaluated on herd level data to predict fertility and reproductive success within a breeding season. The ranking system developed in the current study is not used as a prediction for calving rate or success. The ranking system is a way to evaluate calving rate differences between bulls at the end of the breeding season, and identify those top and bottom producing bulls. Understanding more about the genetic and management of these ranked bulls may be advantageous for predicting reproductive success in a breeding season. Further research is needed to develop methods to accurately classify the rank of the bulls and identify the effect on calving rate. In the present study, we used parentage genotyping to begin to develop methods to rank bulls within a pasture using 21-day intervals.

Established, controlled breeding seasons for a herd increases productivity compared to long or year-around breeding seasons [22]. Analyzing the herd reproductive data from a single breeding season in 21-day intervals allows for an overall assessment of the herd to determine differences in reproductive success between 21-day intervals as the breeding season progresses

compared to desired patterns [23]. Analyzing the percent of calves being born over these intervals serves as a method to evaluate herd-level reproductive efficiency, but does not assess the reproductive efficiency of individual bulls. Assessing individual bulls by their rank within calving intervals serves as a method to determine the total contribution these bulls had to the overall calving percentage of the breeding season and how performance varied across the breeding season.

The ranking system described in this study identifies and compares those bulls with the greatest calving rate to the bulls with a lesser calving rate, and is the first attempt to classify bulls with this type of system to the author's knowledge. The Rank 1 bulls produced a greater percentage of the calving percent per 21-day interval per pasture. This is similar to other research studies that identified a higher percentage of calves sired by a lower percentage of the total bulls per pasture [18, 24]. Rank was modified by the interval of the calving season with the magnitude of the effect of rank on the percent of calves sired per 21-day interval decreasing as the calving season progressed (**Fig 2**). There is value to identify bulls with greater reproductive success compared to the least successful bulls. Our hypothesis was supported in that bulls that sired the greatest number of calves were consistently superior to lower ranked bulls for each 21-day interval of the breeding season. The least ranked bull produced the least calving rate within the three intervals analyzed, which could negatively influence pregnancy risk over an entire breeding season.

Possible management interventions for commercial herds that are able to identify the relative ranking of bulls could be to remove the bull with perceived greatest dominance from a breeding pasture after a prescribed period of time, if bull rankings over time do not change (i.e. once one-half the cows are expected to have been bred). Removing the most dominant bull would allow bulls with desirable genetic worth but less reproductive success to be able to sire an increased number of calves in spite of lower social dominance or other behavioral factors that limit calving success in multiple-sire breeding pastures. Similarly, bulls with less social dominance but desired genetic worth could be removed to a single-sire pastures where social dominance is not expected to influence reproductive success, and therefore be more efficient in their calving success [25]. The effect of age on social dominance and behavior has been studied [26-28], and groups of bulls of the same age achieve higher pregnancy rates than groups of bulls of mixed age [5]. Effect of age on reproductive rank could not be assessed in the current study because the bulls within each pasture were the same age. Understanding how age of bulls effects rank over time would be beneficial. Additional research is needed to determine the genetic and management factors that are associated with variability in bull rankings before changes in sire selection or management of commercial cattle herds is suggested.

One of the limitations of our study was that bulls were most commonly used 2 breeding years due to the herd management established at USMARC. As shown in **Table 2**, most of the bulls ranking did not change over time. The low numbers of bulls that changed ranks did not allow us to evaluate potential reasons for changing ranks in this study. More research is needed to determine frequency and factors related to an individual bull changing ranks over multiple

years. Another limitation of this study is the data can only be extrapolated to the study population available from USMARC, more research is needed to determine the association of different breeding management practices and individual bull rank.

4.1. Conclusion

This study demonstrates variability in the number of progeny by bull in multiple-sire pastures over seven years. Analyzing the percent of calves being born over 21-day intervals as a whole-herd assessment does not assess the reproductive efficiency of individual bulls. Ranking bulls by calving rate for the entire calving season is associated with number of calves sired by individual bulls in each 21-day period of the calving season. More research is needed in order to determine how rank changes for bulls over multiple breeding years, how to identify bulls with the greatest and least rank, and how calving rank is associated with dominance, libido, and fertility.

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Figure 1. Model-adjusted least square means ($\pm$ SE) calving percentage for each 21-day interval.

Effects for repeated measures on pasture within year were included in the model. Interval 1 consisted of days 0 to 21, interval 2 consisted of days 22 to 43, and interval 3 consisted of greater than 43 days.

Interval 1 = days 0 to 21

Interval 2 = days 22 to 43

Interval 3 = greater than 43 days.

Figure 2. Model-adjusted calving percent ($\pm$ SE) per bull by reproductive rank by 21-day intervals. Effects for repeated measures on pasture within year and sire were included in the model. An interaction based on rank and interval was identified ($P < 0.05$). Rank with non-connecting letters were significant ($P < 0.05$) within an individual interval.

Interval 1 = days 0 to 21

Interval 2 = days 22 to 43

Interval 3 = greater than 43 days

Table 1. Average observed and expected percentage of calves sired per bulls categorized in the different ranking. Rank 1 = bulls with the greatest number of calves sired per pasture, Rank 3 = bulls with the least number of calves sired per pasture, and Rank 2 = all other calves. A uniform distribution of calves sired per total number of bulls within a pasture was used to determine the expected percentage of calves sired. Observed percentage of calves sired was determined based on total calves sired by each bull rank per pasture. The standardized rate between the observed and expected percentage of calves sire for each rank was calculated by the formula (Observed % of calves sired per pasture by rank – Expected % of calves sired per pasture by rank) / Expected % of calves sired per pasture by rank.

	Average observed percentage of calves sired per pasture	Average expected percentage of calves sired per pasture	Standardized rate between observed and expected percentage of calves sired
Rank 1 ^a	34%	16%	113%
Rank 2 ^b	15%	16%	-6%
Rank 3 ^c	3%	16%	-81%

^a Bulls with the greatest number of calves sired per pasture

^b All other bulls not included in Rank 1 or Rank 3

^c Bulls with the least number of calves sired per pasture

Table 2. Rank by year for individual bull counts. Breeding years correspond to the number of years a bull was used in a breeding season. Of the bulls that were used for two breeding years, 92 had no change in rank, and 1 had one change in rank. A total of 179 bulls were analyzed, with two bulls having two changes in rank over their breeding years, accounting for the total of rank changes being 181.

Rank change	Number of breeding years-bulls used						Total
	1	2	3	4	5	6	
No change	47	92	5	15	0	1	160
1-2	0	0	1	3	0	0	4
1-3	0	0	0	1	0	0	1
2-1	0	0	4	2	0	0	6
2-3	0	1	2	2	0	0	5
3-2	0	0	2	3	0	0	5
Total	47	93	14	26	0	1	181