Use of Parentage Testing: Implications for Bull Fertility and Productivity[1]

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ABSTRACT

Bull performance in multi-sire breeding pastures was determined using SNP-based DNA parentage testing for 5,052 calves from 3 ranches, for 3 years and 15 calf crops in Northern California. DNA information was unable to uniquely assign paternity to an average of 3.8% of progeny (2.6, 3.0 and 5.7%). Bulls averaged 18.9 calves per calf crop but varied from 0 to 64, with 4.4% siring no progeny. Wide variation in bulls' individual average adjusted 205 day weaning weight was found. However, cumulative total 205 day weight per bull per calf crop was highly correlated to prolificacy, and not average individual calf weaning weight. Weekly conception rates as determined by date of calving varied throughout the calving season but peaked at week 3, with 75% of the calves born by day 42. Calves born early in the calving season were highly skewed toward more prolific bulls, impacting genetic composition of progeny. The subsequent calf crop disproportionally tended (P=0.25) to have more replacement heifers calving from high prolificacy sired heifers than from low prolificacy sired heifers. Prolificacy of young bulls assessed in their first breeding season was positively related to subsequent breeding seasons and offers an opportunity to categorize young bulls according to prolificacy. The repeatability of prolificacy assessment was 0.37 in bulls greater than 2 years of age and 0.33 amongst all bulls. Prolificacy was positively related to scrotal circumference EPD for Angus bulls that had BIF accuracies greater than 0.05. Selection of traits and corresponding EPDs for these conditions and costs suggested emphasis on reproduction traits and correlated EPDs and less on growth traits and their associated EPDs. Prolificacy assessment using DNA information provides opportunity to estimate bull performance in multi-sire breeding pastures under commercial conditions. Based on the results of this study, the high cost of herd bulls, and the development of reliable and fixed-time AI protocols, it is probably time for commercial producers to re-evaluate the economics of AI versus the exclusive use of natural service bulls.

Introduction

Natural service breeding is the predominant practice for beef cattle operations in the U.S. but few studies have examined the variation in number of calves sired and the consistency of an individual bull's performance in multiple sire breeding pastures. In previous work we found that five of 27 (19%) herd sires in a large multi-sire breeding group produced over 50% of the calves, whereas 10 sires produced no progeny and of these nine were yearling bulls (Van Eenennaam et al., 2007).

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Likewise an Australian study looking at full or partial Bos indicus bulls in multiple sire breeding groups found 14% of the bulls produced over 30% of the calves, 58% sired 10% or fewer calves, and 6% of bulls sired no calves (Holroyd et al., 2002). In that study the number of progeny sired was found to be a moderately repeatable trait (r=0.43-0.69) from year to year. These data suggest that certain bulls in a multi-sire team are disproportionately impacting both herd genetics and ranch income.

Few genetic tools exist for selecting bulls with superior breeding performance. Holroyd et al. (2002) found that there were breed differences in a variety of traits related to calf output (e.g. scrotal circumference, testicular tone, dominance, libido score, and semen quality), but that those traits explained only 35-57% of the phenotypic variation in the number of progeny sired.
We evaluated bull paternity and performance in multi-sire breeding pastures from three large commercial beef ranches in Northern California.

Ranch descriptions

Ranch A consisted of a spring calving (start of calving Jan. 1) herd (n= 550) that were summered in the mountains, and a fall (start of calving Sept 1) herd (n= 350) remaining on the valley floor. Ranch B consisted of a spring (Feb. 1) calving herd (n=200) that remained on the valley floor and a fall (Oct. 1) herd (n=300) that was summered in the mountains. Ranch C had only a fall (Aug. 15) calving herd (n=700) that remained on the valley floor. Nutrition was comprised of grazed perennial grasses, alfalfa stubble, and grass and alfalfa hay during the winter.

Breeding seasons varied from 70 to 120 days with a 25 to 1 ratio of cows to bulls maintained in various size breeding groups, ranging from 2 to 9 bulls and breeding pastures of approximately 100 acres. Cows were predominantly Angus due to multiple generations of Angus sires and selection of replacement heifers from within herd. Angus bulls were predominantly used with a few South Devon, Hereford, Red Angus and other breeds. Bulls passed breeding soundness exams and were removed when injured or judged in poor condition by experienced producers. Young bulls were grouped together. Cows were randomly assigned to breeding groups each year. Bulls were culled when judged to be unable to service cows; predominantly due to injuries. Bovine SeekSire genotyping (GeneSeek Inc., Lincoln, NE) using a ~100 SNP panel was used to determine paternity. Bull genetics are described by their mean EPDs for various traits (Table 1). Statistically different EPDs were observed (primarily for carcass traits and scrotal circumference) but were generally small numerical differences.

Ranches marketed calves at about 12 months of age to the same feedlot/processor in a vertically integrated partnership. Ranches received income for feedlot inweight plus premiums for superior carcasses. Carcass premium standards and range of acceptable EPDs for herd sires were the same for all ranches but management to achieve targets were determined by the ranch management, leading to more similarity in purchased Angus bulls than likely typical of random ranches (Table 1).

Table 1. Mean Angus EPD values of bulls for ranches A, B and C.

	CED	BW	WW	YW	SC	Milk
N	214	217	219	219	179	219
Ranch A	6.9 a	1.3 a	41.1 a	79.9 a	0.54 a	22.1 a
Ranch B	5.4 b	1.5 a	39.4 a	77.0 ab	0.50 a	22.7 a
Ranch C	5.0 bc	1.6 a	42.5 ab	75.8 b	0.22 b	20.2 b
P value	<.01	0.2	0.01	0.01	<.01	<.01

	CW	Marb	RE	Fat
N	209	212	210	207
Ranch A	25.9 a	0.65 a	0.38 a	0.023 a
Ranch B	22.2 ac	0.39 b	0.30 b	0.011 b
Ranch C	16.3 bc	0.28 c	0.27 b	0.010 b
P value	<.01	<.01	<.01	<.01

	RADG	YH	Doc	HP	CEM	MW	MH
N	61	146	91	69	219	140	134
Ranch A	0.15 a	0.31 a	8.0 a	9.2 a	9.3 a	34.2 a	0.34 a
Ranch B	0.15 a	0.41 a	13.5 b	5.8 b	7.7 b	17.7 b	0.26 a
Ranch C	0.12 a	0.35 a	8.2 a	8.8 a	8.1 b	26.4 bc	0.26 a
P value	0.09	0.22	<.01	<.01	<.01	<.01	0.14

	$EN	$W	$F	$G	$QG	$YG	$B
N	213	219	219	212	212	212	212
Ranch A	-0.03 a	25.8 a	25.1 a	33.8 a	30.7 a	3.1 a	71.6 a
Ranch B	1.00 ac	25.8 a	22.5 ab	26.2 b	22.5 b	3.7 ab	60.1 b
Ranch C	3.4 bc	26.7 a	19.8 b	23.0 bc	18.0 c	5.0 b	49.1 c
P value	0.01	0.27	<.01	<.01	<.01	<.01	<.01

Bull natural service reproductive performance: aggregate values

Mean output of progeny per bull for ranch (18.6±6.0, 19.9±3.8, 21.1±13.2), year (19.9±3.8, 20.1±1.9, 19.7±7.7), and season (Spr. 20.5±12.2, Fall 19.2±5.0) were remarkably similar (Table 2). Overall bulls sired an average of 19 calves each calf crop (18.9±13.1). Mean output varied more when calculated for any given calf crop ranging from 14.4 to 26.5 calves per bull. Under these conditions the mean bull age was 4.4±1.7 years, ranging from 1.3 to 11.6.

Table 2. Reproductive performance of natural service bulls for three vertically-integrated northern California commercial beef ranches (A, B and C) using DNA paternity identification to identify the sire of calves conceived in multi-sire breeding pastures.

								Per bull		
Ranch	Year	Calf crop	No. of sires	Min bull age, yr	Max bull age, yr	Mean bull age ±SEM[a]	Total no. of calves	Min no. calves	Max no. calves	Mean number calves±SEM[b]
A	2009	Spring	18	2.3	6.9	4.3±0.3	353	3	47	19.9±3.8
A		Fall	19	2.4	4.6	3.5±1.4	346	1	47	19.6±18.2
A	2010	Spring	22	1.9	5.9	4.3±0.9	435	3	45	19.8±3.8
A		Fall	19	2	5.6	3.9±1.2	328	1	48	18.4±22.1
A	2011	Spring	17	2.4	5.9	4.7±1.2	402	4	53	24.2±4.7
A		Fall	19	2	6.6	4.2±1.8	286	1	33	16.8±14.5
B	2009	Spring	8	1.4	9.8	4.3±0.3	141	1	45	16.7±10.0
B		Fall	10	2.1	9.6	4.3±0.3	214	10	50	21.8±9.3
B	2010	Spring	8	2.3	5.9	3.0±1.1	142	3	30	16.5±7.4
B		Fall	12	2.1	10.6	4.3±0.3	247	4	44	20.2±12.9
B	2011	Spring	4	3.4	6.9	4.3±1.4	110	18	42	26.5±14.4
B		Fall	12	2.1	11.6	4.6±1.6	266	3	51	22.8±6.2
C	2009	Fall	30	2.4	6.5	4.3±1.2	642	2	54	20.3±3.0
C	2010	Fall	27	2.5	6.6	4.6±1.7	567	1	52	19.9±3.8
C	2011	Fall	38	2.4	8.5	5.5±0.9	573	1	64	14.4±5.7
A	2009-2011		114	1.9	6.9	4.1±0.7	2150	1	53	18.6±6.0
B	2009-2011		54	1.3	11.6	4.8±0.5	1120	1	51	19.9±3.8
C	2009-2011		95	2.4	8.5	3.9±1.6	1782	1	64	21.1±13.2
A,B,C	2009-2011		263	1.3	11.6	4.4±1.7	5052	1	64	18.9±13.1
	2009		85	1.4	9.8	4.3±0.3	1696	1	54	19.9±3.8
	2010		88	1.9	10.6	4.3±1.0	1719	1	52	20.1±1.9
	2011		90	2	11.6	4.2±0.6	1637	1	64	19.7±7.7
	Spring		77	1.4	9.8	4.0±0.7	1583	1	53	20.5±12.2
	Fall		186	2	11.6	4.5±0.2	3469	1	64	19.2±5.0

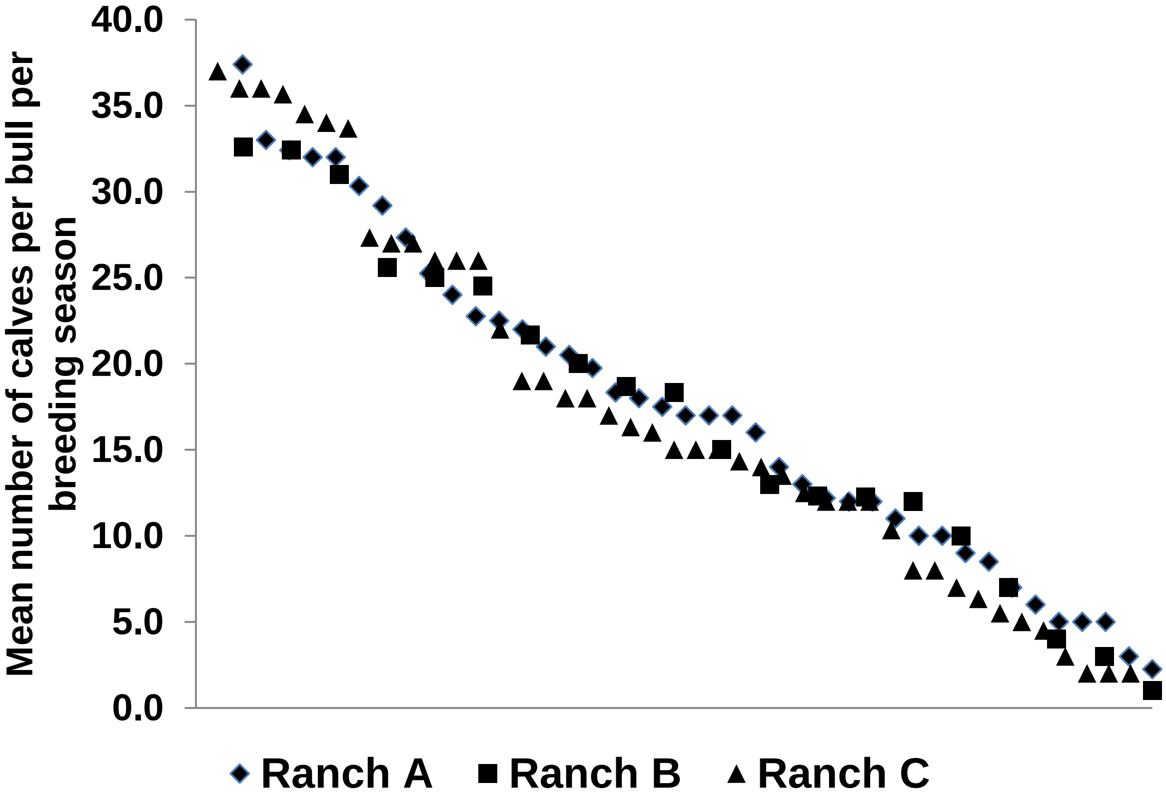
[a] Ranch P=.47, Year P=.94, Season P=.59, Calf crop P=.41

[b] Ranch P=.90, Year P=.96, Season P=.94, Calf crop =.51

Bull natural service reproductive performance: individual values

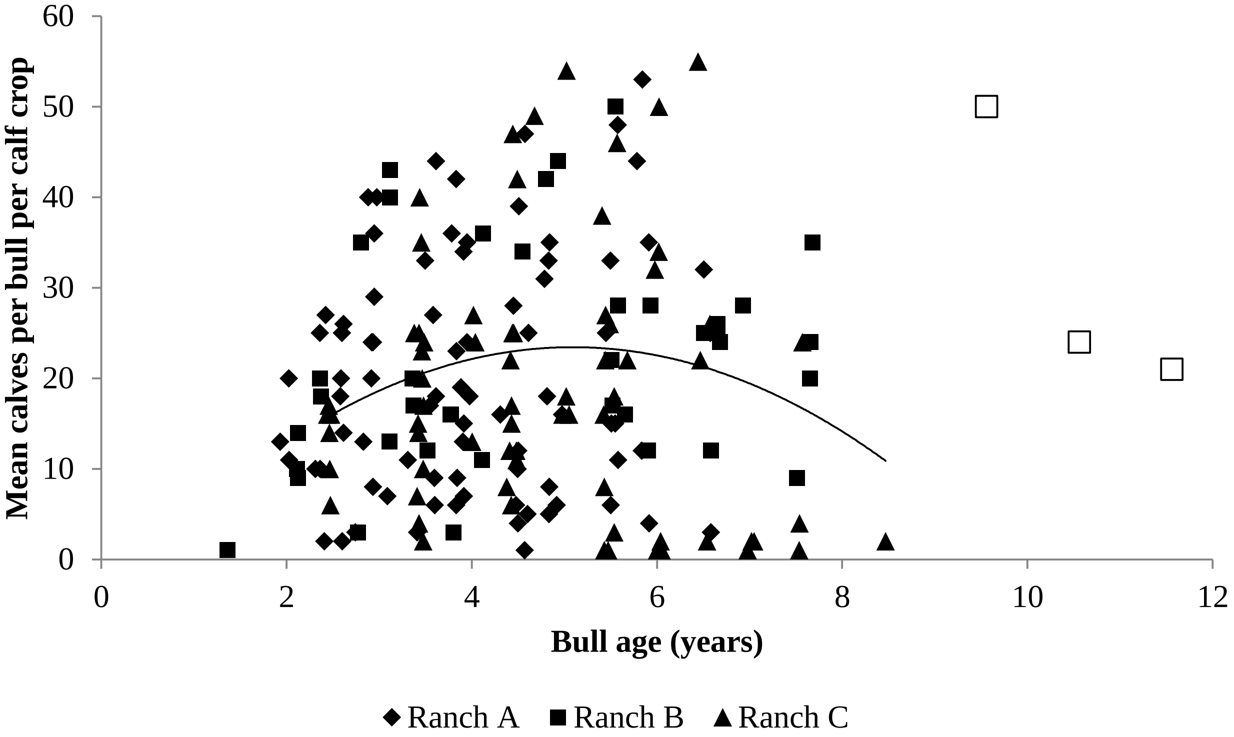
Individual bull performance was significantly more varied than aggregate values (Table 2). The minimum and maximum progeny for an individual bull for a calf crop ranged from 0 to 64. In 40% of the calf crops a sire produced only one calf, and conversely in 40% of the calf crops a sire produced 50 or more calves. The mean number of calves per bulls (**CB**) (bulls 3 years of age or older with at least 2 calf crops) varied widely (P<.01) ranging from means of 3.3±6.3 to 39.1±10.9 **CB** (Figure 1). Prolificacy repeatability for these bulls was 0.37, which is similar to 0.43 found by Holroyd et al., 2002 under extensive Australian conditions. Reproductive failure, no calves produced, occurred in 4.4% of the bulls (12/275 bull breeding season opportunities), similar to the 6% of *Bos indicus* bulls in northern Australian that sired no calves (Holroyd et al., 2001).

Figure 1. Mean number of calves produced per bull per calving season varied (P<.01) between bulls.



Bull prolificacy tended to increase up to about 5 years of age and then declined (Figure 2). However, this accounted for only a small portion of the total variation (R^2=.05) in prolificacy.

Figure 2. Calves per bull (**CB**) per calf crop increased (P<.01) in a curvilinear manner peaking at about 5 years of age when one old bull (□) that was a significant outlier was removed.



Prolificacy and EPDs

Scrotal circumference (SC) EPD (ACC greater than 0.05) was not significantly related (P=.16) to prolificacy when including all bulls in the data set. However, when the single outlier bull (from Ranch C) was removed from the analysis, there was a significant relationship between SC (P=.04) and prolificacy (Figure 3) where,

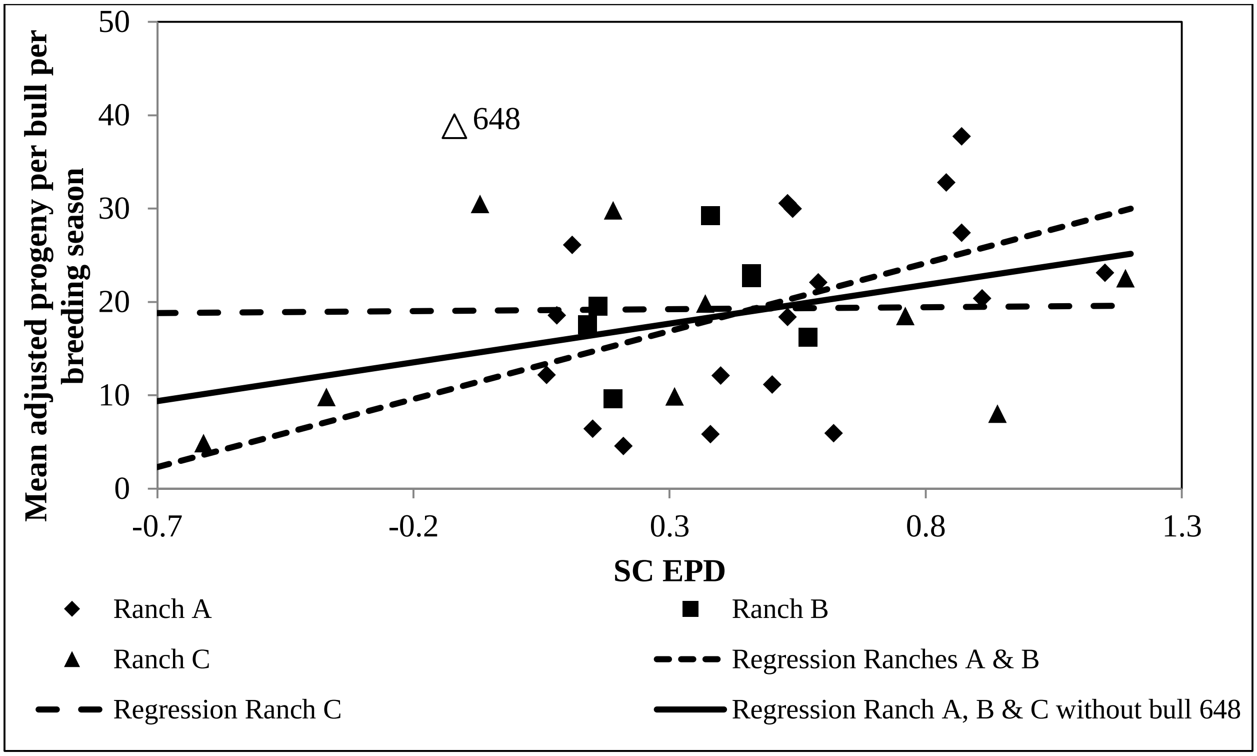
$$\boldsymbol{CB} = 15.2 + 8.27 \times \boldsymbol{SC},\ R^2=0.13,\ \text{SE of the coefficient}=3.0$$

Scrotal circumference has previously been associated to **CB** (Coulter and Kozub, 1989), however Holroyd et al. (2001) did not generally find scrotal circumference related to prolificacy except for 5/8 Brahman bulls. Scrotal circumference has strong associations with various other traits of importance to reproduction. No other EPDs examined were related to prolificacy.

Scrotal circumference has consistently been reported to be a useful method for assessing reproductive function in bulls (Burns et al., 2011). Scrotal circumference EPDs have been positively associated with sperm motility and total BSE score (Moser et al., 1996). Burns et al. (2011) published an excellent review of the correlation between scrotal circumference and reproductive traits. Favorable influence of scrotal circumference and SC EPD on heifer maturity has been reported (Brinks et al., 1978; Moser et al., 1996; Smith et al., 1989; Toelle and Robison 1985; Martinez-Velazquez et al., 2003). Scrotal circumference is a component of the breeding soundness examination that has been related to bull fertility (Kealey et al., 2006), and scrotal circumference estimates testicular tissue that impacts semen quantity. The reverse of scrotal circumference selection, tropical cattle selected for high or low pregnancy rate breeding value resulted in bull progeny with larger scrotal circumference at 18 months of age for the higher pregnancy rate group (Mackinnon et al., 1987). Bamualim et al., (1984) found actual scrotal circumference was correlated to pregnancy rate (.15) in the year of measurement but negatively to lifetime pregnancy rate (-.10), much lower than breeding soundness scores (.36 and .47, respectively).

The most valuable scrotal circumference measurements are at about one year of age. SC EPD may provide an early indication of potential sire prolificacy and avoid environmental influences associated with actual scrotal circumference measurements. This relationship between scrotal circumference EPDs and male reproduction as measured by prolificacy during a natural service breeding season does not appear to be among published studies and is an interesting topic for further investigation.

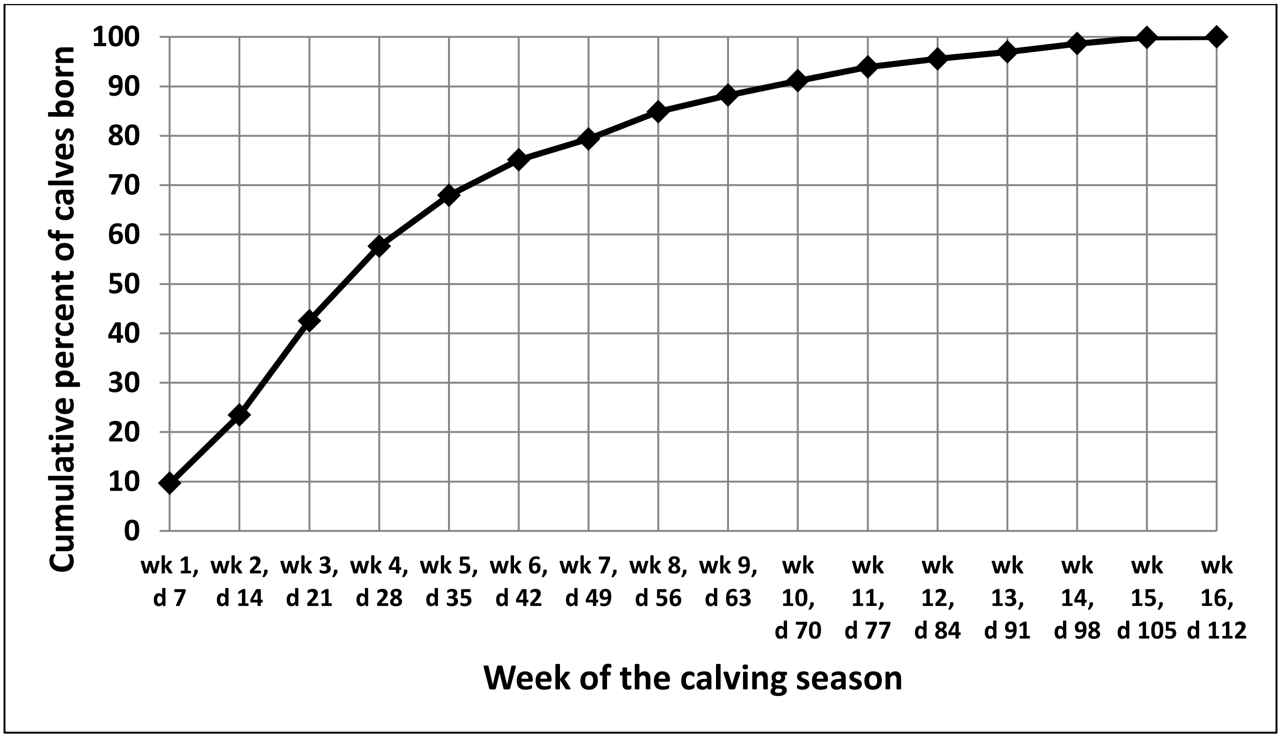
Figure 3. Prolificacy was related to scrotal circumference (SC) EPD for Ranches A and B combined and Ranches A, B and C when bull 648, an outlier, was removed. About 12% of the variation in prolificacy (R^2=.12) was explained by SC EPD.



Calving Distribution

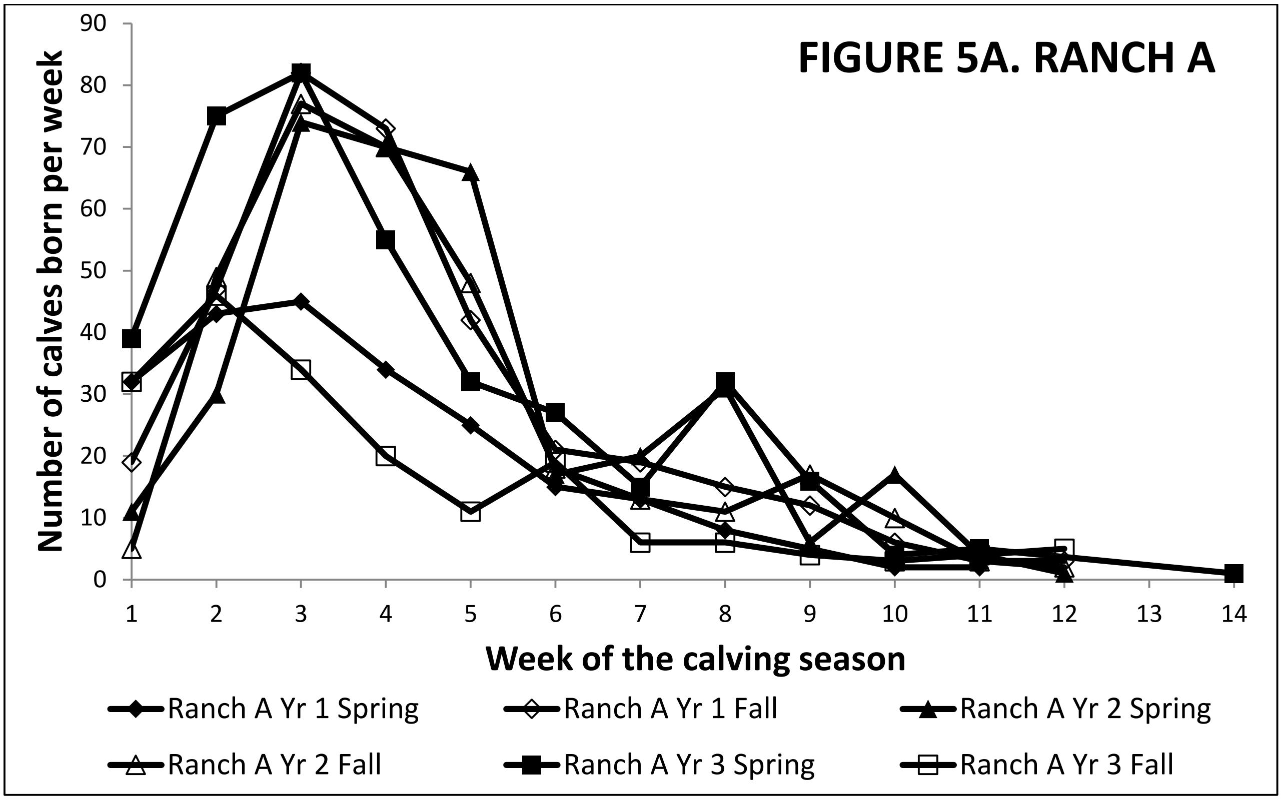
With the ranches combined (Figure 4), 42% of the calves were born by the end of 21 days and 75 percent by the end of 42 days (2 heat cycles). The calving distribution of calves for each calf crop at each ranch had a similar pattern (Figure 5 Ranch A, B and C). Typically calving rate increased, peaking at week 3 of the calving season and declining thereafter. In 80% (12/15) of the calf crops peak calving occurred in week 3. In calf crops where the peak was not week 3 peak calving occurred in week 2 twice and week 1 once. This pattern is also supported (Figure 6) using the mean number of calvings per week per calf crop for each ranch.

Figure 4. By 21 days of the calving season (reflecting the breeding season) a mean (all ranches combined) of 42% of the calves were born. By 42 days (2 heat cycles) a mean of 75% of the calves were born.



The largest number of calves born in a single week occurred in week 3 in 12 of the 15 (80%) calving seasons evaluated. Pooled across ranches and adjusted for ranch, year and season, peak calving occurred in week 3. In the three seasons where peak calving was not during week 3 it occurred in week 2 twice and week 1 once.

Figure 5 A, B and C. Calving distribution for each calf crop at each ranch was similar. Typically the calving rate increased, peaking at about week 3 and declined thereafter.



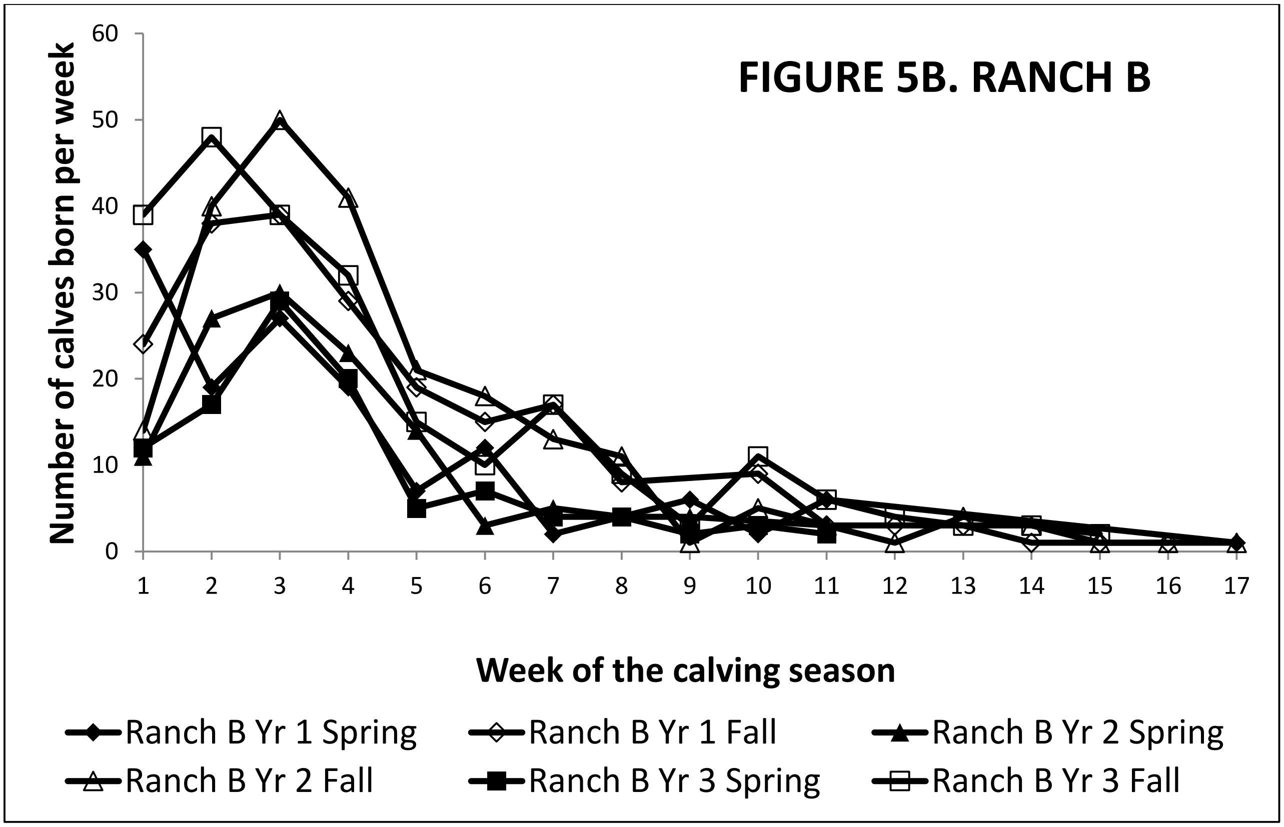


Figure 5. ***Continued.***

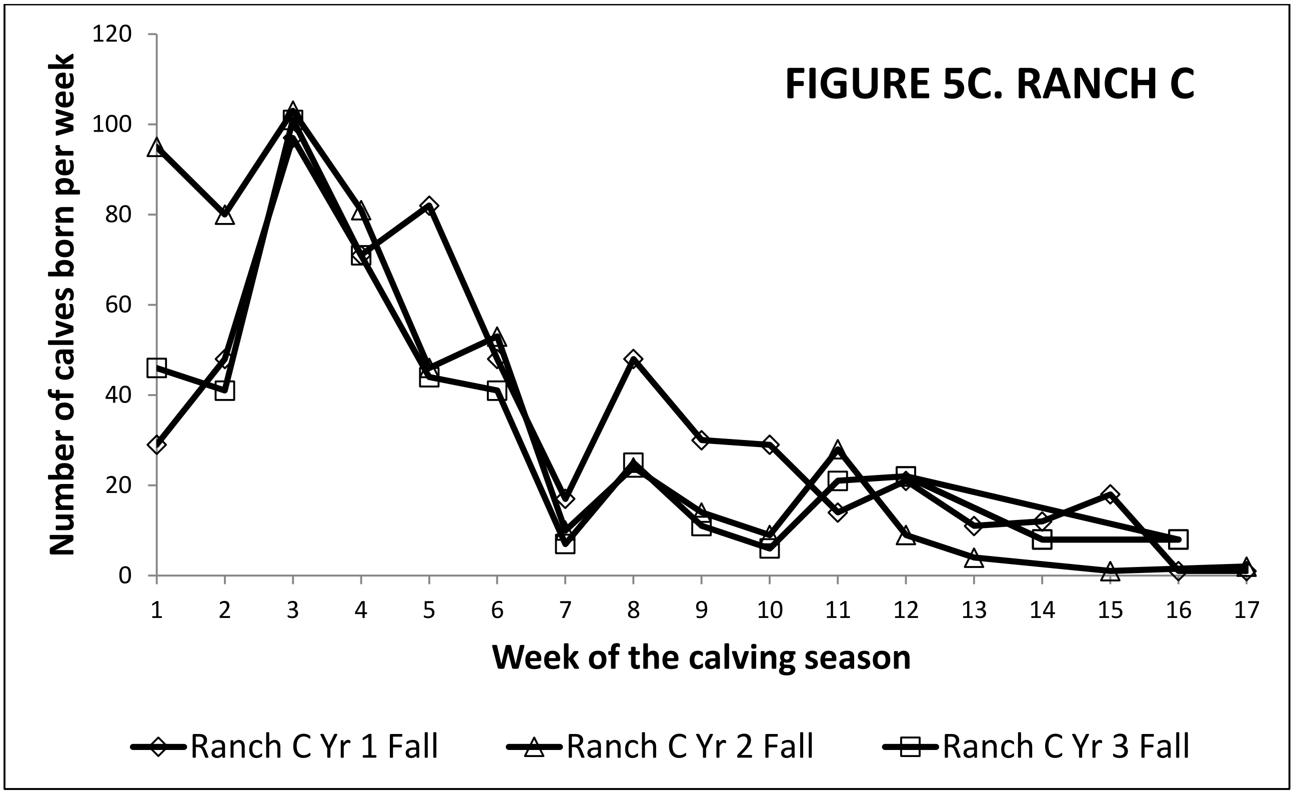
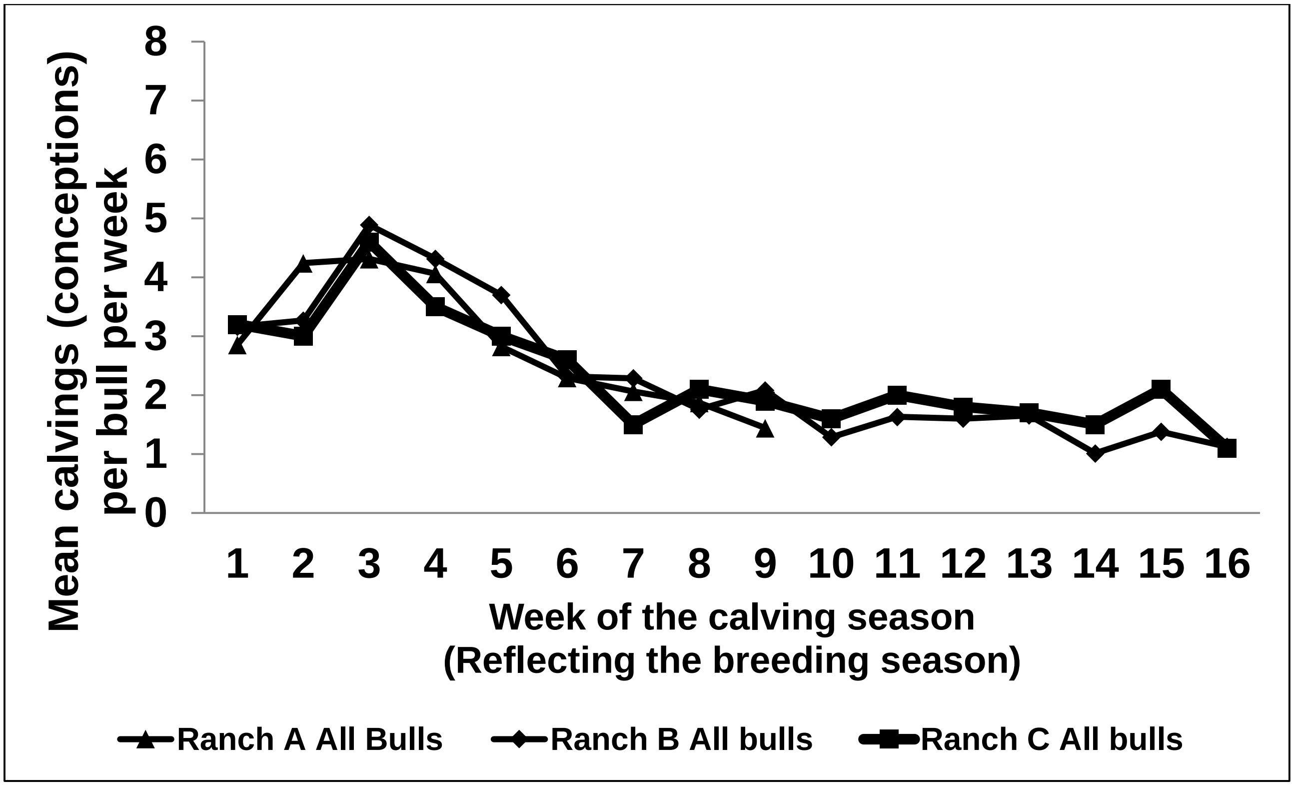


Figure 6. Mean calvings per week per bull per calf crop (with calf crops combined for each ranch) reflected the typical pattern of an increasing calving rate to week 3 followed by a decline.



Calving distribution and bull prolificacy

Bulls prolificacy status were assessed based on total progeny for each calf crop at each ranch: categories of high, medium and low prolificacy we designated by assigning an equal number of bulls into each of the three categories based on **CB**. Calving distribution by bull prolificacy assessment (ranches combined) indicated high prolificacy bulls sired more calves early in the breeding season based on calving date of progeny (Figure 7). Peak calving occurred in week 3. Low prolificacy bulls had calves born at about the same rate throughout the calving season. After about week 6 bulls of all prolificacy categories had calves born at about the same rate. Genetic composition of the calf crop reflects the variation in prolificacy of bulls.

The pattern of calving distribution suggests potential for management changes that alter distribution. Management to promote earlier calving than the peak seen at week 3 would result in a greater number of older calves at sale, which are generally more desirable, of higher quality and more profitable (Minyard and Dinkel, 1965; Lesmeister et al., 1973; Funston et al., 2012).. Similarly, efforts to promote cows with calves born toward the end of the calving season to calve earlier could enhance profit with older calves. Changing from natural service to estrus synchronization procedures and fixed time insemination resulted in earlier calves (Patterson et al., 2006). A fixed time artificial insemination trial at Ranch B (unpublished data) resulted in calves an average of 10d older at a single fixed-date weaning.

Ranches retaining their own replacement heifers are likely to be retaining more replacement heifers from high prolificacy bulls due to the disproportionately large number of older heifers from these sires (Figure 7). Typically replacement heifers are selected from older heavier heifers. These would be heifers born in the early part of the calving season. As shown (Figure 7) heifers born early in the calving season are predominantly sired by high prolificacy bulls. Conversely, a small number of replacement heifers are also likely from low prolificacy sires. The effect of sire prolificacy on daughter's fertility has not been reported in the literature. Mackinnon et al (1990) reported the heritability of bull (.08) and cow fertility (.11) were correlated (r^2 =.16) and suggested indirect trait selection in males for fertility traits could be an approach to improved female fertility.

Prolificacy assessment of young bulls

Prolificacy of young bulls (N=24) in their first year of use was related (P=.03) to subsequent prolificacy but explained only 20% (r^2=0.20) of the subsequent prolificacy. Their first year performance was also correlated (0.45) to subsequent performance. But young bulls categorized into high, medium and low prolificacy did not remain in those categories (P=0.20). However young bulls assessed as high prolificacy tended (P=.11) to remain as high, and only 12.5% dropped to low prolificacy (Table 3). And, similarly low prolificacy bulls based on their first year of service tended (P=.10) to remain low with only 12.5% increasing to high. Culling based on first year performance may be beneficial but due to the initial investment and small salvage value of bulls used only one year may not be economical.

Figure 7. Bulls categorized by prolificacy (for the entire calf crop): High, medium and low and mean number of calves born per bull per week by week of calving season for ranches combined.

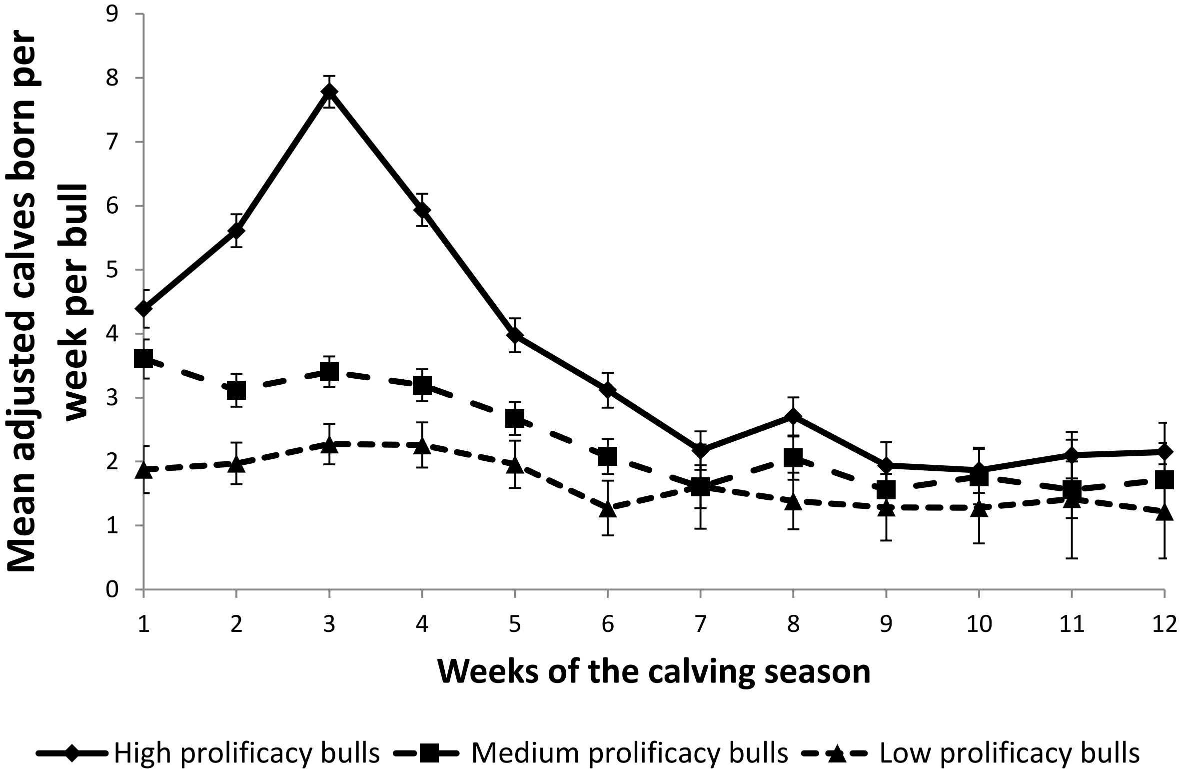


Table 3. Prolificacy assessment of young bulls in their first year of use and subsequent prolificacy.

Prolificacy assessment based only on first year of service	Subsequent prolificacy category		
	High	**Medium**	**Low**
High	37.5	50	12.5
Low	12.5	25	62.5

High prolificacy bulls sired more calf births per week during the early part of the calving season than medium prolificacy or low prolificacy bulls ($P < 0.01$) (Figure 7). Bulls siring more progeny in total had a disproportionately higher percentage of calves born early in the calving season. Low prolificacy (LP) bulls tended to have a consistently low number of calves born throughout the calving season. These data suggest that high prolificacy is associated with the breeding of a greater than expected number of cows early in the breeding season ultimately leading to a larger total number of progeny for the calf crop.

Alternative prolificacy assessment methods

Prolificacy was initially assessed by dividing all bulls in a calf crop into three equal sized groups based on their total progeny for the calf crop: categorized as high, medium and low prolificacy. As an alternative, prolificacy was re-assessed using only the number of progeny born in either 1.) weeks 2, 3 and 4 or 2.) only week 3. The alternate methods would greatly reduce the number of DNA samples required and would be relatively easily conducted in the field especially if age and source verification was being conducted. Instead of sampling all calves (e.g. N=313) by sampling only weeks 2, 3 and 4 (N=157) or only week 3 (N=63) the number of samples would be reduced to 50 or 20 percent, respectively.

Results of sampling only calves from weeks 2, 3 and 4 indicated (Table 4) no calves would be assessed into low prolificacy that had been assessed high prolificacy using all calves and only 1.4% using calves from only week 3. Similarly, samples from weeks 2, 3 and 4 would incorrectly assess as high only 3% using week 3 only and none using weeks 2, 3 and 4 compared to their initial assessment of low using all calves. The alternative assessment methods could greatly reduce costs associated with prolificacy assessment with little reduction in identification of low or high prolificacy bulls.

Table 4. Percent change in prolificacy using alternative assessment methods consisting of only DNA sampling for paternity calves from 1.) weeks 2, 3 and 4 or 2.) week 3 only to assessment using all calves in the calf crop. Sampling only calves from weeks 2, 3 and 4 would assess no calves into low prolificacy that had been assessed high prolificacy and only 1.4% using calves from only week 3. Similarly, samples from weeks 2, 3 and 4 would incorrectly assess as high only 3% using week 3 only and none using weeks 2, 3 and 4 compared to their initial assessment of low using all calves. The alternative assessment methods could greatly reduce costs associated with prolificacy assessment with little reduction in identification of low or high prolificacy bulls.

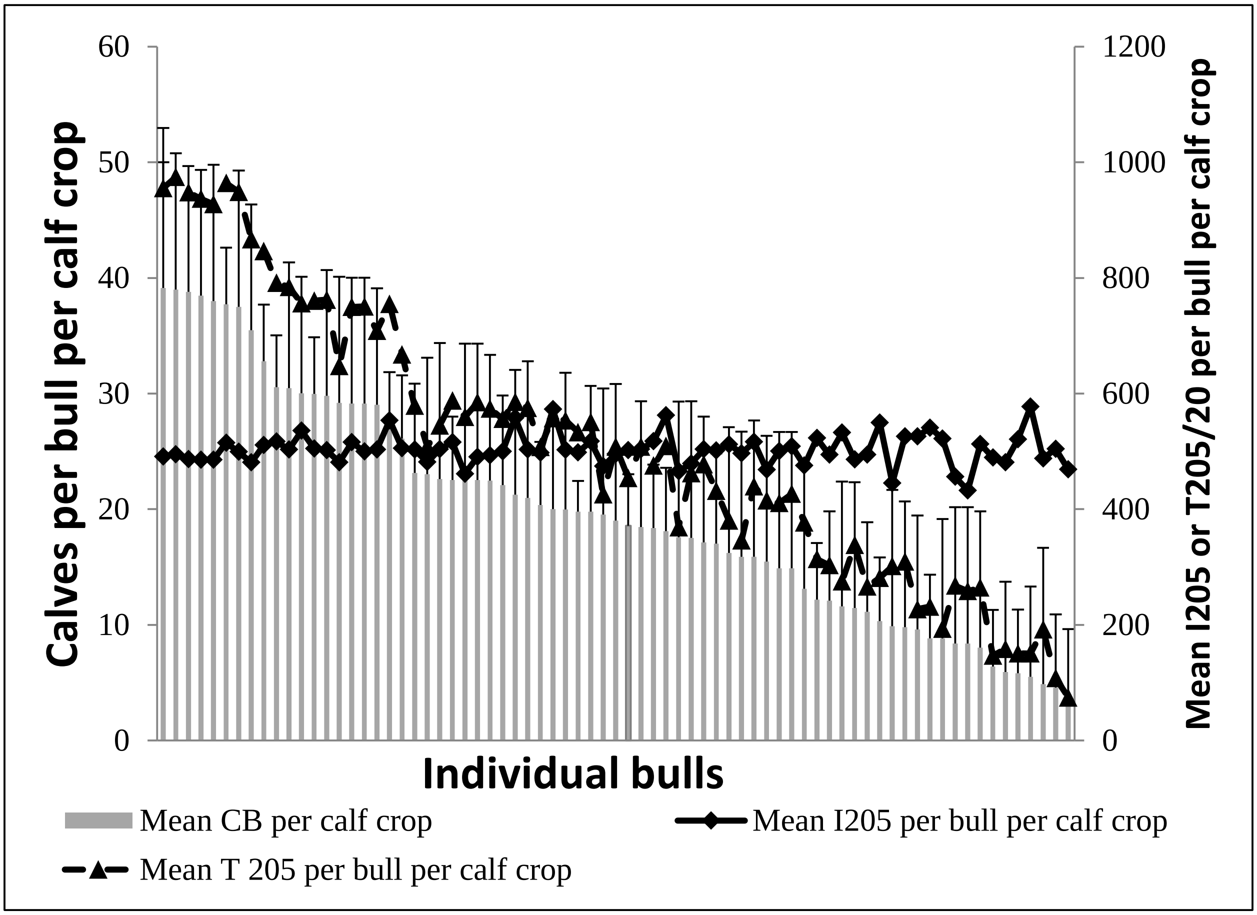
Original Prolificacy Assessment (based on entire calf crop)	**Reassessed using weeks 2, 3 and 4**			**Reassessed using only week 3**		
	High	**Medium**	**Low**	**High**	**Medium**	**Low**
	%			**%**		
High	**83**	**17**	**0**	**79.6**	**19**	**1.4**
Medium	**14**	**63**	**23**	**15**	**71**	**14**
Low	**0**	**17**	**83**	**3**	**25**	**72**

Bull contributions to ranch income

On the income side of the profit equation total income is a function of the number of calves and their feeder value (weight times price) or for retained ownership the number of calves and their carcass value (weight times price). We evaluated bulls' contribution to income in multi-sire breeding pastures using DNA paternity identification. This allowed evaluation of both prolificacy of bulls in combination with growth components of their progeny.

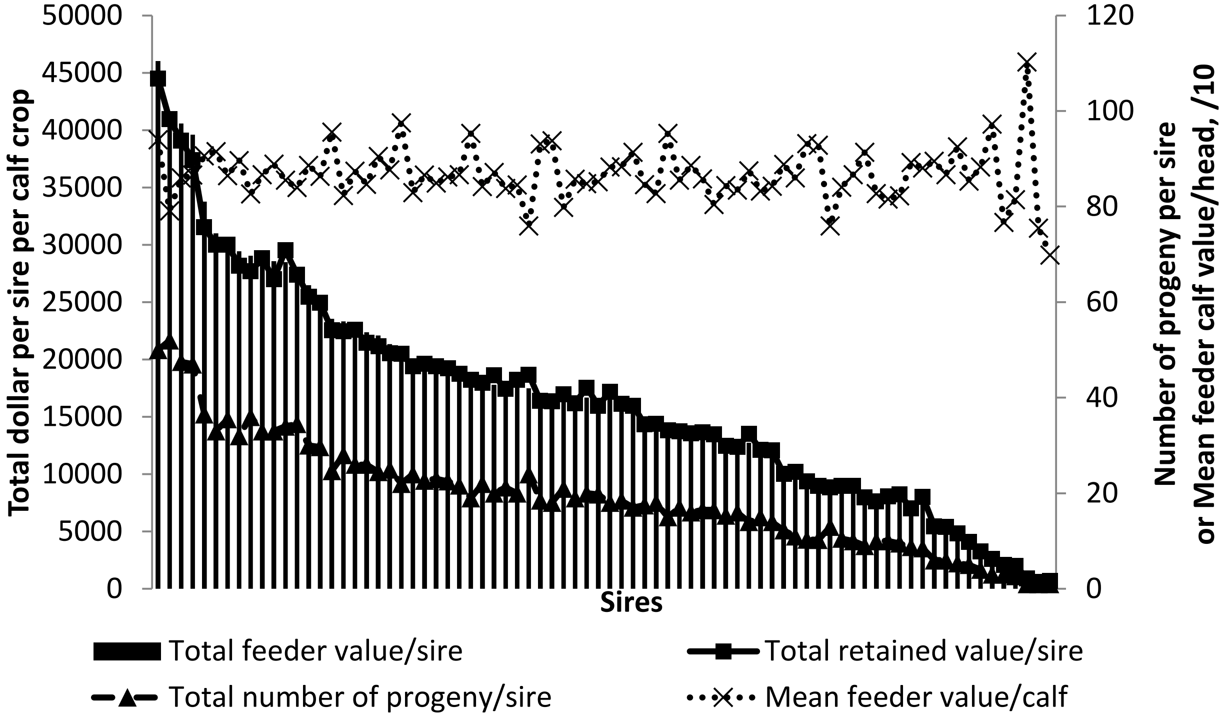
Across all ranches the mean number of calves per bull per calf crop (Figure 8) ranged from 3.3 to 39.1 (P<0.01). Similarly the mean individual 205d weight of progeny varied widely (P<.01) between bulls. And, correspondingly, total 205d weight varied (P<0.01) between bulls ranging from an average of 1490 – 19,488 lbs. per bull per calf crop. Total 205d weight was highly correlated to calves per bull (0.98) compared to individual 205d weight (0.15).

Figure 8. The mean number of calves per bull (**CB; bars, left axis**) per calf crop varied widely (P<.01) ranging from 3.3 to 39.1. Weight as individual 205d sex adjusted wt (**I205; diamonds, right axis**) or total 205d sex adjusted weight (**T205; ; triangles, right axis**) also was different (P<.01) between bulls. **CB** was highly correlated (P=.98) to **T205** but not to **I205** (0.15). After adjusting for ranch, year and season **CB** explained 96.9 percent of the variation in **T205** (R^2=0.969) compared to 2 percent for **I205** (R^2=.02).



Multiple regression analysis showed calves per bull explained 96.9% of the variation in total 205d weight compared to 2% for individual 205d weight of bulls' progeny. Highly prolific bulls are making a far greater contribution to ranch income than less prolific bulls siring progeny with superior growth traits under multi-sire natural service conditions. Similar results were observed when retained ownership was evaluated (Figure 9).

Figure 9. Total value of feeder calves and total retained value per sire were closely related to total number of progeny per sire. Mean feeder value per sire was not closely related to total retained ownership values per sire.



Summary and Implications

DNA testing was used to assign paternity to 5,052 calves conceived in natural service multi-sire breeding pastures from 3 commercial ranches in northern California representing 15 calf crops over 3 years. Bulls present for 60 to 120d at a 25:1 cow to bull ratio in both fall and spring breeding seasons in 100 acre or smaller fenced breeding pastures sired a highly variable (P<.001) number of calves, ranging from 0 (4.4% of bulls present in any given breeding season) to 64 calves per bull (**CB**) per breeding season, with an average of 18.9 (±13.1). There was little variation in **CB** among ranch (P=0.90), year (P=0.96), and season (P=0.94). Bulls varied widely (P<0.01) in individual 205d adjusted weaning weight (**I205**) of progeny and **I205** varied between years (P<0.01) and season (P<.01), but not ranch (P=0.29). The pattern for total 205d adjusted weaning weight of all progeny sired by a bull (**T205**) was highly correlated to CB with small differences between ranches (P=0.35), year (P=0.66) and season (P=.20) , but large differences (P<.01) between bulls ranging from an average of 1490 – 19,488 lbs. per bull per calf crop. Total gross receipts from the sale of offspring generated by each bull were highly correlated to **CB** and had little correlation with **I205**. **CB** was curvilinear for bull age (P=0.03) with the peak **CB** at about 5 years of age for bulls ranging from 2 to 11 years of age.

By paternity testing only calves born in weeks 2, 3 and 4 or only from week 3, sampling costs would be reduced to approximately 50 and 20 percent, respectively, of that required to sample the entire calf crop in this study. Due to age and source verification marketing, birthdates are often known and samples could be collected at marking time from a designated group of calves. Even without whole-herd birthdate records, strategic planning during the third week of calving could include recording or marking calves born during that time period for later sampling. Given the moderate repeatability of prolificacy this type of reduced sampling could provide an approach to identify bulls with the greatest likelihood of being either highly or lowly prolific. The costs involved in DNA collection include not only the costs of the tests (currently ~$15/head for parentage testing; http://www.neogen.com/; accessed 9/4/2014) which are likely to continue to decrease in the future, but also the costs associated with unique animal identification, labor to process each animal and collect the DNA sample, and also that required to manage the records and integrate the DNA information back into herd management decisions.

The value of parentage information needs to outweigh the costs of genotyping. One study examined the value of DNA paternity identification on commercial beef cattle operations. Using the data obtained in this study it can be estimated that if the entire calf crop was sampled to obtain prolificacy estimates then the cost per bull to obtain prolificacy data would be approximately 20 times the cost of the test (1 bull + 19 offspring), or $300/bull in the case of a $15 test. Less expensive alternative sampling strategies could be envisioned including sampling all bulls and only those calves born in week 3 (~20% of the calf crop), or alternatively only those offspring produced by young sires in their first breeding season based on the observation that young bulls categorized as either high prolificacy or low prolificacy tended to remain in those categories in subsequent breeding seasons. However given the small number of young bulls involved in this study (8 each initially categorized as high prolificacy and low prolificacy) care should be taken in over interpreting these results. In addition to prolificacy data, the DNA information could also be used to calculate genetic merit estimates of these commercial bulls and identify those producing superior or problematic classes of calf (e.g. high birth weight calves).

These results reveal that highly prolific bulls sire a disproportionately large number of the preferred more-valuable, early-born calves (Funston, 2012) in well-managed herds that have a large numbers of females cycling early in the breeding season. In self-replacing beef systems, replacement heifers are often selected based on age to enhance the potential for conception early in their first breeding season. This study showed that only a small percentage of replacement heifers would likely be sired from low prolificacy bulls, providing indirect selection on male fertility. Using DNA paternity assignment to evaluate the relationship between heifer fertility and sire prolificacy would provide information of economic interest given the high costs of raising replacement heifers and the overriding importance of fertility to the beef enterprise (Melton et al., 1979; Melton 1995).

Weekly conception rates as assessed by date of calving varied significantly and peaked at week 3 of the calving season. The distribution of calves born early in the calving season was markedly skewed towards the highly prolific bulls. DNA paternity testing of only those calves born in week 3 of the calving season was highly predictive of overall bull prolificacy and may offer a reduced cost option for assessing prolificacy. To be cost effective, the costs of parentage testing need to be recouped by the value derived from this resulting information. One such use might be the cost savings associated with the removal of low prolificacy bulls, although the feasibility of this approach would depend upon the continued ability of the more prolific bulls in one year to be able to successfully service an increased cow:bull ratio in the following year. Prolificacy of young bulls in their first breeding season was positively linearly related ($P=0.03$) to subsequent breeding seasons explaining about 20 percent of the subsequent variation ($r^2=0.20$). Prolificacy was also positively linearly related ($P=0.04$) to scrotal circumference EPD for Angus bulls that had BIF accuracies over 0.05. The varying prolificacy of herd bulls also has implications for the genetic composition of replacement heifers; the genetics of the highly prolific bulls siring a large number of early-born calves are likely to be disproportionately represented in the replacement heifer pool. However, the best genetic bulls according to genetic merit estimates are not always the most prolific, which may slow overall rate of genetic process. Based on the results of this study, the high cost of herd bulls, and the development of reliable and fixed-time AI protocols, it may be time for commercial producers to re-evaluate the economics of using elite genetics available via artificial insemination (AI) sires versus the exclusive use of natural service bulls.

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