Journal of Agricultural and Applied Economics, 46,1(February 2014):139–155

Net Returns from Feeding Cull Beef Cows: The Influence of Initial Body Condition Score

Zakou Amadou, Kellie Curry Raper, Jon T. Biermacher, Billy Cook, and Clement E. Ward

The impact of initial body condition scores on net returns from retaining beef cull cows for delayed marketing was investigated in a three-year experiment. Cows were retained either on native grass pasture or in a low-input dry lot setting. Net returns are examined across five alternative marketing periods, including culling. Sensitivity of net returns to changes in retention cost is also examined. Although a native grass pasture system was generally more profitable than a low-input dry lot system, thin and medium cows were typically more profitable than cows with higher initial body condition score regardless of the feeding system.

Key Words: body condition score, cow-calf management, cull cows, net returns, retention system

JEL Codes: Q1, Q13

Anecdotal evidence suggests that cow-calf producers may leave money on the table when it comes to marketing cull cows. Studies such as Blevins (2009) have shown that 15–30% of cow-calf producers' profit is earned from marketing cull cows. Carter and Johnson (2007) point out that, in a typical year, increasing the net income from sales of cull cows by even 10% results in nearly doubling ranch profit margins. Increasing a cow's salvage value as a capital asset at the end of its useful life to the ranch then becomes a key management issue that deserves more attention.

Cow-calf producers tend to devote energy to producing and marketing steers and heifers but generally give less attention to marketing cull cows. Cows are typically culled from the herd in the Fall after weaning calves and sold immediately when cow markets are at the seasonal low price. The most common reason that cows are removed from the herd is that they failed to become pregnant during the most recent breeding cycle. Strohbehn and Sellers (2002) suggested that retaining and feeding sound, healthy cows with thin to moderate initial body condition scores (BCS) would significantly increase the overall profitability of cull cows.[1] The seasonal

Zakou Amadou is a former graduate research assistant, Oklahoma State University, Stillwater, Oklahoma. Kellie Curry Raper is an associate professor of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma. Jon T. Biermacher is a research economist, Agriculture Division, The Samuel Roberts Noble Foundation, Inc., Ardmore, Oklahoma. Billy Cook is senior vice-president and director, Agriculture Division, The Samuel Roberts Noble Foundation, Inc., Ardmore, Oklahoma. Clement E. Ward is a professor emeritus of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma.

We thank Devlon Ford, The Samuel Roberts Noble Foundation, Inc., Ardmore, Oklahoma, and Tina Colby, USDA Agricultural Marketing Service, Oklahoma City, Oklahoma, for assistance in data collection.

[1] Body conditions scores (BCS) are a visual estimate of the external fat carried by a cow. It is often used by producers, extension personnel, and researchers to communicate the nutritional status of an individual cow. Scores are assigned from one (emaciated and carrying virtually no fat) to nine (excessively fat) (Wagner et al., 1988). BCS information may be used to adjust feeding strategies for feeding efficiency.

price pattern in slaughter cows has the widest extreme from seasonal low to seasonal high of any class of cattle, offering producers an opportunity to add 10% to nearly 25% to the price for cull cows from the seasonal low to the following spring (Peel and Doye, 2008). Figure 1 illustrates this seasonal movement for the past 10 years. In addition to seasonal price increases, cow-calf producers must also consider resource cost and availability, including management capacity, feeds, labor and pasture, or holding facilities, when deciding whether to retain and feed cull cows or to market them immediately when culled from the herd. In certain situations, feeding cull cows may actually increase the efficiency of underused labor resources and low-quality forage (Peel and Doye, 2008). In other cases, the cost may outweigh the benefit.

Blevins (2009) contends that managed marketing of cull cows has the potential to increase overall profitability of the cow-calf herd. Roeber et al. (2001) indicated that beef producers could increase returns from cull cows by as much as $70 per head or more when quality defects, health, and condition of cull cows are well managed and cows are marketed in a timely manner. Amadou (2009) found positive net returns for retaining cull cows beyond fall culling on native grass for 90–120 days. This practice takes advantage of the normal seasonal pattern in cull cow prices at a relatively low feed cost.

Some studies have suggested that, in addition to capturing additional value from the seasonal price upswing, retaining cows culled from the breeding herd in a short-term feeding system with a specified forage or concentrate ration may allow producers to increase pounds sold along with slaughter quality grade of the animal (Feuz, Stockton, and Bhattacharya, 2006; Wright, 2005). Peel and Doye (2008) concluded a relationship exists among ending BCS, marketing classification, and estimated dressing percentage. That is, the BCS at marketing can be an indicator of other characteristics that impact the price per pound received. Apple (1999) found that cows with higher BCS scores at slaughter (seven to eight) had the highest gross and net carcass values, whereas cows with lower BCS scores (two to three) at slaughter had less value. Schnell et al. (1997) pointed out that improvement in the quality and consistency of beef products obtained through feeding a high-concentrate diet could enhance the salvage value of cull beef cows. Carter and Johnson (2007) stated that cows with higher ending BCS and heavier weight optimize economic returns by having both a higher carcass value and a higher live value. However, Wright (2005) contends that the value added to cull cows from this practice depends on feed costs and availability as well as on final cow carcass quality and days on feed. The studies mentioned here are focused on the ending BCS at marketing and do not account for the cost to the cow-calf producer of holding and feeding cull cows to obtain a higher ending BCS.

According to Feuz and Hewlett (2012), a one-point increase in BCS requires 60–80 pounds of gain depending on the frame of the individual cow. Encinias and Lardy (2000)

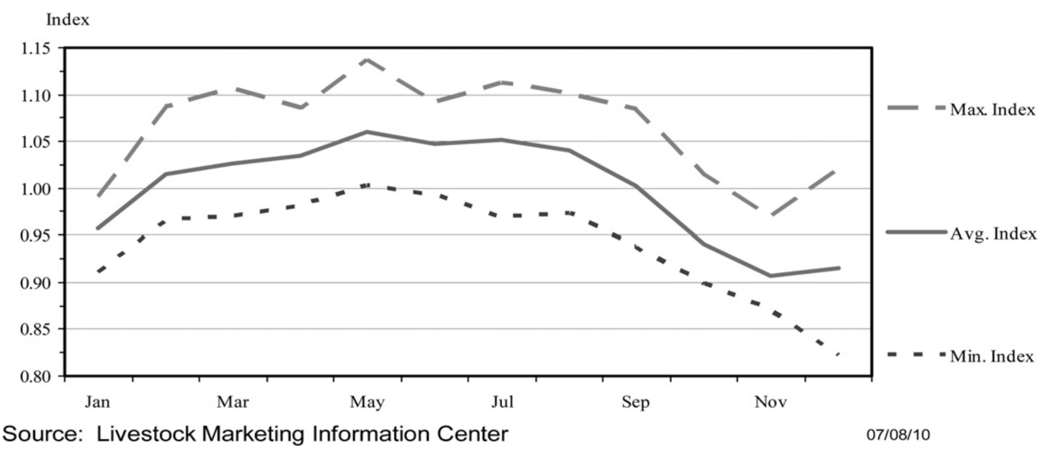


Figure 1. Seasonal Price Index for Utility Cows in the Southern Plains, 2000–2009

recommend a BCS of greater than four at weaning and five at calving for mature cows to maximize breeding potential. Cows that end the weaning season with a relatively low BCS (i.e., leaner) should be more feed-efficient in a retention setting. That is, a greater percentage of feed should go to weight gain rather than to weight maintenance for these animals. Thus, the cost of gain will likely be less for cows with lower initial BCS, enhancing the opportunity for a positive net return from retaining cull cows for a period rather than marketing them immediately at culling.

Although many have suggested that BCS at marketing plays a role in determining value and that BCS is a useful tool when making culling decisions, there is little information on the influence of initial BCS on net returns from feeding cull cows. The objective of this research is to determine the influence of BCS at culling on net returns per head from retaining cull cows for a period of time beyond the culling date in one of two minimal maintenance retention systems: a native grass pasture system or a low-cost dry lot system. We hypothesize that cull cows with lower initial BCS will have higher net returns per head from feeding in a retention setting than cows with higher initial BCS.

Methodology

The producer's choice in maximizing net returns from retaining a cull cow j for i feeding periods relative to culling revenue at weaning ($i = 0$) can be defined as:

$$\max_{i=0}^{5} NR_{ij} = \left\{ \begin{array}{l} P_{0j}W_{0j}, \quad if\ i = 0, \\ P_{ij}W_{ij} - P_{0j}W_{0j} - \sum_{i=0}^{i} C_{ij}, \text{otherwise} \end{array} \right\}, \tag{1}$$

where NR_{ij} is total net return from selling cull cow j at feeding interval i (where $i\epsilon(0.1,2.3,4.5)$); P_{oj} is the price for cow j at culling; W_{oj} is the weight for cow j at the time of culling; P_{ij} represents the price for cow j at feeding interval i; W_{ij} is the ending weight for cow j at feeding interval i; and C_{ij} is the cumulative retention cost from the culling point to the marketing period for cow j at feeding interval i. For an individual cow j, the optimal marketing period i (at culling or at the end of a subsequent feeding interval) is that period in which net return over retention cost is maximized.

If net return for each feeding interval, i, is known, the producer's decision is simplified. Because that is not the case, we estimate the adjusted mean net returns that take into account the fixed effects in the experiment. Specifically, maximum likelihood estimation is used to estimate adjusted (least squares) means for net returns at the culling period and for alternative marketing periods with both random and fixed effects. Fixed effects include initial BCS category at culling (thin, medium, heavy), retention management system (pasture or dry lot), and feeding interval (0, 35, 63, 91, 126, and 155 days beyond initial culling), whereas cow and year are considered as random effects. Therefore, the general least square means model can be expressed as follows:

$$\begin{aligned} NR_{jksi} = \alpha_0 &+ \sum_{k=1}^{3} \alpha_k BCS_k + \sum_{s=1}^{2} \alpha_s System_s \\ &+ \sum_{i=0}^{5} \alpha_i FI_i + \alpha_{ks} BCS_k System_s \\ &+ \alpha_{ki} BCS_k FI_i + \alpha_{si} System_s FI_i \\ &+ \alpha_{ksi} BCS_k System_s FI_i \end{aligned} \tag{2}$$

where NR_{jksi} is the adjusted mean for net return of cow j with initial BCS category k (k = thin, medium, and heavy) in management system s (s = pasture, dry lot) at feeding interval (FI) i where i = {0, 1, 2, 3, 4, 5} represents approximately monthly periods beyond culling. Specifically, those monthly intervals are zero, 35, 63, 91, 126, and 155 days beyond the initial culling date. The model represented in equation (2) can be estimated as a least squares mixed model using Proc Mixed in SAS 9.2. Fixed effects include initial BCS category (thin, medium, heavy), management system (pasture or dry lot), and feeding interval (zero, 35, 63, 91, 126, and 155 days), whereas cow and years are considered random effects.

Cull cow price can be obtained in two ways: ex post and ex ante. Ex post prices are those prices observed after the fact; thus, actual cull cow market prices for the appropriate cow quality and marketing week are observed and used to calculate net returns from cull cow retention and delayed marketing. An ex ante approach uses historical price data to model the price generating function, which is then used to estimate prices for the current event. Here, two possibilities are considered for the functional form of the cull cow price equation. A model using dummy variables for monthly and quality grade impacts is compared with a trigonometric model using a likelihood ratio test where

$$\text{(3)}\quad H_0: P_{mgt} = \alpha_0 + \sum_{m=1}^{11} \beta_m M_m + \sum_{g=1}^{2} \alpha_g Q_g + \mu_t + \varepsilon_{mgt}$$

where P_{mgt} is price at month m (m = 1, . . . ,12) at given quality grade Q_g (lean, boner, or breaker) in year t, M_m = month, μ_t is the year random effect with $\mu_t \sim N(0,\sigma_t^2)$ and $\varepsilon_{mgt} \sim N(0,\sigma_\varepsilon^2)$, and

$$\text{(4)}\quad H_a: P_{mgt} = a_0 + \sum_{m=1}^{11} \beta_m M_m + \sum_{SL=13.26,52} \left[a_{SL} Cos\left(\frac{2\pi M}{SL}\right) + b_{SL} Sin\left(\frac{2\pi M}{SL}\right)\right] + \sum_{g=1}^{2} \alpha_g Q_g + \mu_t + \varepsilon_{mgt}$$

where SL is the seasonal frequency length—here approximately three months (13 weeks), six months (26 weeks), and 12 months (52 weeks)—and where other variables are as previously defined. The dummy variable model (equation [3]) is a restricted version of the trigonometric model (equation [4]). The likelihood ratio test statistic is calculated as $D = -2\ln(LLF_{H_0}/LLF_{H_a}) = -2\ln(LLF_{H_0}) + 2\ln(LLF_{H_a})$. The associated critical χ^2 value is $\chi^2_{6,}$ where the degrees of freedom are six because H_0 and H_a have 14 and 20 parameters, respectively. If D > $\chi^2_{6,}$, then the null hypothesis is rejected, indicating that the trigonometric model is a better fit than the dummy variable model. Alternatively, if D < $\chi^2_{6,}$, the null hypothesis is not rejected and the preferred model is the more simplistic dummy variable model, because the trigonometric model does not add sufficiently better information to the data-generating process.

Data

This cull cow retention and marketing experiment was conducted at The Samuel Roberts Noble Foundation in Ardmore, Oklahoma. Spring calving cows culled from a herd of black-hided Angus cows were retained either in a grazing environment (pasture) or in a low-cost dry lot environment (dry lot). Ranch managers made culling decisions based on cow performance and breeding history. Data were collected at culling and then at approximately monthly intervals for cows culled in October 2007 and marketed in April 2008, for cows culled in October 2008 and marketed in March 2009, and for cows culled in October 2009 and marketed in March 2010. The herd's average cow age was six years old with little variation in age across the herd at the beginning of the study period in October 2007. A total number of 162 cows were included in the study across the three-year period equally and randomly assigned to pasture and dry lot systems. Specifically, the study included 48 cows in year one, 43 cows in year two, and 71 cows in year three. In the dry lot system, cows were fed on a relatively low-cost ration consisting of rye hay and protein cubes. Cubes with 10% crude protein were fed from mid-October to December with 25% crude protein cubes fed for the remainder of the retention period. In the pasture system, cows were retained on stockpiled native grass pasture (350 acres) supplemented with hay and cubes only during icy periods. Both groups received mineral supplements.

Physical data were collected approximately monthly from culling through March each year on individual cows and included weight, estimated U.S. Department of Agriculture (USDA) slaughter cow grade, and estimated dressing percentage. Initial BCS was also collected in years two and three. To minimize bias in subjective measures across time periods, the same USDA Agricultural Marketing Services (AMS) agent was used to assign USDA grade, dressing percentage, and BCS at each weigh period when data were collected, including at culling.

Cost data include feed, pasture, labor, and operating interest. Feed cost data are assigned monthly within each study year on an average per-cow basis by marketing interval and management system. Feed quantity data include protein range cubes (pounds fed), mineral supplement (pounds fed), and hay (tons fed). Cube and mineral prices were charged at the rate offered by the local feed milling company during the feeding period. Rye hay cost is based on tons fed and is priced at actual purchase price, which is consistent with prices reported in the Oklahoma Market Report for grass hay, east region during the study period (Oklahoma Department of Agriculture, Food and Forestry). Pasture costs are assessed as per-acre cash rental rate based on local rates, which are within the range of rates reported by Doye and Sahs (2011) for native pasture in the east region of Oklahoma. Feed costs are based on an "as fed" calculation by pen for each feeding period and are converted to a per-cow average for individual cows based on management system and number of animals in the pen. Labor is tracked in hours by feeding period for each system and assigned a wage rate consistent with that offered locally for hourly ranch hands as reported by the Oklahoma Employment Security Commission's Oklahoma Wage Report for Farming, Fishing, and Forestry for the years in the study period. Operating interest is charged at the annual rate of 7.5% on the estimated value of the cow at initial culling. A comparison of the inputs included in the two feeding systems is presented in Table 1.

Price data for cull cows are taken from the Slaughter Cow portion of AMS' price reports KO_LS155 and KO_LS795 for Oklahoma National Stockyards, Oklahoma City (USDA-AMS, 2003-2010a and USDA-AMS, 2003-2010b). Both ex post and ex ante methods are used to assign individual cow prices. The ex post analysis uses the market reported price. Estimated USDA grade and dressing percentage are used in conjunction with the nearest in time weekly AMS price report to identify a specific price per hundredweight for each cow at each of the five feeding/marketing intervals in the culling year. The ex ante analysis uses an estimated price where weekly AMS price data from 2003–2010 are used to generate a price function for slaughter cows, which then assigns individual cow prices ($/cwt) based on the marketing period and the animal's USDA grade.

The initial BCS of an individual cow at culling is used to assign the cow to one of three BCS categories. Cull cows are classified as thin (initial BCS < 5), medium (5 ≤ initial BCS ≤6), or heavy (initial BCS > 6). This division of BCS scores, particularly with respect to the thin category, is supported by Encinias and Lardy (2000) as well as Steward and Dyer (2000). Anecdotally, discussions with ranch managers also suggest that they sort cows in a manner similar to these classifications when assessing nutritional needs and adjusting feeding regimens of the cow herd. Initial BCS was not collected in the first year of the experiment. However, BCS was collected in the initial culling periods for the second and third experiment years as well as for three other periods during the study. The relationship of BCS, cow weight, dressing percentage, fill, and quality grade is estimated using data from the five available periods as follows:

Table 1. Management System Inputs and Associated Cost Data Source

Input	Pasture System	Dry-lot System	Cost Data Source
Pasture	✓		Oklahoma pasture rental rates
Hay	Icy periods only	✓	Oklahoma Market Report, Oklahoma Department of Agriculture, Food and Forestry (2007–2010)
Protein range cubes	Icy periods only	✓	Stillwater Milling Company
Mineral supplement	✓	✓	Stillwater Milling Company
Labor	✓	✓	Oklahoma Employment Security Commission (2012)
Operating interest	✓	✓	Local and regional lending institutions

$$BCS_j = \beta_1 + \beta_2 W_{oj} + \beta_3 DP_j + \beta_4 Boner + \beta_5 Breaker + \beta_6 Fill + n_j \quad (5)$$

where DP is dressing percentage, Boner and Breaker are dummy variables representing quality grade, $\eta \sim N(0,\sigma_\eta^2)$, and other variables are as previously defined. The resulting equation is used to predict initial BCS score, and thus placement in a BCS category (thin, medium, and heavy), for cows included in the first year of the experiment.

Results

The two alternative cull cow price-generating functions represented in equations (3) (dummy variable model) and (4) (trigonometric model) were estimated and compared through a likelihood ratio test. The likelihood ratio test statistic $D = -2\ln LLF_{H_0} + 2\ln LLF_{H_a} = -5798.2 + 5807.5 = 9.3$, whereas $\chi^2_{6,} = 12.59$ at 95% statistical significance. Hence, $D < \chi^2_{6,}$ and H_0 is not rejected, indicating that the dummy variable model represented in equation (3) is preferred to the trigonometric model. Price function parameter estimates for the dummy variable model are reported in Table 2. Estimates for equation (4) have been omitted in the interest of space. Figure 2 illustrates that the price function generates a similar seasonal price pattern to that reflected by the seasonal price index in Figure 1. Although the actual market price reflects short-run market dynamics, the price function measures the long-run dynamics of price. Relative to the October price, the November coefficient is negative and significant, representing the seasonal low in the Fall when cow culling decisions are typically made resulting in high supply. Price effects for February through September are positive and significant, peaking in April. Coefficients for yield grades of boner and breaker are also positive and significantly related to price relative to a yield grade of lean. The coefficients in Table 2 are used to estimate price per hundredweight for each cow at each possible marketing period. Ex post analysis assigns the observed market price from the associated marketing period with the specific cow. For example, a cow marketed in December 2007 classified as a breaker is assigned an actual price of $39.50/cwt as reported in the nearest weekly AMS marketing report. However, an ex ante analysis using the estimated price function would assign that same cow an estimated price of $46.95/cwt at marketing based on what

Table 2. Estimated Slaughter Cow Price as a Function of Month and Yield Grade (2003–2010)

Parameters	Independent Variables	Estimates	Standard Error	*p* Values
β_0	Intercept	41.640	0.5508	<0.0001
β_1	January	1.090	0.7832	0.1644
β_2	February	3.599	0.7472	<0.0001
β_3	March	4.146	0.7348	<0.0001
β_4	April	4.619	0.7396	<0.0001
β_5	May	4.604	0.7196	<0.0001
β_6	June	3.311	0.7396	<0.0001
β_7	July	4.600	0.7472	<0.0001
β_8	August	3.634	0.7196	<0.0001
β_9	September	3.808	0.7325	<0.0001
β_{11}	November	–1.669	0.7136	0.0196
β_{12}	December	–0.989	0.8326	0.2353
α_1	Breaker	6.308	0.3823	<0.0001
α_2	Boner	6.740	0.3826	<0.0001
σ_t^2	Year random effect	11.144		
σ_ε^2	Variance of error term	23.681		
–2LL	Log likelihood	5807.5		

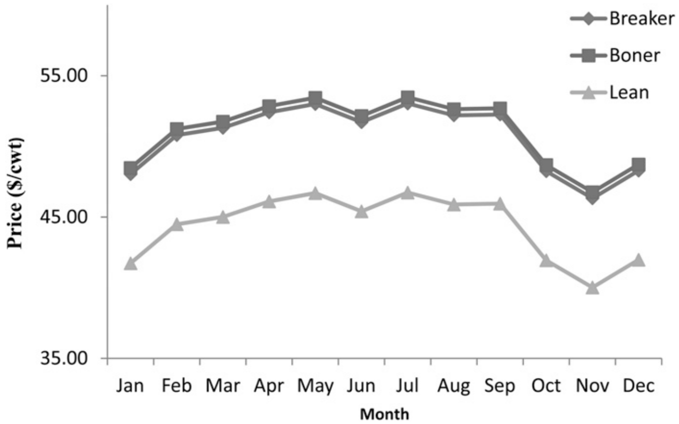


Figure 2. Estimated Slaughter Cow Price as a Function of Month and Quality Grade, 2003–2010

historical price movements suggest that price would be for that marketing period.

Parameter estimates and p values for the body condition score relationship represented in equation (5) are:

$$\begin{aligned} BCS_j = & -3.14 + 0.3\,\text{boner} + 0.74\,\text{breaker} \\ & + 0.02\,\text{W} + 0.01\,W^2 + 0.16\,\text{DP} \\ & + 0.15\,\text{Fill}. \\ & (0.046)(0.040)(0.001)(0.848) \\ & \times\ (0.235)(<0.0001)(0.0001) \end{aligned} \tag{6}$$

where p values are in parentheses. Quality grade, dressing percentage, and fill are positive and significantly related to BCS. The resulting equation (6) is used to estimate initial BCS for each cow in year one. The estimated initial BCS is then used to assign individual cows to a BCS category: thin, medium, or heavy. Summary statistics of initial BCS and distribution of cull cows across initial BCS categories and treatment groups are presented in Table 3. In general, a disproportionate number of cows are classified as medium across all three study years. The percentage of cows in each study year classified as medium ranged from 51% to 78%, suggesting that the source herd is well managed with respect to optimal BCS at weaning.

Net returns from retaining cull cows are estimated using the model represented in equation (2). The ex post model is estimated using period-specific observed cull cow prices, whereas the ex ante model is estimated using prices generated by the function represented in Table 2. Both basic models are also estimated assuming ±10% change in costs to give insight into the sensitivity of the results. All net return models use an unstructured covariance matrix, because likelihood ratio tests indicated that it was most appropriate for modeling the data. Figures 3 and 4 illustrate net returns for the base cost scenario across BCS categories for the dry lot system and pasture system, respectively, using observed (ex post) market prices. Figure 3 shows that net returns are positive beyond 35 days for both thin and medium cows in the pasture system but that heavy cows retained in the pasture system generated negative

Table 3. Distribution of Cow Initial Body Condition Score at Culling by Management System and Body Condition Score (BCS) Category

Characteristics		Value
Initial BCS	Mean	5.5
	Standard deviation	0.86
	Minimum	4
	Maximum	8
Distribution of cows		
No.		162
Management system		
Pasture		81
Dry lot		81
BCS category (initial BCS)		
Thin (BCS < 5)		37
Medium (5 ≥ BCS ≤ 6)		94
Heavy (BCS > 6)		31

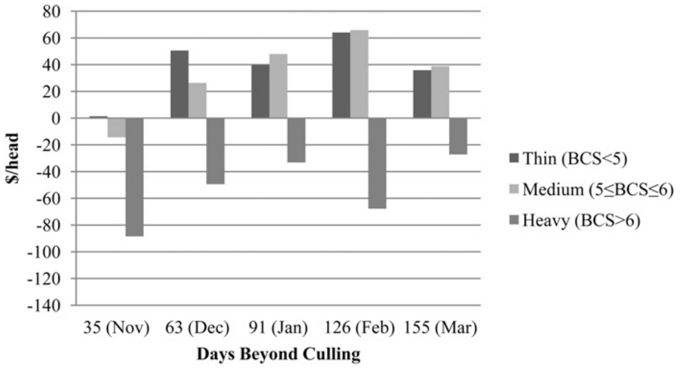


Figure 3. Ex Post Analysis of Net Returns ($/head) Across Marketing Periods for Cull Cows Retained in a Pasture System, Market Reported Price

net returns when held beyond culling. Very little positive net returns are generated from retention in a dry lot system with delayed marketing, as seen in Figure 4. The only positive net return for delayed marketing comes at 126 days in the case of thin cows. Together, Figures 3 and 4 emphasize that cows classified as heavy at culling do not generate positive changes in net returns over revenue at culling in either retention setting.

These results are supported by the statistical results in Table 4, which reports ex post estimated change in net returns relative to revenue at culling for the three BCS categories across management systems and weigh periods along with associated p values. The change in net returns for cows classified as thin and retained in the pasture system were positive and significant ($p < 0.10$) at 63 days ($50.60), 91 days ($39.73), and 126 days ($64.10). Net returns peaked at 126 days but required holding cows 60 days longer to capture the additional $23.50 in net returns. Changes in net returns for cow in the pasture system classified as medium were positive and statistically significant at 63 days ($26.36), 91 days ($47.93), 126 days ($65.88), and 155 days ($38.82), again peaking at 126 days. By contrast, pooled net returns for cows classified as heavy retained in the pasture system were negative and statistically significant at all weigh periods. The most striking result from Table 4 is the lack of positive changes in net returns in the dry lot management system. In all cases under the dry lot system, net returns relative to revenue at culling are either negative and significant ($p < 0.10$) or not significantly different from zero. Table 4 also reports sensitivity of net returns to a ±10% change in feed cost. Results show that a 10% change in feed cost is not enough to influence producers'

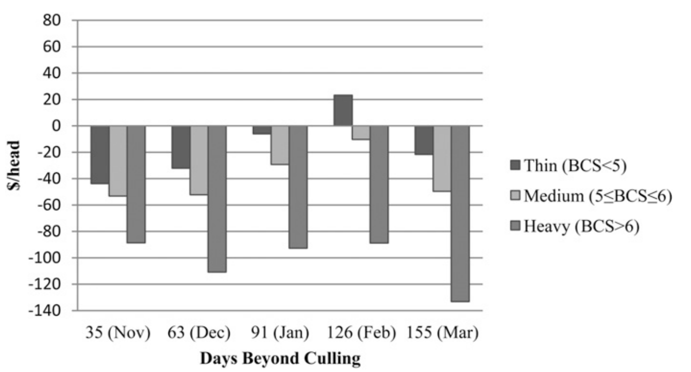


Figure 4. Ex Post Analysis of Net Returns ($/head) Across Marketing Periods for Cull Cows Retained in Dry Lot System, Market Reported Price

Table 4. Ex Post Analysis of Change in Net Returns ($/head) Relative to Mean Revenue at Culling for Initial Body Condition Score (BCS) Categories by Management System and Marketing Interval using Market-reported Cow Price and with ±10% Change in Feed Costs (FC)

		Thin (Beg BCS < 5)				Medium (5 ≥ Beg BBCS ≤ 6)				Heavy (Beg BCS > 6)			
			Change in Net Return				Change in Net Return				Change in Net Return		
	Days Beyond Culling	Revenue at Culling	Base Scenario	10% FC Decrease	10% FC Increase	Revenue at Culling	Base Scenario	10% FC Decrease	10% FC Increase	Revenue at Culling	Base Scenario	10% FC Decrease	10% FC Increase
Pasture	0	$522.26				$589.27				$721.49			
	35		1.41	4.87	–0.13		–14.33*	–10.90	–15.85*		–88.48*	–85.24*	–89.9*
	(November)		(0.9168)	(0.7186)	(0.9924)		(0.0728)	(0.1723)	(0.0472)		(<0.0001)	(<0.0001)	(<0.0001)
	63		50.60*	53.52*	49.63*		26.36*	29.42*	25.31*		–49.45*	–45.48*	–51.01*
	(December)		(0.0050)	(0.0026)	(0.0065)		(0.0129)	(0.0049)	(0.0181)		(0.0099)	(0.0158)	(0.0085)
	91 (January)		39.73*	44.09*	37.42*		47.93*	52.45*	45.6*		–33.13	–27.82	–35.50
			(0.0625)	(0.0361)	(0.0819)		(0.0002)	(<0.0001)	(0.0004)		(0.1436)	(0.2119)	(0.1206)
	126		64.10*	68.42*	61.75*		65.88*	70.99*	63.10*		–67.74*	–61.35*	–70.68*
	(February)		(0.0123)	(0.0133)	(0.0275)		(<0.0001)	(<0.0001)	(0.0002)		(0.0223)	(0.0366)	(0.0180)
	155		35.82	40.35*	33.44		38.82*	43.82*	36.30		–27.2	–19.82	–30.50
	(March)		(0.1557)	(0.0994)	(0.1937)		(0.0095)	(0.0026)	(0.0173)		(0.3119)	(0.4456)	(0.2606)
Dry lot	0	$527.48				$596.97				$719.45			
	35		–43.80*	–36.80*	–47.5*		–53.23*	–46.04*	–57.12*		–88.67*	–81.45*	–92.65*
	(November)		(0.0006)	(0.0036)	(0.0002)		(<0.0001)	(<0.0001)	(<0.0001)		(<0.0001)	(<0.0001)	(<0.0001)
	63		–32.10*	–21.55	–38.86*		–52.25*	–41.53*	–58.9*		–110.79*	–98.52*	–118.23*
	(December)		(0.0520)	(0.1840)	(0.0204)		(<0.0001)	(0.0002)	(<0.0001)		(<0.0001)	(<0.0001)	(<0.0001)
	91		–6.07	5.25	–13.5		–29.29*	–17.01	–37.10*		–92.75*	–77.07*	–102.51*
	(January)		(0.756)	(0.7849)	(0.4941)		(0.0258)	(0.1863)	(0.0053)		(<0.0001)	(0.0004)	(<0.0001)
	126		23.19	34.85	15.06		–10.30	3.54	–19.65		–88.83*	–68.76*	–101.84*
	(February)		(0.3629)	(0.16870)	(0.5569)		(0.5440)	(0.8330)	(0.2510)		(0.0021)	(0.0158)	(0.0005)
	155		–21.62	–8.80	–30.06		–49.62*	–34.17*	–59.64*		–133.21*	–110.24*	–147.84*
	(March)		(0.3519)	(0.6953)	(0.2050)		(0.0016)	(0.0237)	(0.0002)		(<0.0001)	(<0.0001)	(<0.0001)

[a] Numbers in parentheses are p values and * denotes statistical significance at $p < 0.10$.

Table 5. Ex Post Anaylsis of Difference in Net Returns ($/head) Across Body Condition Score (BCS) Categories by Management System and Feeding Interval with ±10% Change in Feed Cost (FC) Using Market Reported Cull Cow Price[ab]

Days Beyond Culling	BCS Comparison		Pasture System Net Return ($/head)			Dry Lot System Net Return ($/head)		
			Base Scenario	10% FC Increase	10% FC Decrease	Base Scenario	10% FC Increase	10% FC Decrease
35 (November)	Thin	Medium	15.74 (0.3155)	15.72 (0.3156)	–9.44 (0.3156)	9.42 (0.5287)	9.62 (0.5193)	9.25 (0.5377)
	Thin	Heavy	89.90* (<0.0001)	89.77* (<0.0001)	90.12* (<0.0001)	44.87* (0.0172)	44.15* (0.0163)	44.65* (0.0180)
	Medium	Heavy	74.15* (<0.0001)	74.05* (<0.0001)	74.33* (<0.0001)	35.44* (0.0298)	34.52* (0.0292)	35.40* (0.0101)
63 (December)	Thin	Medium	24.24 (0.2420)	24.22 (0.2457)	24.09 (0.2378)	20.15 (0.3081)	20.04 (0.3159)	20.98 (0.3050)
	Thin	Heavy	100.06* (0.0002)	100.64* (0.0002)	89.58* (0.0002)	78.69* (0.0017)	79.37* (0.0017)	76.97* (0.0018)
	Medium	Heavy	75.82* (0.0162)	76.32* (0.0006)	74.92* (0.0006)	58.54* (0.0068)	59.32* (0.0067)	56.99* (0.0075)
91 (January)	Thin	Medium	–8.19 (0.7391)	–8.17 (0.7420)	–8.37 (0.7301)	23.20 (0.3240)	23.02 (0.3203)	22.27 (0.3366)
	Thin	Heavy	72.85* (0.0197)	72.72* (0.0207)	71.92* (0.0194)	86.68* (0.0036)	89.00* (0.0030)	82.34* (0.0049)
	Medium	Heavy	81.05* (0.0020)	81.08* (0.0022)	80.28* (0.0019)	63.47* (0.0135)	62.40* (0.0117)	60.06* (0.0176)
126 (February)	Thin	Medium	–1.77 (0.9558)	–1.34 (0.9667)	–2.56 (0.9356)	33.49 (0.2745)	32.72 (0.2607)	31.30 (0.3030)
	Thin	Heavy	131.85* (0.0013)	131.44* (0.0013)	129.77* (0.0014)	112.02* (0.0038)	116.90* (0.0027)	103.61* (0.0068)
	Medium	Heavy	133.62* (0.0001)	133.58* (0.0001)	132.34* (0.0001)	78.54* (0.0188)	82.17* (0.0147)	72.32* (0.0290)
155 (March)	Thin	Medium	–3.02 (0.9174)	–3.86 (0.9233)	–3.48 (0.9021)	28.01 (0.3156)	27.57 (0.2991)	25.37 (0.3483)
	Thin	Heavy	62.94* (0.0881)	61.94* (0.0895)	60.16* (0.0926)	111.60* (0.0016)	110.78* (0.0011)	101.43* (0.0030)
	Medium	Heavy	65.97* (0.0324)	66.80* (0.0336)	63.64* (0.0332)	83.59* (0.0062)	81.20* (0.0047)	76.05* (0.0101)

[a] Numbers in parentheses are p values and * denotes statistical significance at $p < 0.10$.

[b] A positive number indicates that the first BCS category generates higher net returns than the second BCS category.

decisions on cull cow retention strategies based on ex post net return measures, because the pattern of positive and negative net returns is quite similar in either case.

Table 5 compares differences in net returns between initial BCS categories as measured ex post with observed market prices. Results show that, in general, the difference between net returns of thin and medium cows retained on both pasture and dry lot is not significantly different from each other. Additionally, the difference between pasture system net returns of both thin and medium cows as compared with those of heavy cows was positive and statistically significant. Thin and medium cows retained on pasture at 35 days produced \$89.90 ($p < 0.0001$) and \$74.15 ($p < 0.0001$) higher net returns, respectively, than heavy cows retained on pasture. At 63 days, medium and thin cull cows on pasture generated \$100.06 ($p = 0.0002$) and \$75.82 ($p = 0.0162$) higher net returns than heavy cull cows retained on pasture. At 91 days, net returns of thin and medium cows on pasture were \$72.85 ($p = 0.0197$) and \$81.05 ($p = 0.0020$) higher than heavy cows held on pasture. The largest difference in net returns come at 126 days where thin and medium cows on pasture produced \$131.85 ($p = 0.0013$) and \$133.62 ($p = 0.0001$) higher net returns, respectively, than heavy cows. Results are similar for cull cows retained in the pasture system for 155 days. Overall, cows classified as thin or medium by initial BCS generated higher net returns in either retention setting as compared with those classified as heavy.

Analysis of net returns relative to revenue at culling yields similar results when using an ex ante analysis with estimated prices rather than observed market prices. Figures 5 and 6 illustrate net returns estimated using the price function. Figure 5 indicates that changes in net returns are positive beyond 35 days for both thin and medium cows in the pasture system using the price function. In Figure 6, net returns for dry lot systems were slightly positive for thin and medium cows at 126 days, although Table 6 indicates neither is significantly different from zero. Figures 5 and 6 again highlight that cows classified as heavy at culling produce little or no positive changes in net returns over revenue at culling in either feeding program. Table 6 reports mean net returns by BCS category across management systems and weigh periods based on prices generated with the price function described earlier. Net returns for thin cows compared with revenue at culling in a dry lot setting were all negative but significantly different from zero only at 35 days. Changes in net returns for cows classified as thin and retained in the pasture system were positive and statistically significant at each marketing period, peaking at 155 days (\$72.92). Changes in net returns for cows classified as medium and retained in the pasture system were also positive and significant for each marketing period, peaking at 155 days (\$66.07). Table 6 also reports the sensitivity of net returns to a 10% change in feed cost. Results suggest that only the magnitudes of net returns have changed, but the direction of coefficients remains unchanged as

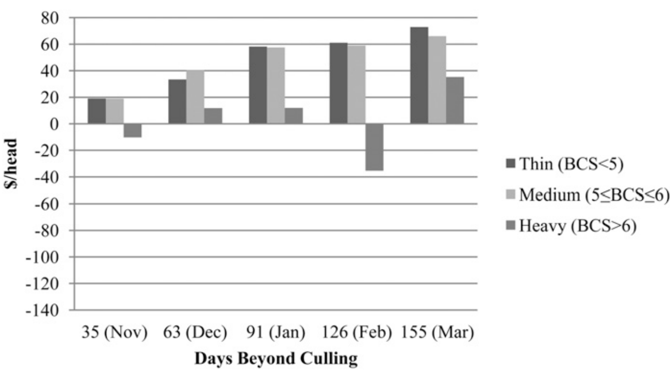


Figure 5. Ex Ante Net Returns (\$/head) Across Marketing Periods for Cull Cows Retained in a Pasture System, Estimated Prices (2003–2010)

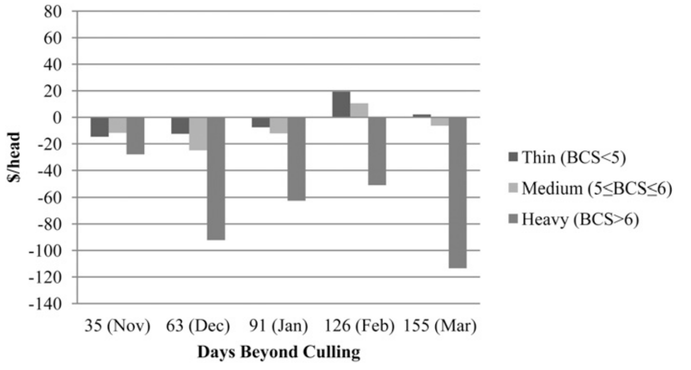


Figure 6. Ex Ante Net Returns ($/head) Across Marketing Periods for Cull Cows Retained in a Dry Lot System, Estimated Prices (2003–2010)

a result of 10% change in feed cost. In this scenario, the 10% change in input costs again has little impact on producers' decision to retain and feed cull cows beyond culling.

Table 7 reports pairwise BCS comparisons of the change in net returns relative to revenue at culling across all alternative marketing intervals for both retention systems using ex ante prices. At each period, the difference between net returns of thin and medium cows held on pasture is not statistically significant. The same holds true for cull cows retained in the dry lot system. However, results do suggest significant positive differences in net returns for both thin versus heavy and medium versus heavy cows in the pasture system at multiple periods. The largest differences come at 126 days where thin and medium cows produced $96.44 and $94.25 higher, respectively, than net returns of heavy cows retained on pasture.

Figures 7 and 8 illustrate cumulative average daily gain (ADG) for thin, medium, and heavy cull cows in the pasture management system and the dry lot management system. Figure 7 illustrates that ADG of all cows generally decreased over time with ADG of thin cull cows higher than those of medium and heavy cows.[2] Similarly, Figure 8 shows that ADG of all cull cows in the dry lot setting decreased over time, but the ADG of thin cull cows was higher than for medium and heavy cows in all but the first weigh period. This corresponds with the notion that as cows get heavier, more feed goes to weight maintenance as opposed to weight gain and feed efficiency decreases. Here, evidence supporting that theory is seen in both the dry lot and pasture management systems. Average feed cost of holding cull cows in a dry lot management system versus a pasture/forage management system is shown in Figure 9. In the first 35 days of feeding, costs between the dry lot and pasture systems are similar. However, in the periods following, dry lot costs increase more rapidly than do the costs for holding cull cows in a pasture/forage system.

A comparison of ex ante and ex post analyses indicates that the ex ante analysis based on historical price movements tends to estimate smaller losses for heavy cows (BCS > 6) on pasture than does the ex post analysis. Additionally, losses for the dry lot system are estimated to be less overall when using the ex ante approach versus the ex post approach. This highlights the need for cow-calf operators to partner knowledge of historical price movements with knowledge of current market and policy conditions when making the decision regarding retention of cull cows.

Conclusions

Initial BCS appears to be an important factor in determining net returns from retaining and

[2] The exception is heavy cows at the day 155 weigh period. However, ADG is calculated for the days between weigh periods. The fact that heavy cows lost weight in the previous period and then had increased pasture available from spring green-up likely influenced ADG measures in this period.

Table 6. Ex Ante Analysis of Change in Net Returns ($/head) Relative to Mean Revenue at Culling for Initial Body Condition Score (BCS) Categories by Management System and Marketing Interval with ±10% Change in Feed Cost (FC) Using Estimated Cow Price (2003–2010)[a]

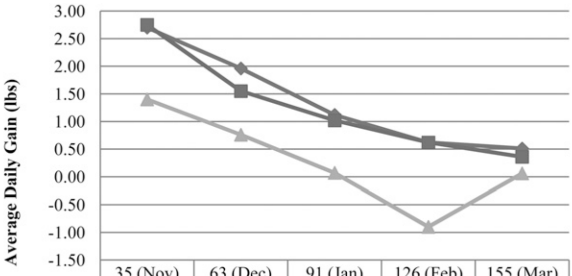
		Thin (Beg BCS < 5)				Medium (5 ≥ Beg BBCS ≤ 6)				Heavy (Beg BCS > 6)			
			Change in Net Return				Change in Net Return				Change in Net Return		
	Days Beyond Culling	Revenue at Culling		10% FC Decrease	10% FC Increase	Revenue at Culling		10% FC Decrease	10% FC Increase	Revenue at Culling		10% FC Decrease	10% FC Increase
Pasture	0	$522.26				$589.27				$721.49			
	35		19.05*	20.59*	17.52*		18.98*	20.48*	17.46*		–10.25	–8.82	–11.67
	(November)		(0.0402)	(0.0264)	(0.0599)		(0.0006)	(0.0002)	(0.0016)		(0.1698)	(0.3679)	(0.1374)
	63		33.36*	34.34*	32.38*		40.22*	41.26*	39.17*		11.80	13.37	10.24
	(December)		(0.0361)	(0.0296)	(0.0437)		(<0.0001)	(<0.0001)	(<0.0001)		(0.3884)	(0.4232)	(0.3431)
	91		58.20*	60.52*	55.89*		57.52*	59.85*	55.18*		11.93*	14.30	9.55*
	(January)		(0.0015)	(0.0009)	(0.0027)		(<0.0001)	(<0.0001)	(<0.0001)		(0.0070)	(0.4515)	(0.0054)
	126		61.07*	63.42*	58.72*		58.88*	61.67*	56.11*		–35.37*	–32.44	–38.32
	(February)		(0.0088)	(0.0057)	(0.0134)		(<0.0001)	(<0.0001)	(<0.0001)		(<0.0001)	(0.1797)	(0.1272)
	155		72.92*	75.30*	70.55*		66.07*	68.60*	63.54*		35.24*	38.62*	31.86
	(March)		(0.0014)	(0.0007)	(0.0028)		(<0.0001)	(<0.0001)	(<0.0001)		(0.0058)	(0.0962)	(0.1981)
Dry lot	0	$527.48				$596.97				$719.45			
	35		–14.63*	–10.92	–18.33*		–11.72*	–7.82	–15.62*		–27.88	–31.87*	–23.89*
	(November)		(0.0870)	(0.1988)	(0.0330)		(0.0401)	(0.1680)	(0.0067)		(0.0038)	(0.0010)	(0.0126)
	63		–12.43*	–5.67	–19.17		–24.90*	–18.25*	–31.55*		–92.25*	–99.69*	–84.82*
	(December)		(0.3943)	(0.6945)	(0.1936)		(0.0112)	(0.0595)	(0.0015)		(<0.0001)	(<0.0001)	(<0.0001)
	91		–7.49	–0.06	–14.92		–12.08	–4.27	–19.90*		–62.50*	–72.25*	–52.74*
	(January)		(0.6534)	(0.9969)	(0.3786)		(0.2776)	(0.6970)	(0.0798)		(0.0010)	(0.0002)	(0.0046)
	126		19.28	27.40	11.16		10.57	19.91	1.22		–51.13*	–64.15*	–38.13
	(February)		(0.3648)	(0.1905)	(0.6066)		(0.4557)	(0.1534)	(0.9327)		(0.0326)	(0.0088)	(0.1038)
	155		2.10	10.55	–6.34		–6.27	3.74	–16.29		–113.41*	–128.05*	–98.77*
	(March)		(0.9190)	(0.5983)	(0.7666)		(0.6489)	(0.7795)	(0.2541)		(<0.0001)	(<0.0001)	(<0.0001)

[a] Numbers in parentheses are p values and * denotes statistical significance at $p < 0.10$.

Table 7. Ex Ante Analysis of Difference in Net Returns ($/head) Across Body Condition Score (BCS) Categories by Management System and Feeding Interval with ±10% Change in Feed Cost Using Estimated Cow Price (2003–2010)

			Pasture System Net Return ($/head)			Dry Lot System Net Return ($/head)		
Days Beyond Culling	BCS Comparison			10% Feed Cost Decrease	10% Feed Cost Increase		10% Feed Cost Decrease	10% Feed Cost Increase
35 (November)	Thin	Medium	0.07 (0.9942)[ab]	0.10 (0.9923)	0.05 (0.9961)	–2.90 (0.7761)	–3.10 (0.7604)	–2.70 (0.7918)
	Thin	Heavy	29.30* (0.0309)	29.42* (0.0096)	29.18* (0.0105)	13.25 (0.2996)	12.97 (0.3089)	13.55 (0.2907)
	Medium	Heavy	29.22* (0.0100)	29.32* (0.0298)	29.13* (0.0321)	16.16 (0.1457)	16.07 (0.1467)	16.25 (0.1447)
63 (December)	Thin	Medium	–6.85 (0.7088)	–6.93 (0.7032)	–6.77 (0.7144)	12.47 (0.4766)	12.58 (0.4690)	12.37 (0.4844)
	Thin	Heavy	21.55 (0.3511)	20.96 (0.3602)	45.65 (0.3428)	79.82* (0.0003)	79.13* (0.0003)	80.52* (0.0004)
	Medium	Heavy	28.40 (0.1410)	27.89 (0.1447)	28.92 (0.1377)	67.34* (0.0005)	66.55* (0.0005)	68.14* (0.0005)
91 (January)	Thin	Medium	0.69 (0.9736)	0.67 (0.9741)	0.72 (0.9732)	4.60 (0.8184)	4.20 (0.8315)	4.99 (0.8059)
	Thin	Heavy	46.27* (0.0812)	46.22* (0.0776)	46.33* (0.0853)	55.00* (0.0290)	52.67* (0.0340)	57.33* (0.0250)
	Medium	Heavy	45.57* (0.0396)	45.54* (0.0372)	45.62* (0.0853)	50.40* (0.0213)	48.47* (0.0247)	52.34* (0.0185)
126 (February)	Thin	Medium	2.18 (0.9350)	1.75 (0.8468)	2.62 (0.9237)	8.70 (0.7332)	7.46 (0.7660)	9.95 (0.7027)
	Thin	Heavy	96.44* (0.0047)	95.85* (0.0945)	97.03* (0.0853)	70.42* (0.0284)	65.54* (0.0377)	75.30* (0.0216)
	Medium	Heavy	94.25* (0.0010)	94.09* (0.0008)	94.42* (0.0012)	61.71* (0.0269)	58.06* (0.0377)	65.36* (0.0216)
155 (March)	Thin	Medium	6.84 (0.7924)	6.69 (0.7906)	7.00 (0.7946)	8.37 (0.7360)	6.82 (0.7770)	9.95 (0.6989)
	Thin	Heavy	37.68 (0.2509)	36.68 (0.2484)	38.68 (0.2585)	115.51 (0.7360)	109.33* (0.0004)	121.70* (0.0002)
	Medium	Heavy	30.83 (0.2594)	29.98 (0.2572)	31.67 (0.2626)	107.14* (0.0001)	102.52* (0.0001)	111.76* (<0.0001)

[a] Numbers in parentheses are p values and * denotes statistical significance at $p < 0.10$.
[b] A positive number indicates that the first BCS category generates higher net returns than the second BCS category.

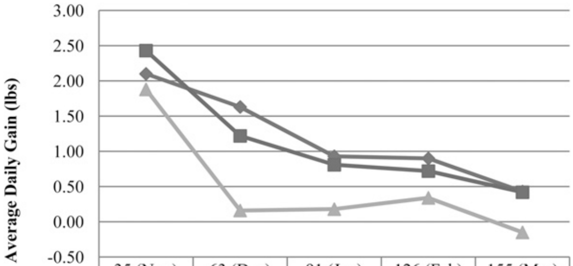


	35 (Nov)	63 (Dec)	91 (Jan)	126 (Feb)	155 (Mar)
Thin (BCS<5)	2.70	1.96	1.12	0.62	0.51
Medium (5≤BCS≤6)	2.75	1.55	1.02	0.62	0.36
Heavy (BCS>6)	1.40	0.76	0.07	-0.90	0.06

Figure 7. Cumulative Average Daily Gain from Culling to Marketing Period, Pasture System

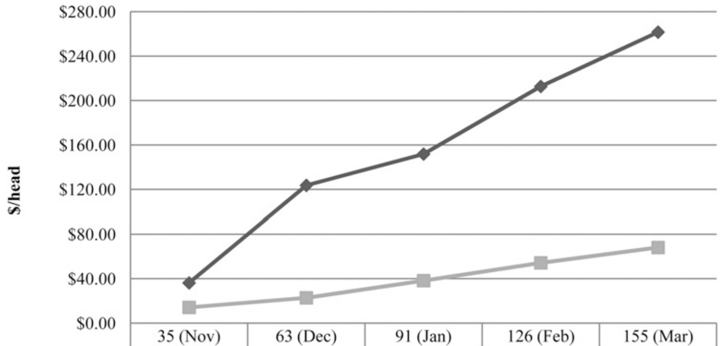
feeding cull cows beyond the culling date. As such, the initial BCS should also play an important role in the decision of whether to sell cull cows at the time of culling or to retain and feed them for a period of time. In this study, cows classified as heavy at culling (initial BCS > 6.0) generally yielded negative net returns regardless of the retention system or pricing method. Cows with lower initial BCS scores generally yielded positive net returns in a native grass pasture retention system, although net returns were typically negative in the dry lot system. Recall that ADG decreased over time for each BCS category in each management system, but thin and medium cows tended to have a higher ADG than heavy cows in each system. From a practical management perspective, together these results suggest that heavy cows should be sold immediately after culling. When cull cows fall into the lower BCS categories at culling, producers should consider their available and potentially underused resources, cash flow needs, input prices, and expectations of price movements on a yearly basis when determining whether to retain cows with lower BCS for delayed marketing. The opportunity cost of delayed income is partially captured by the operating interest, but in reality, producers may have pressing cash flow needs that strongly influence the retention decision. Additionally, although pasture rental rate reflects the value of pasture land in an alternative use, that rate is based on the region's general demand for grazing. In the decision-making process regarding cull cow retention, the producer should consider his or her own alternative use of those resources.

In this study, results favor a native grass pasture system over low-cost dry lot retention. Net returns relative to revenue at culling are



	35 (Nov)	63 (Dec)	91 (Jan)	126 (Feb)	155 (Mar)
Thin (BCS<5)	2.10	1.63	0.93	0.90	0.43
Medium (5≤BCS≤6)	2.43	1.22	0.81	0.72	0.42
Heavy (BCS>6)	1.88	0.16	0.18	0.34	-0.15

Figure 8. Cumulative Average Daily Gain from Culling to Marketing Period, Dry Lot System



	35 (Nov)	63 (Dec)	91 (Jan)	126 (Feb)	155 (Mar)
Pasture Feed Cost	14.16	22.77	38.23	54.26	68.1
Dry Lot Feed Cost	36.22	123.64	151.81	212.71	261.61

Days Beyond Culling

Figure 9. Cumulative Average Feed Cost per Head by Management System

higher for pasture system cows than for dry lot system cows at each marketing interval for each BCS category. That is, the potential for positive net returns is higher in the native grass pasture-based system than in the dry lot-based system. Recall that the dry lot system in this study was designed for minimal input use as opposed to a dry lot system where cows are fed a high-energy ration. This would suggest that an accurate assessment of relative feed costs of retention systems, along with predicting the likely magnitude of seasonal price movements in cull cow markets, is particularly important in the decision to hold cows beyond culling in any given year.

The initial BCS appears to be an important factor in determining which cull cows to retain and feed for delayed marketing. In the context of producer decisions regarding feeding cull cows, the results suggest that producers should carefully consider the BCS of cows when making the decision to retain and feed versus marketing cows at culling. Although our study suggests that the native grass pasture system was generally more profitable for retention than a dry lot system, cows with an initial BCS <6.0 generated higher net returns relative to marketing at culling than cows with an initial BCS of ≥6.0 regardless of the feeding system. The study also suggests that ex ante analysis of cull cow marketing has potential as a decision-making tool for cow-calf producers when coupled with input price information and education regarding the influence of outside factors on cull cow price movements.

[Received September 2010; Accepted October 2013.]

References

Amadou, Z. “Management Production Systems and Timing Strategies for Cull Cows.” Unpublished Master’s thesis. Oklahoma State University. May 2009.

Apple, J.K. “Influence of Body Condition Score on the Live and Carcass Values of Cull Beef Cows.” *Journal of Animal Science* 77(1999): 2610–20.

Blevins, P. *Marketing Cull Cows in Virginia*, Virginia Cooperative Extension Service, E-400-761, Communications and Marketing, College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 2009.

Carter, J.N., and D.D. Johnson. *Improving the Value of Cull Cows by Feeding Prior to Slaughter*. Animal Sciences Department, Institute of Food and Agricultural Sciences, AN-169. Florida Cooperative Extension Service, University of Florida, Gainsville, Florida. 2007.

Doye, D., and R. Sahs. *Oklahoma Pasture Rental Rates*. Oklahoma Cooperative Extension Service CR-216, Stillwater, OK. 2011. Internet site: http://osufacts.okstate.edu (Accessed September 15, 2012).

Encinias, A.M., and G. Lardy. *Body Condition Scoring I: Managing Your Cow Herd through Body Condition Scoring*. North Dakota State University, Department of Animal and Range

Sciences, AS-1026, NDSU Extension Service, Fargo, North Dakota. December 2000.

Feuz, D.M., and J.P. Hewlett. "Marketing and Feeding Cull Cows." RightRisk Information Sheet, #IS-12-01. Internet site: www.farmmanagement.org/Wiki/Gallery/cullcow/MarketingAndFeedingCullCows.pdf (Accessed September 15, 2012).

Feuz, D.M., M.C. Stockton, and S. Bhattacharya. "The Relationship of U.S. and Canadian Cull Cow Prices to Lean Beef Prices: A DAG Analysis." Paper presented at the Annual Meeting of the American Agricultural Economics Association, Long Beach, CA, July 23–26, 2006. Internet site: http://econpapers.repec.org/paper/agsaaea06/21358.htm (Accessed July 10, 2012).

Oklahoma Employment Security Commission. "Oklahoma Wage Report." Various Years. Internet site: www.ok.gov/oesc_web/index.html (Accessed October 1, 2012). National Research Council. Nutrient Requirements of Beef Cattle. 7th rev. ed. Update. Washington, DC: National Academic Press, 2000.

Oklahoma Market Report, Oklahoma Department of Agriculture, Food and Forestry. 2007–2010. Internet site: www.oda.state.ok.us/mktdev/marketreport.htm (Accessed September 15, 2012).

Peel, D.S., and D. Doye. "Cull Cows Grazing and Marketing Opportunities." Oklahoma Cooperative Extension Service Fact Sheet AGEC-613. Stillwater, Oklahoma. 2008. Internet site: http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-5148/AGEC-613web.pdf (Accessed July 10, 2012).

Roeber, D.L., P.D. Mies, C.D. Smith, K.E. Belk, T.G. Field, J.D. Tatum, J.A. Scanga, and G.C. Smith. "National Market Cow and Bull Beef Quality Audit—1999: A Survey of Producer-related Defects in Market Cows and Bulls." *Journal of Animal Science* 79(2001): 658–65.

Schnell, T.D., K.E. Belk, J.D. Tatum, R.K. Miller, and G.C. Smith. "Performance, Carcass, and Palatability Traits of Cull Cows Fed High-energy Concentrate Diets." *Journal of Animal Science* 75(1997):1195–202.

Steward, L., and T. Dyer. *Body Condition Scoring Beef Cows*. GS11/13. The University of Georgia Cooperative Extension, 2000. Internet site: www.caes.uga.edu/commodities/fieldcrops/forages/events/GS11/13/BCS_Update.pdf (Accessed July 10, 2012).

Strohbehn, D.R., and J. Sellers. "Economics of Adding Values to Cull Cows." Iowa Beef Center. December 2002. Internet site: www.iowabeefcenter.org/pdfs/IQCCP/cc_econ_presnt.pdf (Accessed December 20, 2009).

U.S. Department of Agriculture, Agricultural Marketing Service. "KO_LS155, Oklahoma City, Oklahoma Weekly Cattle Narrative." January 2003–December 2010a. Internet site: www.ams.usda.gov (Accessed January 10, 2011).

———. "KO_LS795, Oklahoma City Wtd Average Cattle Summary." January 2003–December 2010b. Internet site: www.ams.usda.gov (Accessed January 10, 2011).

Wagner, J.J., K.S. Lusby, J.W. Oltjen, J. Radestraw, R.P. Wettemann, and L.E. Walters. "Carcass Composition in Mature Hereford Cows: Estimation and Effect on Daily Metabolizable Energy Requirement during Winter." *Journal of Animal Science* 66(1988):603–12.

Wright, C.L. "Managing and Marketing Cull Cows." Proceedings of the Range Cow Beef Symposium XIX, pp. 153–60. Rapid City, SD, 2005.