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MANAGEMENT STRATEGIES FOR IMPROVING LIFETIME REPRODUCTIVE SUCCESS IN BEEF HEIFERS.

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Introduction

Research has indicated it takes the net revenue from approximately 6 calves to cover the development and production costs of each replacement heifer (E. M. Mousel Unpublished data). In addition, any cow that misses a single calving is not likely to recover the lost revenue of that missed calf (Mathews and Short, 2001). Therefore, longevity of a beef female is important to the sustainability and profitability of any beef operation. Considering the importance of longevity, an important question is as follows: Why are females culled from a beef herd? According to the 2007-08 NAHMS survey the greatest percentage of cows culled from the herd were for pregnancy status (33.0%); other reasons for culling included age or bad teeth (32.1%), economic reasons (14.6%), other reproductive problems (3.9%), producing poor calves (3.6%), temperament (3.6%), injury (2.9%), udder problems (2.7%), bad eyes (1.8%), and other problems (1.8%). Furthermore, 15.6% of animals culled were less than 5 years of age and 31.8% were 5 to 9 years of age. These females that are culled from a herd prior to producing 6 calves increase the developmental cost of other heifers and do not contribute to the profitability and sustainability of the farm. Therefore, understanding how management decisions impact pregnancy success and longevity will have an effect on the profitability and sustainability of an operation.

Management of Replacement Heifers

Heifers need to calve by 24 months of age to achieve maximum life-time productivity (Patterson et al., 1992), and heifers that lose a pregnancy or conceive late in the breeding season are not likely to have enough time in the subsequent breeding season to conceive. Conversely, heifers that calve early with their first calf have a longer post-partum interval and are more likely to breed back as two year olds and continue to calve early in the calving season. This is important to overall profitability since age of calf at weaning is the single largest factor that affects weaning weight. Analysis of 3,700 calves at the USDA- Meat Animal Research Center indicated that for each day of age after the beginning of the breeding season that a calf is born 2.4 pounds of weaning weight is lost (R. Cushman unpublished data).

Research has indicated that animals that conceive earlier in the breeding season are more likely to conceive in the subsequent breeding season compared to cows that conceive late in the breeding season (Burris and Priode, 1958). In a more recent study by Kill et al., (2012), longevity data were collected on 2,195 heifers from producers in South Dakota, and longevity

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and weaning weight data were collected on 16,549 heifers at the USMARC. Data were limited to heifers that conceived during their 1st breeding season. Heifers that calved with their first calf during the first 21 day period of the calving season had increased ($P < 0.01$) longevity compared to heifers that calved in the second 21 day period, or later. Average longevity for South Dakota heifers that calved in the 1st or later period was 5.1 ± 0.1 and 3.9 ± 0.1 yr, respectively. Average longevity for USMARC heifers that calved in the 1st, 2nd, and later period was 8.2 ± 0.3, 7.6 ± 0.5, and 7.2 ± 0.1 yr, respectively. Calving period also influenced ($P \leq 0.03$) weaning weight of the 1st, 2nd, 3rd, 4th, 5th, and 6th calf born from these heifers. In addition, calving period influenced total pounds weaned and average weaning weight ($P < 0.01$), with heifers that calved during the 1st period having increased weaning weights, total pounds weaned, and average weaning weight compared to heifers calving in the 2nd period or later, and heifers calving during the 2nd period had increased weaning weight, total pounds weaned, and average weaning weight compared to heifers calving later. Therefore, heifers that calved early in the calving season with their first calf had increased longevity and pounds weaned compared to heifers that calved later in the calving season.

Heifer Development

The goal of all heifer development methods is to have a heifer that has reached puberty and has good fertility at the start of the breeding season. However, one also needs to consider how the method of development can influence management after insemination (AI or natural service), and how this management can impact pregnancy success. There are many methods that can be used to develop replacement heifers. In several locations, heifer development usually involves placing heifers into a feedlot or a confined feeding situation from weaning until breeding. This allows for intensive management of nutrient intake and growth to insure proper development for successful breeding. However, utilizing this method of heifer development usually results in a diet transition, from the development diet to grazing forage, at the start of the breeding season. This change in nutritional management has the potential to influence reproductive efficiency and performance of the heifer for her entire life, since heifers need to calve by 24 months of age to achieve maximum life-time productivity (Patterson et al., 1992). Nutritional status can also have an influence on embryonic survival through many mechanisms. Heifers fed 85% maintenance requirements of energy and protein had reduced embryo development on day 3 and day 8 compared to heifers fed 100% maintenance (Hill et al., 1970) indicating decreased embryonic growth. Therefore, changes in nutrition can have a tremendous impact on embryo survival and the ability of heifers to conceive during a defined breeding season.

Several studies have reported a genetic effect on the size of a heifer at puberty (Taylor and Fitzhugh, 1971), and that developing heifers to lighter weights result in heifers being older when they reach puberty (Short and Bellows, 1971; Wiltbank et al., 1985). However, the timing of puberty is dependent on both age and weight and varies among breeds (Wiltbank et al., 1966; Short and Bellows, 1971; Varner et al., 1977). Therefore, the idea of developing heifers to a specific target weight (i.e., usually 65% of mature weight) has become a typical management practice, but specific target weights vary across breed because the age and weight will differ among breeds (Freetly and Cundiff, 1998). Thus, adequate growth and body condition appears necessary for the initiation of normal estrous cycles.

Some recent studies have proposed that heifers can be developed to only 50 to 55% of mature weight prior to the breeding season. In one study however, fewer crossbred heifers that were developed to 53% of mature weight were cycling prior to the start of the breeding season compared with heifers developed to 58% of mature weight, but the percent pregnant in a 45 d breeding season was similar between treatments (Funston and Deutscher, 2004). When heifers were developed to 55% compared with 65% of mature weight, there was no difference between groups in percentage of pubertal heifers at 12 months of age or yearling pregnancy rates after an 80-day breeding season (Patterson et al., 1991). However, more heifers developed to 65% of mature weight were pregnant during the first 45 days of the breeding season compared with heifers developed to 55% of mature weight (Patterson et al., 1989). There also tended to be a difference in postpartum interval with heifers developed to 55% of mature weight taking longer to reinitiate postpartum estrous cycles after calving compared with heifers developed to 65% of mature weight (Patterson et al., 1991). When crossbred heifers were developed to 50% of mature weight 15.7% fewer heifers conceived during the first 30 days of the breeding season compared with heifers developed to 55% of mature weight (Creighton et al., 2005). This is consistent with a recent study that reported that across several breeds, heifers were 55 to 60% of mature weight when puberty was attained (Freetly et al., 2011). Therefore, consideration should be made for heifers to reach 65% mature body weight in order to conceive early in the breeding season.

Impact of Development Method on Heifer Performance. Grazing skills and dietary habits are learned early in life (Provenza and Balph, 1988). This learning resulted in the development of motor skills necessary to harvest and ingest forages (Provenza and Balph, 1987), and allow animals to increase their consumption of forage (Lyford, 1988). These skills learned between weaning and breeding have been reported to carry through to the next grazing season (Olson et al., 1992). Furthermore, the willingness to try novel food declines with age (Provenza and Balph, 1988). Thus young livestock ingest small amounts of novel food and gradually increase the amount ingested if no adverse effects occur (Chapple and Lynch, 1986; Burritt and Provenza, 1987). Therefore, when introduced to novel food/environment livestock may spend more time and energy foraging (Osuji, 1974), but ingest less food (Arnold and Maller, 1977; Hodgson and Jamieson, 1981; Curll and Davidson, 1983). When heifers developed in a dry lot were moved to spring forage, they lost 1.6 ± 0.08 kg/d for the first week. This resulted in a change in their growth curve compared to heifers developed on forage. However, these heifers were given an adaption period before the breeding season and there was no difference between treatments in synchronized or breeding season pregnancy rates. When heifers were kept in the drylot until AI and then moved to spring forage, there tended ($P = 0.108$) to be more Range developed heifers pregnant to AI (56.8%) compared to Lot developed heifers (44.7%; Table 1). This difference in AI pregnancy success can likely be attributed to the differences observed in the previous experiment where heifers lost weight during the first week after they were moved to spring forage.

Table 1. Reproductive performance of heifers that were weaned and developed on range (Range) compared to heifers weaned and developed a drylot (Lot) (all heifers were moved to grass following AI on the first day of the breeding season).

	Range	Lot
Number of heifers	91	92
Puberty status, (%)[a]	89/91 (94)	90/92 (98)
Synchronized conception rate, (%)[b]	52/91 (57)[y]	41/92 (45)[z]
Final pregnancy rate, (%)[c]	82/91 (90)	81/92 (88)

[a] Percentage of heifers that had reached puberty before the start of the breeding season
[b] Percentage of heifers pregnant during the 10 d synchronization period to natural service
[c] Overall pregnancy rate (60 d breeding season)
[yz]Means within a row having difference superscripts tended to differ (P = 0.108)

Since, energy used for all body functions; a hierarchy must exist designating which function is most important when nutrients are limiting. This is often referred to as nutrient partitioning. The priority for nutrients taken into the body is usually listed as follows: 1) basal metabolism, 2) activity, 3) growth, 4) basic energy reserves, 5) pregnancy, 6) lactation, 7) additional energy reserves, 8) estrous cycles and initiation of pregnancy, 9) excess reserves (Short et al., 1990). Therefore, a change in energy intake could have a significant impact on reproductive success as it is far down the list in order of importance. When nutrients are limited at or immediately after insemination, this lack of energy may perturb fertility through direct or indirect regulation of the uterine environment. Nutritionally mediated changes to the uterine environment can occur by changing components of uterine secretions or by influencing the circulating concentrations of progesterone that regulate uterine environment (see review by Foxcroft, 1997). More specifically, heifers fed 85% of maintenance requirements of energy and protein had reduced embryo development on d 3 and d 8 compared to heifers fed 100% maintenance (Hill et al., 1970) indicating decreased embryonic growth. Therefore, under nutrition can have an impact on embryo survival and the ability of heifers to conceive during a defined breeding season.

To test if increasing nutrient intake immediately after AI could impact pregnancy success, beef heifers at two locations (n = 144 and 164 at location 1 and 2, respectively) were developed in a drylot from weaning to breeding. At time of insemination heifers were randomly allotted to one of two treatments: 1) heifers were moved from drylot to graze spring forage (PASTURE), or 2) heifers were moved to graze spring forage and supplemented with DDGS (5 lbs/hd/day) for 42 days (PASTURE-SUPP). Pregnancy success was determined 42 days after AI. At both locations, PASTURE heifers were placed on the higher quality pasture that had more available forage. However, when moved to pasture immediately following AI, there was a treatment ($P < 0.01$) and a treatment by herd interaction ($P < 0.01$) on weight change, but no effect of herd ($P = 0.17$; Table 2). Overall, PASTURE-SUPP heifers gained weight from AI to pregnancy determination while RANGE heifers lost weight (Table 2). Similarly at location 2, PASTURE-SUPP heifers gained weight and PASTURE heifers lost weight. However, at location 1, there was no difference (P = 0.79) between treatments. Furthermore, conception rates to AI were affected by treatment (P = 0.02; Figure 1), with PASTURE-SUPP heifers having increased pregnancy success compared to PASTURE heifers. However, there was no effect of herd (P = 0.64), treatment by herd (P = 0.21), BCS at AI (P = 0.40), or weight change from AI to pregnancy determination (P = 0.47) on AI conception rates. Breeding season pregnancy rates were not different (P = 0.20) between PASTURE and PASTURE-SUPP heifers (91% and 94%, respectively).

Table 2. Weight change from AI to pregnancy determination on day 42 after AI.

	Location 1		Location 2		Combined	
	PASTURE	PASTURE-SUPP	PASTURE	PASTURE-SUPP	PASTURE	PASTURE-SUPP
Weight at AI (lb)	940 ± 9.9	962 ± 9.7	865 ± 9.9^{y}	919 ± 8.8^{z}	902 ± 7.1^{y}	939 ± 6.6^{z}
Weight at pregnancy diagnosis (lb)	957 ± 8.8	977 ± 8.6	838 ± 8.8^{y}	965 ± 7.7^{z}	897 ± 6.2^{y}	970 ± 5.7^{z}
Weight change (lb)	17 ± 4.0	15 ± 4.0	-37 ± 4.0^{y}	45 ± 3.1^{z}	-5.5 ± 4.0^{y}	32 ± 3.5^{z}

^{xyz}Means within a row and location having difference superscripts are different ($P < 0.01$)

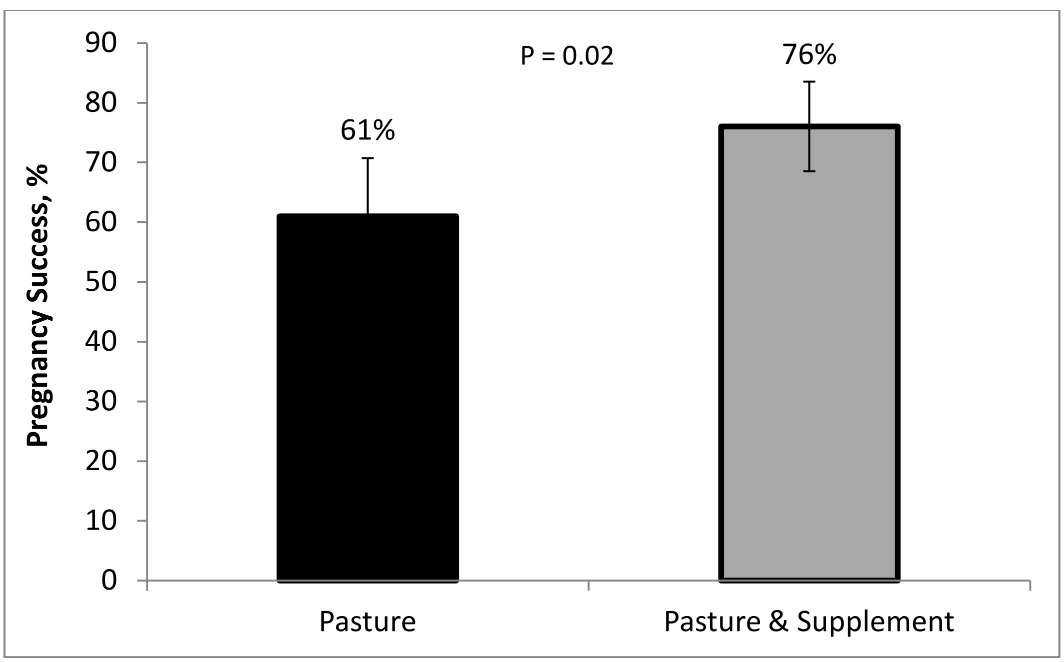

Figure 1. Artificial insemination conception rates for heifers developed in a drylot from weaning to AI, and moved to pasture following AI. Heifers were moved from drylot to graze spring forage (Pasture), or moved to graze spring forage and supplemented with DDGS (5 lbs/hd/day) for 42 days (Pasture and Supplement). Pregnancy success was determined 42 days after AI.

To further investigate if a short term (first week after AI) change in energy intake could impact embryo survival, we recently conducted a study in beef heifers to further elucidate the direct effects of an immediate change in nutrition at AI on early embryonic development. The objective of this study was to determine if post-AI nutrient restriction directly impacted early embryo quality and the number of live/dead blastomeres. This study was conducted at two locations, University of Minnesota's North Central Research and Outreach Center (UMN) and South Dakota State University (SDSU). All heifers were on a common diet during development. Estrus was synchronized and timed-AI was conducted. On the day of AI, heifers were placed in one of two nutritional treatments. At UMN, half of the heifers continued on the pre-AI diet (approximately 120% NRC requirements), targeting an ADG of 1.5 lbs/hd/d (treatment designation = GAIN). The remaining heifers were fed at 80% NRC requirements (treatment designation = LOSE). At SDSU, half of the heifers continued on the pre-AI diet (approximately 125% NRC requirements). The remaining heifers were fed at 50% NRC requirements (treatment designation = LOSE). Dietary treatments were fed until embryo collection was done using non-surgical embryo flush techniques six days after AI. Recovered embryos were microscopically evaluated, classified by developmental stage (morula, blastocyst, expanded blastocyst) and graded on a 1 to 5 scale (1 = excellent, 2 = good, 3 = fair, 4 = poor, and 5 = degenerate) to evaluate embryo quality. Then embryos were transferred to the laboratory where number of dead blastomeres and total number of blastomeres was evaluated using epifluorescent staining. Results across both locations were combined to illustrate the effects of nutrient restriction on early embryonic development. Nutrient restriction immediately following AI resulted (Table 3) in poorer quality embryos that were developmentally retarded as indicated by being at an earlier stage of development and having fewer total blastomeres (Table 3). In addition, embryos from nutrient restricted heifers had a decreased (P = 0.01) percentage of live blastomeres.

Table 3. Effect of post-AI nutrition on day 6 embryo development

TRT	n[a]	% Embryos Recovered	Embryo Stage[b]	Embryo Quality[c]	Dead Cells (n)	Total Cells (n)	% Live Cells
GAIN	46	70.8 (46/65)	4.6 ± 0.1	2.0 ± 0.2	7.8 ± 0.9	70.6 ± 5.6	83.3 ± 3.0
LOSE	42	62.1 (42/66)	3.8 ± 0.2	2.8 ± 0.2	9.7 ± 1.0	48.9 ± 3.9	71.1 ± 4.1
P-value	.	NS	< 0.01	0.02	0.42	0.03	0.01

[a] Defined as embryo number; not heifer with the exception of recovery rate
[b] Stage of development (1-9;1=UFO; 9=expanded hatched blastocyst; per IETS Standards)
[c] Quality of embryo (1-5;1 = excellent; 5 = degenerate; per IETS Standards)

These results indicate that the early embryo, oviduct, and uterus are sensitive to immediate changes in nutrition. It is proposed that the immediate retardation of embryonic development observed is likely responsible for reduced pregnancy rates due to an inability of the embryo to successfully signal maternal recognition of pregnancy at later stages of development. Currently, the mechanisms by which an abrupt change in nutritional inputs immediately following AI affects early embryonic development are not definitive and numerous physiological and endocrine processes may contribute.

To investigate the idea that the decrease in AI pregnancy success may be due to grazing behavior and not a change in diet, we conducted an experiment where heifers were moved from a grazing environment to a drylot following AI. Beef heifers at one location (n= 333) were developed on a forage diet from weaning to breeding. All heifers were brought into a feedlot and synchronized with a 7-d CO-Synch + CIDR protocol. At time of insemination heifers were randomly allotted to one of three treatments: 1) heifers were moved to graze spring forage (RANGE), 2) heifers were moved to graze spring forage plus supplemented with DDGS (5 lbs/hd/day) for 42 days (RANGE-SUPP), or 3) heifers were returned to the feed lot for 42 days (LOT). Pregnancy success was determined 42 days after AI. Body condition increased ($P < 0.01$) from the day synchronization began (day -7; 5.4 ± 0.05) to day 42 in both the heifers that were supplemented on pasture (RANGE-SUPP) and the heifers that were kept in the feed lot (LOT; 5.9 ± 0.04 and 5.8 ± 0.04, respectively; Table 4). Body condition did not change from day -7 to day 42 among the heifers that were on grass alone (RANGE; 5.4 ± 0.05 and 5.4 ± 0.04 for day -7 and day 45, respectively; Table 4). Pregnancy success did not differ among treatments [59% (65/111), 57% (63/111), and 56% (62/111) for heifers on grass alone (RANGE), heifers on grass plus supplemented (RANGE-SUPP), and heifers in the feed lot (LOT), respectively. Therefore, when heifers were developed on grass, there was no effect on pregnancy success whether they were returned to grass with or without supplementation or even kept in the feed lot.

Table 4. Reproductive performance of heifers that were weaned and developed on range and following AI were returned to range (Range), returned to range and supplemented (Range-SUPP), and moved to a drylot (LOT).

	RANGE	RANGE-SUPP	LOT
Number of heifers	112	112	112
Percent of heifers with a CL on d -7, (%)[a]	90/112 (80)	88/112 (79)	81/112 (72)
Body Condition Score on d -7	5.4 ± 0.05	5.4 ± 0.05	5.4 ± 0.05
Body Condition Score on d 42 after AI	5.4 ± 0.04[x]	5.9 ± 0.04[y]	5.8 ± 0.04[z]
Synchronized conception rate, (%)[b]	66/112 (59)	64/112 (57)	63/112 (56)
Final pregnancy rate, (%)[c]	99/112 (88)	100/112 (89)	96/112 (86)

[a] Percentage of heifers that had circulating concentration of progesterone > 1ng/mL on d -7 (day of CIDR insertion)
[b] Percentage of heifers pregnant during the 10 d synchronization period to natural service
[c] Overall pregnancy rate (28 d breeding season)
[xyz]Means within a row having difference superscripts are different ($P < 0.01$)

As previously described when feedlot-developed heifers were moved to grass average daily gains were decreased compared to range-developed heifers for the first 27 days. However, after 27 days of being on spring forage average daily gains were similar between treatments. Therefore, we conducted a study to determine the influence of moving feedlot-developed heifers to grass before time of AI on pregnancy success. In the first replicate of this study, 50 heifers were equally divided into 2 treatments: 1) moved to grass 30 days prior to AI and 2) left in the feedlot until AI. Following AI all heifers were placed in the same pasture for 35 days until pregnancy determination. From AI to pregnancy determination (day 35 after AI) heifers moved to grass early gained 17 lb but heifers left in the feedlot only gained 0.6 lbs ($P = 0.07$). Final AI pregnancy success was 57% (12/21) for grass heifers and 46% (11/24) for lot heifers. In the second replicate of this study, 191 heifers were equally divided into 2 treatments: 1) moved to grass 30 days prior to AI and 2) left in the feedlot until AI. Following AI all heifers were placed in the same pasture for 35 day until pregnancy determination. From AI to pregnancy determination (day 70 after AI) heifers moved to grass early gained 105 lb but heifers left in the feedlot only gained 2.8 lb ($P < 0.01$). Final AI pregnancy success following detection of standing estrus was 63% (52/82) and 58% (46/80) for heifers moved to grass and left in the lot, respectively. Combined pregnancy rates were 62% and 55% for heifers moved to grass and left in the lot, respectively ($P = 0.28$).

To further investigate if method of heifer development could impact grazing behavior, we conducted an experiment to measure daily activity between drylot developed heifers that had been moved to grass before AI compared to heifers that were moved to grass on the day of AI. Sixty-nine drylot developed heifers were randomly allotted to one of two treatments 42 days before AI: 1) heifers remained in the drylot until AI, or 2) heifers were moved to graze spring forage for the 42 days prior to AI. Daily activity was measured by a pedometer. Prior to AI, heifers that were grazing spring forage took more ($P < 0.01$) steps per day compared to heifers in the drylot (Figure 2). However; following AI, heifers that had remained in the drylot until AI had increased activity compared to heifers that had previous experience grazing spring forage (Figure 3). When activity is increased energy requirements are also increased. Cows that were forced to walk 3.2 km per day had a greater than 30% increase in energy requirements compared to cows that were held in a drylot (Bellows et al., 1994). Hence, heifers switched from a drylot to pasture are not accustom to grazing, forced to eat a novel diet, and exert increased energy during the period following AI. These factors combined may be the reason some heifers developed in a drylot and move to forage after insemination have reduced conception rates.

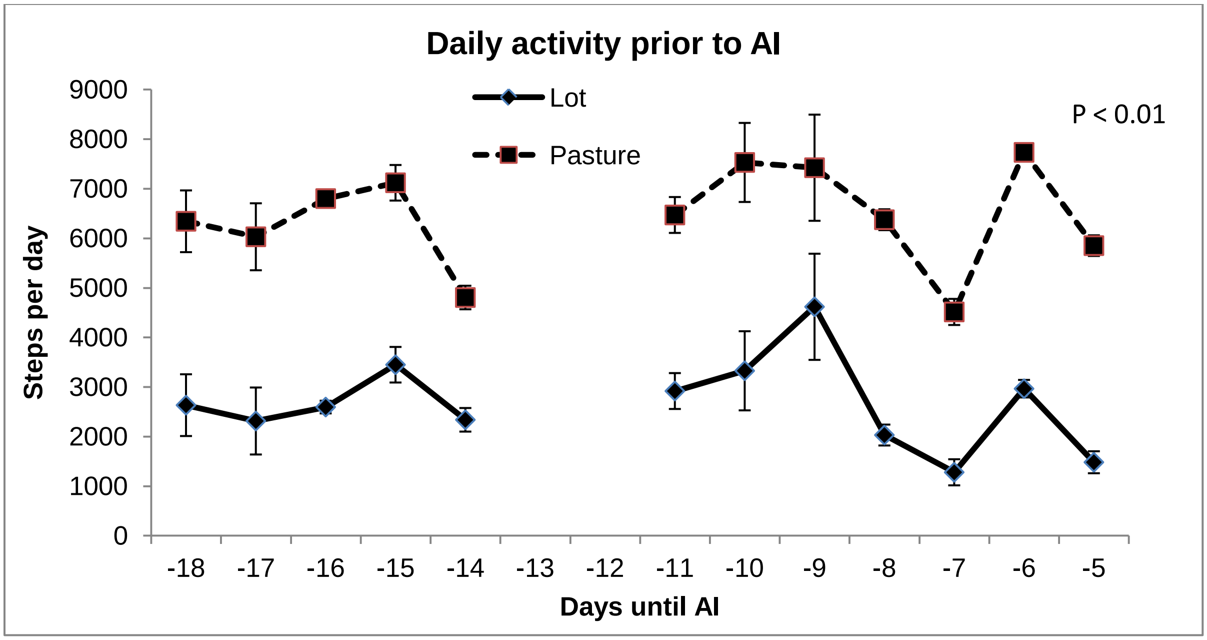

Figure 2. Daily activity for heifers that remained in the drylot until AI (LOT), and heifers were moved to graze spring forage for the 42 days prior to AI (Pasture).

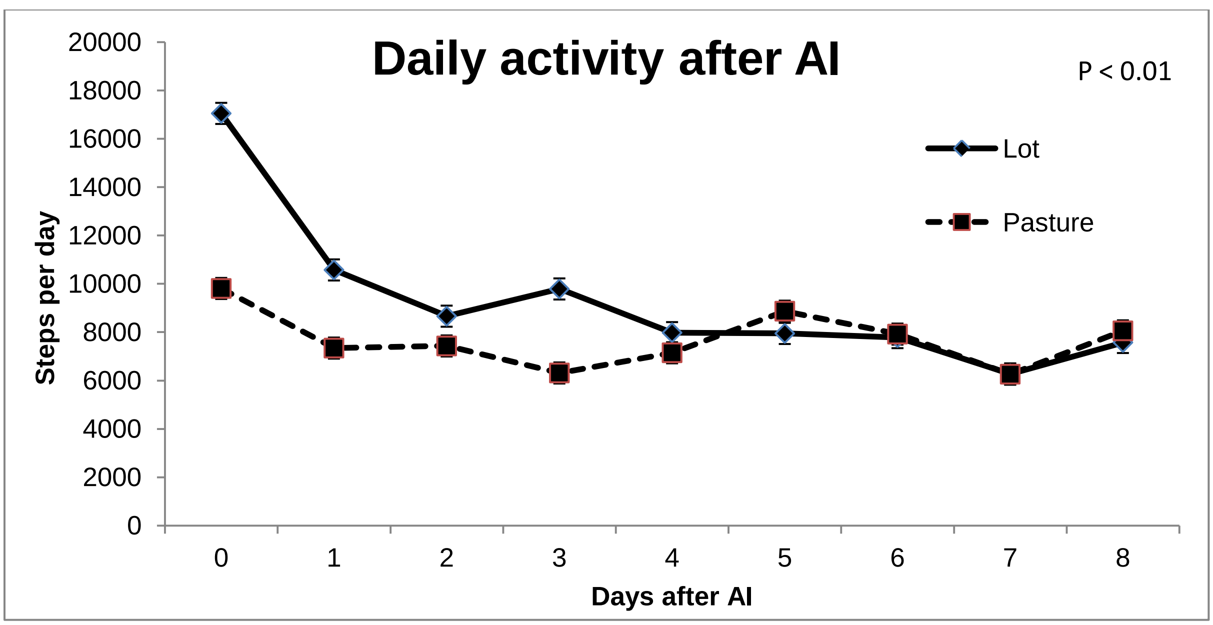

Figure 3. Daily activity for heifers that remained in the drylot until AI (LOT), and heifers were moved to graze spring forage for the 42 days prior to AI (Pasture).

Managing for Reproductive Success.

Fertility is influenced by many factors, and one of the best methods to look at factors that influence fertility is with the "Equation of Reproduction". The Equation of Reproduction includes the following 4 areas: 1) Percentage of animals detected in standing estrus and inseminated, 2) Inseminator efficiency, 3) Fertility level of the semen, and 4) Fertility level of the herd. Each of the preceding areas is discussed below.

Percentage of Animals Detected in Standing Estrus and Inseminated: For successful insemination of cattle to occur, animals must be detected in standing estrus. Detecting standing estrus (also referred to as heat detection or detecting standing heat) is simply looking for the changes in animal behavior associated with a cow/heifer standing to be mounted by a bull or another cow/heifer. With natural service, estrous detection is considered to be easy, as it is "the bulls' job." However, differences in estrous detection exist among bulls. Libido refers to a bull's desire to mate. Libido is thought to be a highly inherited trait with a heritability coefficient as high as 0.59 (Chenoweth, 1997). This is because there is more variation in libido between sons of different sires than between sons of the same sire. It is important to remember that scrotal circumference, semen quality, and physical soundness (evaluated in a Breeding Soundness Evaluation) are not related to libido. Furthermore, libido is not associated with dominance in bulls. Libido has a direct affect on pregnancy rate and, as such, it can influence the success of an entire breeding season. Libido can be practically evaluated by closely watching a bull after introducing him to a cow herd and determining his desire to detect cows in estrus.

For successful artificial insemination of cattle to occur, the producer (herd manager, etc.) must take the place of the herd bull in detecting the cows/heifers that are ready to be inseminated. Accurate detection of animals in standing estrus is the goal of good detection of estrus and plays a vital role in the success of any AI program. In a study conducted at Colorado State University, animals were administered a protocol to synchronize estrus, then monitored for standing estrus 24 hours a day with a computer assisted estrous detection system (HeatWatch®) or twice a day for 30 minutes by visual observation. By day 5 after estrous synchronization, 95% of animals monitored 24 hours a day were detected in standing estrous, while only 56% of animals observed twice a day for 30 minutes were detected in standing estrus (Downing et al., 1998). With a 95% estrous detection rate and a 70% conception rate (95% X 70% = 67%), 67% of the animals will be pregnant; whereas, only a 39% (55% X 70% = 39%) pregnancy rate will occur with a 55% estrus detection rate (Table 5).

Table 5. Effect of estrous detection rate on increasing pregnancy rate

Estrous Detection Rate	**55%**	**60%**	**65%**	**70%**	**75%**	**80%**	**85%**	**90%**	**95%**
Conception Rate	70%	70%	70%	70%	70%	70%	70%	70%	70%
Pregnancy Rate	**39%**	**42%**	**46%**	**49%**	**53%**	**56%**	**60%**	**63%**	**67%**

Therefore, the success of any artificial insemination program requires detecting the animals that are ready to be bred (standing estrus) and inseminating them at the correct time. Errors in detection of estrus can fall into two categories: problems with efficiency or problems with accuracy. Problems occurring with efficiency are normally due to not spending enough time observing the cows or not paying close enough attention. Problems with accuracy occur because the person doing the observing is not looking for the correct sign (standing estrus) that a cows is in heat. Failing to detect estrus and inaccurate detection of estrus can result in significant economic losses (Heersche and Nebel, 1994). Accurate detection of estrus can be a difficult and time-consuming activity. When estrus was detected in 500 Angus cows with HeatWatch® estrus-detection system, the length of estrus averaged 10 hours (range: 0.5 hours to 24 hours); however, 26% of cows exhibited estrus for less than 7 hours and had fewer than 1.5 mounts per hour (Rorie et al., 2002). Although most characteristics of estrus are similar between *Bos Taurus* and *Bos Indicus* breeds, duration of behavioral estrus (Brewester and Cole, 1941, Plasse et al., 1970) and interval from onset of estrus to ovulation (Randel, 1976) are decreased in *Bos Indicus* compared to *Bos Taurus* breeds. Continuous observation of over 500 animals exhibiting natural estrus in 3 separate studies indicated 55.9% of cows initiated standing estrus from 6 p.m. to 6 a.m. (Table 6). Furthermore, when cows were observed for standing estrus every 6 hours (6 a.m., noon, 6 p.m., and midnight), estrous detection increased by 10% with the addition of a mid-day observation and by 19% when observed four times daily (every 6 hours) compared to detecting standing estrus at 6 a.m. and 6 p.m. alone (Hall et al., 1959). Therefore, detection of standing estrus can be one of the most time-consuming chores related to artificial insemination.

Table 6. Time of day when cows exhibit standing estrus

Time of day	Cows exhibiting standing estrus
6 a.m. to 12 noon	26.0 %
12 noon to 6 p.m.	18.1 %
6 p.m. to midnight	26.9 %
Midnight to 6 a.m.	29.0 %

Data adapted from (Hurnik and King, 1987; Xu et al., 1998, G.A. Perry unpublished data).

Inseminator Efficiency: Fertilization rates following natural service or artificial insemination in cattle range from 89 to 100% (Kidder et al., 1954; Bearden et al., 1956; Diskin and Sreenan, 1980; Maurer and Chenault, 1983; Gayerie de Abreu et al., 1984). When pregnancy rates from 13,942 first service artificial inseminations were compared to 6,310 first services by natural service, no difference ($P > 0.10$) was detected between artificial insemination and natural service (Williamson et al., 1978).

With natural service inseminator efficiency is influenced by the ability of a bull to service a cow. The purpose of the physical examination portion of a breeding soundness evaluation is to determine a bull's mating ability. Mating ability can be described as the physical capabilities needed to successfully breed a cow. In addition to structural unsoundness, diseases or injuries to the penis or prepuce can result in an inability to breed via natural service. These abnormalities will only be detected by careful examination or observing an attempted mating of a cow. A bull that has high quality semen but is unable to physically breed cows is unsatisfactory for natural service.

With AI, inseminator efficiency is influenced by semen handling and the ability of the technician to deposit semen in the correct location. A detailed inventory of semen should be easily accessible, so that straws may be located and removed from the tank quickly to avoid exposure of semen to ambient temperature. When removing a straw from a liquid nitrogen refrigerator, it is imperative that the technician keep the canister, cane and unused semen straws as low as possible in the neck of the tank. It is best to keep all unused straws below the frost-line in the neck of the tank. The temperature of liquid nitrogen in a semen tank is -196 degrees Celsius (^{o}C; -326 degrees Fahrenheit, ^{o}F). Sperm injury (as judged by sperm motility) occurs at temperatures as warm as -79 ^{o}C (-110 ^{o}F; Etgen et al., 1957; Bean et al., 1963; DeJarnette, 1999), and injury to sperm cannot be corrected by returning semen to the liquid nitrogen (Berndtson et al., 1976; Saacke et al., 1978).

Using conventional semen, many studies have compared site of deposition on pregnancy success. Although Senger et al. (1988), López-Gatius (1996), and Pursley (2004) reported increased conception rates when semen was deposited in the uterine horns rather than the uterine body, Hawk and Tanabe (1986), Williams et al. (1988), and McKenna et al. (1990) found no difference in fertility when comparing uterine body and uterine horn inseminations. Furthermore, Diskin et al. (2004) reported an inseminator and site of semen deposition interaction, with evidence of either an increase, decrease, or no effect of uterine horn deposition on conception rate for individual inseminators. Unfortunately, it is not clear why some studies have shown an advantage following uterine horn insemination while others have not. A possible explanation for the positive effect of uterine horn inseminations may be related to the minimization or elimination of cervical semen deposition. Cervical insemination errors account for approximately 20% of attempted uterine body depositions (Peters et al., 1984). Macpherson (1968) reported that cervical insemination resulted in a 10% decrease in fertility when compared with deposition of semen in the uterine body. Clearly, all AI technicians must develop sufficient skill to recognize when the tip of the AI gun remains in the cervix. To maximize conception rates, AI technicians must continue to manipulate the reproductive tract until the tip of the AI gun is past the cervix and deposition into the uterus can be accomplished.

Fertility Level of the Semen: Clearly there are differences among bulls in the ability to achieve pregnancy success. For several decades seminal traits have been studied to try to predict reproductive success. Nevertheless, the determination of fertility differences between bulls requires the insemination of several thousand animals under the same management practices. All natural service bulls should have a comprehensive breeding soundness evaluation approximately 60 days prior to each breeding season. Whether natural service or AI is used, two of the most important indicators of bull fertility currently available are sperm motility and morphology.

Fertility Level of the Herd: Fertility level of the herd may be the hardest factor to evaluate. Herd fertility includes cycling/puberty status, compliance with protocols, embryonic mortality, body condition (nutrition level), and disease. Fertilization rates are usually between 89% and 100% when semen is present at the time ovulation occurs (Kidder et al., 1954; Bearden et al., 1956; Diskin and Sreenan, 1980; Maurer and Chenault, 1983; Gayerie de Abreu et al., 1984).

While fertilization usually takes place, conception rates (number of animals that conceive divided by number of animals inseminated) are usually around 60% to 70% for natural service or artificial insemination. Although nature (poor oocyte quality, disease, chromosomal abnormalities, failure of maternal recognition of pregnancy, etc.) contributes much of this loss, management practices can also increase embryonic mortality.

In order to understand embryonic mortality, one must first understand the development of the embryo (Table 7). Just like the estrous cycle, embryo development begins on day 0, or the day of standing estrus. This is the day the female is receptive to the male and insemination occurs. Ovulation occurs on day 1 or about 30 hours after the first standing mount (day 0; Wiltbank et al., 2000). If viable sperm are present, fertilization occurs inside the oviduct shortly after ovulation. The first cell division occurs on day 2, and by day 3 the embryo has reached the 8-cell stage (Shea, 1981). Between days 5 and 6 the embryo migrates into the uterine horn and by day 7 to 8 it forms into a blastocyst (Flechon and Renard, 1978; Shea, 1981; Peters, 1996). At this stage two distinct parts of the embryo can be seen: 1) the inner cell mass, which will form the fetus and 2) the trophoblast, which will form the placenta. Between days 9 and 11 the embryo hatches from the zona pellucida, a protective shell that has surrounded the embryo to this point (Shea, 1981; Peters, 1996). Then, on days 15 to 17, the embryo produces a chemical signal to prevent corpus luteum destruction and allow the cow to remain pregnant (Peters, 1996). The embryo attaches to the uterus beginning on day 19, and around day 25, placentation, an intricate cellular association between the cow and the calf, begins. By day 42 the embryo has fully attached to the uterus of the cow (Peters, 1996).

With the knowledge of the critical time points in embryonic development, it is possible to completely understand how stress from shipping can result in increased embryonic mortality in cows (Table 8). Most heifers are developed in a feedlot and moved to pasture after insemination. However, when animals are loaded on a trailer and hauled to a new location, they become stressed and release hormones related to stress. These hormones lead to a release of different hormones that change the uterine environment in which the embryo is developing. During blastocyst formation, hatching, maternal recognition of pregnancy, and attachment to the uterus, the embryo is vulnerable to these changes. The most critical time points are between days 5 and 42 after insemination. Before day 5, the embryo is in the oviduct and is not subject to changes in the uterine environment. Therefore, stress does not influence embryo survivability at this time. The greater the length of time after day 42, the less severe the influence of shipping stress on embryonic loss appears to be. Consequently, if heifers or cows need to be transported to pasture following fixed-time artificial insemination this should occur before day 5 or after day 42 post insemination.

Table 7. Time course of early bovine embryo development

Event	Day
Estrus	0
Ovulation	1
Fertilization	1
First cell division	2
8-cell stage	3
Migration to uterus	5-6
Blastocyst	7-8
Hatching	9-11
Maternal recognition of pregnancy	15-17
Attachment to the uterus	19
Adhesion to uterus	21-22
Placentation	25
Definitive attachment of the embryo to the uterus	42
Birth	285

Data adapted from: (Shea, 1981) (Flechon and Renard, 1978; Telford et al., 1990; Peters, 1996)

Table 8. Effect of time of transport after insemination on pregnancy rates

	Days after insemination that transportation occurred			
	1 to 4	8 to 12	29 to 33	45 to 60*
Synchronized pregnancy rate	74%	62%	65%	
% pregnancy loss compared to transportation on days 1 to 4		12%	9%	6%*
Breeding season pregnancy rate	95%	94%	94%	

*Loss in heifers compared to percentage pregnant prior to transportation (pregnancy determined by transrectal ultrasonography)

Data adapted from Harrington et al., 1995, and T. W. Geary unpublished data

Conclusions

In summary, the profitability and sustainability of any cattle operation is dependent on the longevity of each animal and the production of a live calf every year. Proper heifer development is essential to increasing longevity and maximizing productivity. Heifers that are properly developed and conceive early in the breeding season had increased longevity compared to heifers bred late in the breeding season. In addition to getting heifers bred early in the breeding season; managing heifers to minimize embryonic losses is essential to maximizing productivity. One of the most comprehensive methods to look at factors that influence fertility is the "Equation of Reproduction." The equation looks at 4 main topic areas: 1) Percentage of animals detected in standing estrus and inseminated; 2) Inseminator efficiency; 3) Fertility level of the herd; and 4) Fertility level of the semen.

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