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CASE STUDY: To Replace or Not to Replace: Determining Optimal Replacement Rates in Beef Cattle Operations

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Abstract

*Data from a Nebraska cattle ranch were used to compare three female replacement strategies to determine optimal replacement and marketing strategies of females for maximizing the long-term profit potential of that operation. The income statement model (**ISM**) maximized 10-yr net income by altering the number of females marketed from different age categories depending on price changes influenced by the cattle cycle. The net present value (**NPV**) model maximized 5-yr herd NPV by adjusting the number of marketed females. The NPV vs the net market value (**NMV**) model maximized the 5-yr difference between herd NPV and herd NMV. The ISM strategy consistently returned the highest average net income per animal annually for the operation and also had the most distinct sales and herd composition pattern of the three strategies. The ISM strategy suggested that the operation market mostly weaned heifers in lower-priced years and mostly bred yearlings in higher-priced years, resulting in an older herd in lower-priced years and a younger herd in higher-priced years. This marketing strategy was influenced by the cattle cycle and by changes in the relative prices of the different female categories. Additionally, altering the cost structure and decreasing calf crop percentages impacted the replacement strategy. The ISM favored a practice by which more cows were sold as bred cows in the fall than as pairs in the spring. The replacement strategy for different ranches will vary with various circumstances; therefore, this decision should be repeatedly addressed to ensure the future success of an operation.*

(Key Words: Female Replacement Rate, Profitability, Beef Cattle.)

Introduction

Many beef cattle producers have the opportunity to market replacement females from their cow herd, turning their replacement decisions into marketing decisions. However, determining the optimal mix of females for retention or marketing, the age of the females to be sold, and the timing of sales or retention are complex decisions. A variety of other factors also complicate the replacement decision, including cow and calf performance, cattle prices, and feed prices and conditions (Rogers, 1972). A method for determining the optimal replacement strategy could assist producers in making decisions that increase an operation's income and would also provide a better understanding of the factors that impact the replacement strategy.

Changing prices is one area that significantly impacts profitability. In a commodity system such as the beef industry, the unit price of the output is equivalent to marginal revenue. Cattle prices have followed a cyclical pattern since the 1880s (Breimyer, 1955), leading some to question whether beef operations should alter production levels in a cyclical manner so that marginal cost remains equal to marginal revenue (Plain and Williams, 1981).

Several studies have been conducted to determine optimal replacement strategies. Trapp (1986) determined that both cow herd size and the herd's age distribution should change with price. In a similar study, King (1979) concluded that cow herd

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size should remain constant, while age distribution should change with price changes. However, Bentley et al. (1976) found no benefit to a cyclical pattern in female replacement, culling, or herd size because of the difficulty in timing changes in replacement; the decreased profitability of retaining a large group of younger, lower-producing females; and the lack of flexibility in utilizing excess resources when an operation is not functioning at its maximum.

The previously mentioned studies assumed that females were marketed at cull cow prices, even though replacement females may be sold at a higher, bred cow price. Therefore, the objective of this case study was to determine an optimal replacement rate and female marketing strategy for a specific beef cattle operation in Nebraska with replacement females sold as bred cows.

Materials and Methods

Data. Cost and production data were obtained from a large cow-calf ranch that markets female replacements and is located in the sandhills of Nebraska. Age groups in this ranch are managed separately, and detailed records are kept on each group. On the ranch, yearling heifers, 2-yr-old cows, and 3-yr-old cows are all managed separately. Cows from 4 to 9 yr old are managed as a group, and cows >9 yr are managed together. Price data were obtained from Cattle-Fax (Denver, CO). Figure 1 is an illustration of the feeder steer price from 1980 to 2001, the time period used in model development and simulation.

The Model. Three strategies were compared to determine optimal replacement strategy for the Nebraska ranch. Each of the strategies was based on the same principle assumptions. First, for simplicity, timing of sales was fixed so that all spring sales occurred in May and fall sales took place in November. We recognize that marketing strategies to minimize the impact of seasonal price swings would likely be used by an astute manager as a practice of profit maximization. Second, replacement females sold in the spring were sold as pairs, and replacements marketed in the fall were sold as bred females. Cows >9 yr were not marketed as replacements. Finally, each year of the female's life was regarded as a separate enterprise so that costs and revenues could be allocated to each enterprise.

Price indexes were calculated to predict the pattern of price fluctuation based on the current phase of the cattle cycle. Separate indexes were calculated for calf and yearling prices, bred cow prices, and cull cow prices because these price indexes followed different patterns. Different price categories were used for different cow age groups to account for the decreasing value of the cow as she aged. It was assumed that 4- to 9-yr-old cows were sold at a utility price and that cows >9 yr were sold at a cutter-canner price. The value of a cull cow was assumed to decrease linearly from a yearling heifer to the 4- to 9-yr-olds; therefore, the cull cow price for 2-yr-olds was one-third of the distance between the yearling heifer cull price and the utility price used for 4- to 9-yr-olds. The price for 3-yr olds was assumed to be two-thirds of the distance between the yearling price and utility price.

A maximum resource utilization level was used to limit the herd size to within the maximum capacity of the forage resource. Next, a forage demand equivalent (**FDE**), similar to an animal unit, was created to allocate the forage resource according to the utilization of the cows in each age group. To calculate an FDE, the annual forage intake was estimated for each age group using equations from the Grazing Lands Application Manual (NRCS, 1994). The FDE accounts for changes in the intake of an animal throughout the year because of stage of production; an animal unit does not. This difference allows the FDE to more precisely estimate the amount of required forage resource to support an animal.

Solver, a linear programming option in Microsoft Excel (Microsoft Corporation, Redmond, WA), was used to determine the optimal number of female sales from each enterprise. There were three analytical approaches used to investigate the optimal replacement rate and female marketing strategy in this case study.

The Income Statement Model. The goal of the first strategy, the income statement model (ISM), was to maximize the long-term net income of the operation. Net income was calculated by first subtracting each enterprise's total expenses from the total revenue. Then, the net income for all of the enterprises was summed, and the fixed cost of the ranch was subtracted, to find the annual net income for the entire cattle operation. The annual net income was summed for a 10-yr

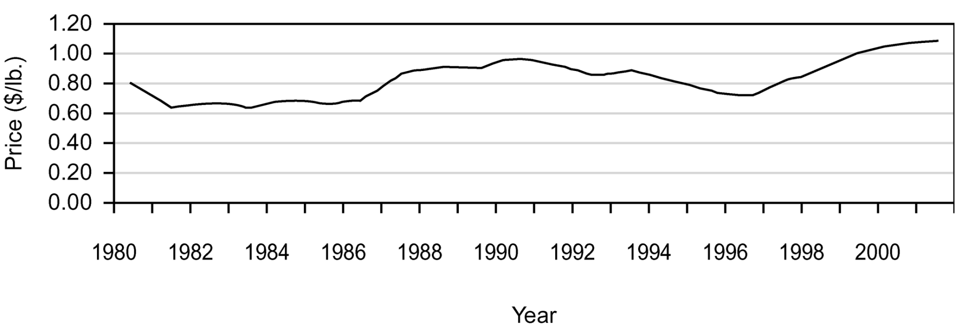

Figure 1. Illustration of the 223-kg feeder steer price from 1980 to 2001 based on information provided by Cattle-Fax (Denver, CO).

period, and the model maximized this 10-yr net income by adjusting the number of sales in each year for each enterprise.

Constraints included the following: 1) the maximum FDE, 2) the requirement that all inventories must remain positive, and 3) the condition that the Yr 10 ending inventory must be greater than or equal to the beginning inventory. This last constraint was used to ensure the long-run sustainability of the operation. Without this constraint, the model would sell large portions of the cow herd in an effort to maximize the total net income.

The Net Present Value Model. Fanning et al. (2002) determined that a replacement strategy that maximized net present value (NPV) increased real net income over constant inventory, counter-cyclical inventory, and dollar-cost averaging strategies. Therefore, the objective of the NPV model was to maximize the herd's NPV. The NPV calculation used in this case study was based on the procedure developed by Meek et al. (1999). The present value of the annual net cash flows was estimated for each enterprise and summed for each year to determine the annual herd NPV. This value was then summed over 5 yr, and the model maximized the 5-yr herd NPV by changing the number of females sold in each year for each enterprise. Constraints included the maximum FDE and positive inventory constraints listed with ISM.

The NPV vs Market Value Model. Hughes (2003) has previously recommended retaining a heifer when her NPV is greater than her market value because the future cash flows of the heifer will return more than if she was sold at the current market price. Hughes (2003) further suggests that management practices that increase the difference between the NPV and market value of a female would increase profitability. Consequently, the goal of the NPV *vs* the net market value (NMV) model was to maximize the difference between the herd NPV and the herd NMV. This difference was calculated by first subtracting the annual herd market value from the annual herd NPV, which was computed in the same manner as in NPV model. In calculating the herd market value, all females <9 yr old and not culled were valued on a bred cow basis. Cows >9 yr and weaned calves were valued at slaughter prices. The annual difference was then summed over a 5-yr period, and the 5-yr difference was maximized by adjusting female sales. Constraints in NMV model were the same as those in NPV model.

Analysis. The different strategies were analyzed using adaptive planning (Bentley and Shumway, 1981) in which the models were simulated over a 22-yr period and were rerun each year with updated information. Five different scenarios were used to determine how the strategies were influenced by different factors. The first scenario involved comparing the strategies using historical prices [historical price scenario (**HPS**)] from 1980 to 2001 (Cattle-Fax). The second scenario used fixed price ratios [fixed price ratio scenario (**FPRS**)] to remove variation in relative prices between price categories, which would allow determination of the impact of the cattle cycle on the different replacement strategies. The fixed prices were calculated by computing the average ratio of each price category to the feeder steer price between 1980 and 2001 then multiplying the feeder steer price by the average ratio from each price category to create a new price series. In this way, the ratio of each price category to the other price categories was fixed in each year. To determine the influence of relative prices on replacement strategies, in the third scenario, the bred cow prices scenario (**BCPS**), bred cow prices were increased by increasing the prices of the replacement categories from the FPRS by 10%. All other prices were the same as in FPRS. In the fourth scenario, the heifer development costs scenario (**HDCS**), heifer development costs were increased by 25% to examine the effect of an operation's cost structure. Using the HDCS, all other costs and inputs remained unaltered, and historical prices from 1980 to 2001 were used. In the fifth scenario, the calf crop percentage scenario, to determine the influence of variations in reproductive rates on the replacement strategy, the calf crop percentage for each age group was reduced by 10%. All other inputs remained unchanged, and historical prices from 1980 to 2001 were used in the CCPS.

Sales and herd composition for the different strategies and scenarios were visually compared using stacked bar graphs, which reflected the percentage that each age group constituted for the total sales or herd inventory. Spring *vs* fall sales were also compared using stacked bar graphs. Profitability was evaluated based on the average net income per animal annually for each strategy in each scenario. The standard deviation, minimum, and maximum values were used to illustrate the variability of the operations income.

Results and Discussion

The majority of sales for ISM using the HPS were composed of weaned heifer calves in lower-priced years and bred yearling heifers in higher-priced years. This result is illustrated in Figure 2. The 4- to 9-yr olds and cows >9 yr made up most of the remaining sales under these circumstances. This sales strategy was reflected in the herd composition, as illustrated in Figure 3. During lower-priced years, when the majority of sales were weaned heifer calves, there were fewer yearlings and more 4- to 9-yr olds and cows >9 yr present in the herd. In higher-priced years, the herd was composed of more yearlings and less 4- to 9-yr olds and cows >9 yr. Overall, an older cow herd characterized lower-priced years, and a younger herd characterized higher-price years. This state follows the conclusions of King (1979) and Trapp (1986), who concluded that herd composition should vary with price. Herd size in this model remained

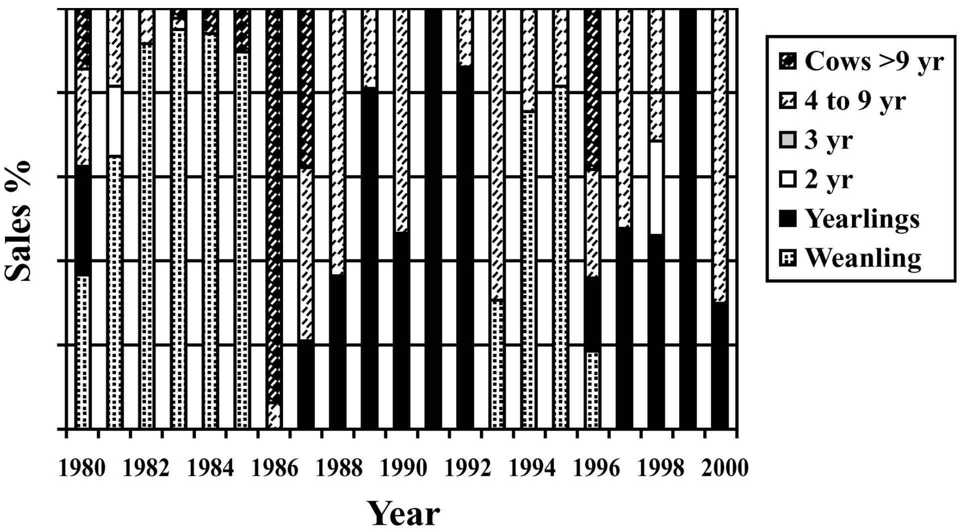

Figure 2. Composition of female sales using the income statement model with historical prices.

relatively constant at the maximum level, which also follows the conclusions of King (1979), but is contrary to the findings of Trapp (1986). Maintaining herd size at the maximum available level ensures that all resources are fully utilized and spreads the fixed cost of an operation over more inventory.

Figure 4 depicts the variation in sales composition using the NPV model under the HPS. A large portion of the sales was 4- to 9-yr olds, with the rest consisting of bred yearlings, 2-yr olds, and 3-yr olds. Very few weaned heifer calves were sold, and no cows >9 yr were marketed after the adjustment period at the beginning of the simulation. Perhaps the greatest difference between the herd composition of the NPV model and the ISM is the number of bred yearlings, which remained relatively constant at approximately 30% of the herd in the NPV model, as seen in Figure 5. The overall herd composition using the NPV model was variable, although there seemed to be an inclination toward fewer 4- to 9-yr olds and more 2-yr olds and 3-yr olds in low price years compared with higher-priced years. No cows >9 yr were present after the initial adjustment period.

Figures 6 and 7 portray that sales and herd composition using the NMV model were more variable than those when using the other strategies. As a result, it is difficult to draw conclusions regarding patterns in the replacement strategy. The majority of sales were 4- to 9-yr olds; weaned heifers, bred yearlings, 2-yr olds, and 3-yr olds made up the remainder of sales. No cows >9 yr were present in the herd or were sold after the adjustment period.

Profitability. The ISM strategy consistently returned a higher average net income per animal annually than the NPV or NMV models, as shown in Table 1. This is especially true of the HPS in which the net income of ISM was notably greater. Profitability of all strategies was impacted most in the CCPS, indicating the importance of management practices that optimize calf crop rates. The standard deviations, minimums, and maximums remain relatively constant among the different strategies, which suggests that the variability of the strategies is comparable.

Scenario Results. The ISM was used in the comparison of the different scenarios. Because of its consistently higher net income, this model appeared to be the best alternative for increasing the profitability of the Nebraska operation. The distinctive pattern in sales and herd composition also indicated that ISM would be a strategy that is easier to be implemented and followed.

Compared with the HPS, the FPRS increased the sale of weaned heifers, 4- to 9-yr olds, and cows >9 yr using ISM, but this same scenario decreased the sale of bred yearlings, 2-yr olds, and 3-yr olds. The pattern of sales composition is similar to the HPS, with more weaned heifer calves marketed in lower-priced years. During high-priced years, more bred females were sold; the majority of these were 4- to 9-yr olds and cows

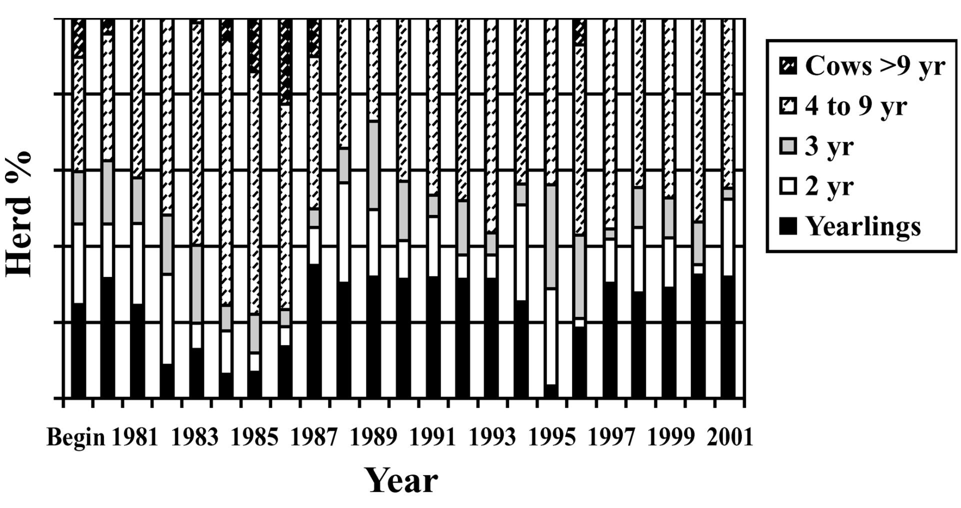

Figure 3. Composition of the cow herd across cow age groups using the income statement model with historical prices.

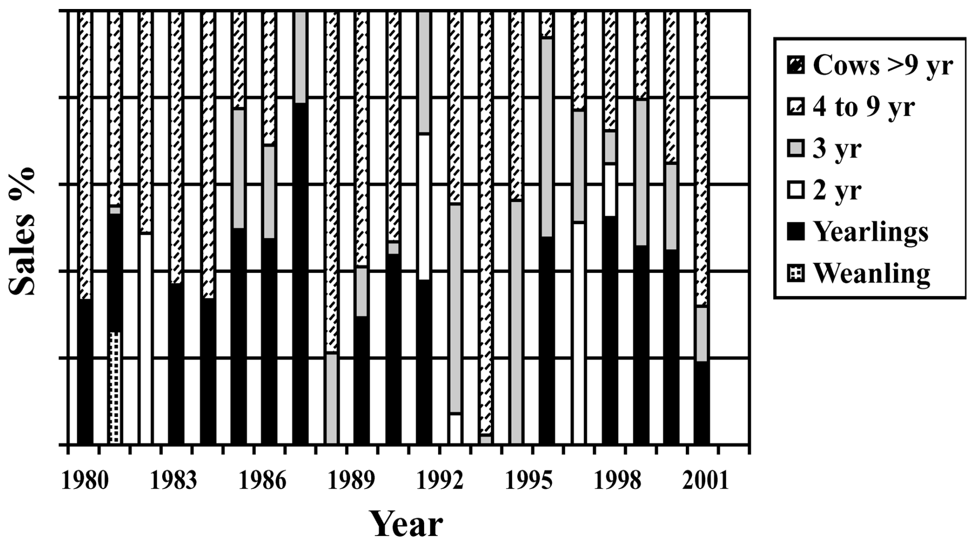

Figure 4. Composition of female sales using the net present value model with historical prices.

>9 yr. In general, the herd was composed of fewer yearlings and more 2-yr olds, 3-yr olds, and 4- to 9-yr olds than under the HPS. The herd composition pattern was similar to the HPS, with an older herd in lower-priced years and a younger herd in higher-priced years. These patterns are likely a result of cattle cycle price fluctuation because the variation in relative price has been removed in this scenario. Therefore, cattle cycle does influence replacement strategy.

Increasing the bred cow prices increased the sale of bred yearlings and decreased the sale of weaned heifer calves when compared with these values under the HPS. Herd composition was more constant using this scenario with more yearlings in nearly all years, indicating that relative price may have a greater impact on replacement strategy than cattle cycle. Increasing the bred cow price removed cyclical variation in sales and herd composition because the relative price of the bred cow categories was consistently greater than the other categories. Relative prices also impact replacement strategy.

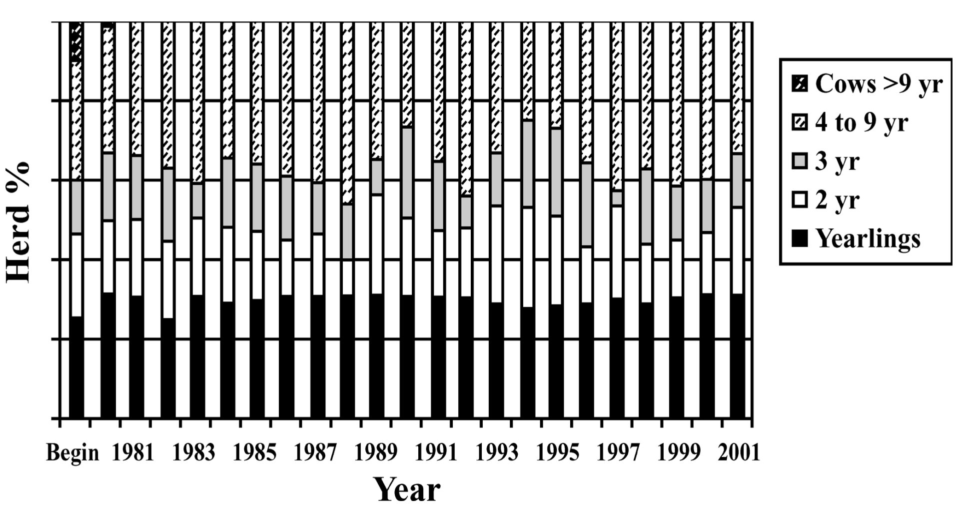

Figure 5. Composition of the cow herd across cow age groups using the net present value model with historical prices.

Compared with the HPS, more weaned heifers and fewer bred yearlings were sold when heifer development costs were increased. The 4- to 9-yr olds and cows >9 yr constituted the majority of the remaining sales. The number of bred yearlings present in the herd also decreased in this scenario, but the number of 2-yr olds, 3-yr olds, and 4- to 9-yr olds increased relative to the HPS. The number of yearlings might have decreased by marketing the heifer as a weanling to avoid the increased cost of the female's second year. Also, other age groups were relatively less expensive to maintain when compared with yearlings; so, the herd composition shifted away from the yearlings to minimize the effects of the increased cost.

The sales composition was less predictable under the decreased CCPS, although the general sales pattern found in the HPS was also found in this scenario. Fewer yearlings were sold overall and more 4- to 9-yr olds were sold than when using the HPS. The overall herd composition pattern was also found under this scenario, although there was less variability in the number of yearlings and 4- to 9-yr olds than with HPS.

Even though the general pattern in sales and herd composition is similar in all scenarios for the Nebraska ranch, the impact of changes in cost structure and calf crop percentages on the replacement strategy suggests that strategies may be different for other operations because of differences in production and performance.

In all of the scenarios, very few cows >9 yr were present in the herd, usually only during lower-priced years when the overall herd age was increased. This result conflicts with the practices of most producers in the beef industry, who retain cows as long as possible to spread the cost of developing the replacement over as many progeny as possible (Taylor et al., 1985). However, other studies have suggested that the optimal culling age is between 7 and 10 yr (Bentley et al., 1976; Bourdon and

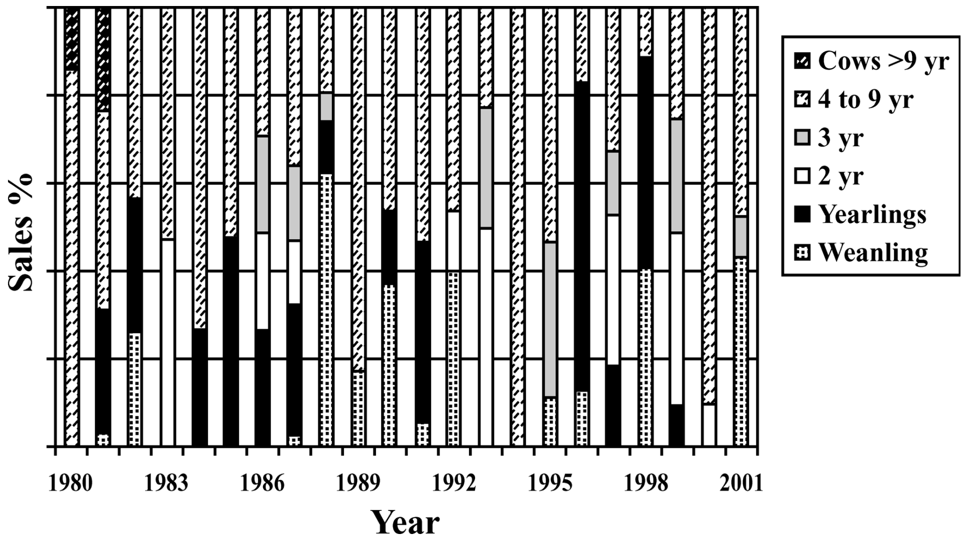

Figure 6. Composition of female sales using the net present value vs the net market value model with historical prices.

Brinks, 1987; Rogers, 1972). The operation may be missing an opportunity to increase profitability by marketing their cows before their value significantly decreases at older ages. Available markets and ranch reputation for bred females among potential customers would impact this approach.

Spring *vs* Fall Sales. Once again, ISM was used to compare spring and fall sales of the different scenarios. Figure 8 illustrates the percentage of total sales that were in the spring or in the fall under the HPS. Spring sales were rare and inconsistent. The number of spring sales was greater under the HPS, BPCS, and the HDCS compared with the number under the FPRS and the CCPS. The reduced number of spring sales under the FPRS is likely due to the lack of variability in relative price. Perhaps with non-fixed ratios, the seasonal variation in relative price caused spring sales to occur in some years. By fixing the price ratio, the sales shifted to the fall. Under the CCPS, the reduction in spring sales could be an attempt to maintain the sale of weaned calves in the fall. The pairs were not sold in the spring, so the calves remained in the fall; therefore, the number of calves for sale in the fall would be similar to when calf crop percentages were normal.

Many times the price for pairs is not appreciably different from the price of a bred female. The calf sold with the cow is not given its full value, which may be the reason that spring sales are so rare in this case. By maintaining the cow through the summer, an operation profits from the sale of the cow and the calf, which separately receive their full value.

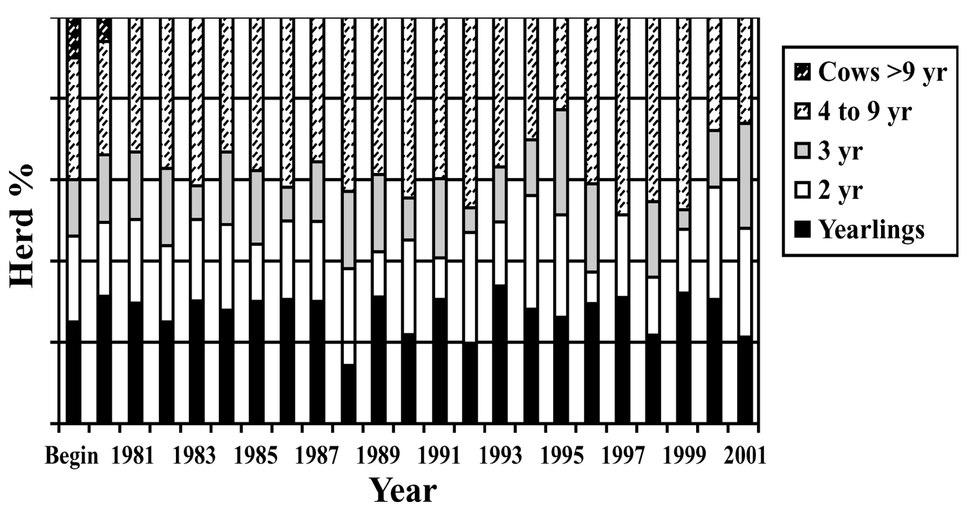

Figure 7. Composition of the cow herd across cow age groups using the net present value vs the net market value model with historical prices.

Implications

The optimal replacement strategy for this Nebraska ranch involved marketing weaned heifer calves in lower-priced years and marketing bred yearlings in higher-priced years, which resulted in an older herd during lower-priced years and a younger herd during higher-priced years. This strategy is impacted by changes in relative price between price categories and by variations in the cattle cycle. Changing the cost structure or calf crop percentages also alters the replacement strategy, suggesting that the optimal strategy may differ from operation to operation depending on the cattle enterprise configuration. The majority of female sales occurred in the fall. Because the replacement strategy varies with different circumstances, this decision should be repeatedly addressed to ensure the future success of an operation.

Acknowledgments

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TABLE 1. Average net income per animal per year, SD, and maximum and minimum values for the income statement model (ISM), the net present value (NPV) model, and the NPV *vs* the net market value model (NVM) model.

Model	Average profit per head	SD	Minimum	Maximum
Historical prices scenario				
ISM	$33	58	–$68	$118
NPV	$21	55	–$47	$98
NPV vs MNV	$20	57	–$53	$106
Fixed price ratio scenario				
ISM	$32	49	–$40	$95
NPV	$22	50	–$42	$104
NPV vs NMV	$19	52	–$66	$103
Increased bred cow price scenario				
ISM	$39	54	–$23	$113
NPV	$21	55	–$47	98
NPV vs NMV	$24	54	–$50	$108
Increased heifer development cost scenario				
ISM	$29	56	–$68	$103
NPV	$5	54	–$65	$83
NPV vs NMV	$7	57	–$75	$92
Decreased calf crop percentage scenario				
ISM	$7	54	–$65	$74
NPV	–$9	53	–$81	$62
NPV vs NMV	–$10	61	–$101	$118

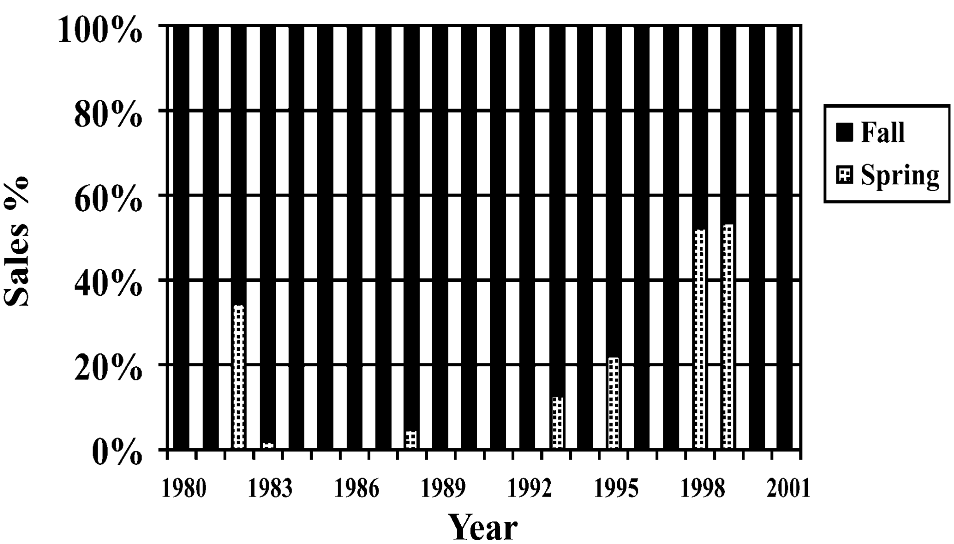

Figure 8. Composition of female sales using the income statement model and spring vs fall sales with historical prices.

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