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A simulation model to estimate the relative economic value of three different open female management strategies among cow-calf herds in the United States

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Abstract

The sale of non-pregnant (open) females constitutes significant annual income for cow-calf producers, thereby requiring critical evaluation of multiple open-female management opportunities. A stochastic model was constructed to estimate the relative economic value of three common open female management practices within spring-calving beef herds consisting of 50, 300, and 600 head of cattle: A) cull open females and replace with purchased pregnant females, B) maintain open females in the herd, and C) transfer open females into a fall herd. The temporal confines of each model reflect the time frame from the original open diagnosis until the time point of marketing first-generation calves produced by females from each respective management option. Based upon the model assumptions, Option C, on average, was a profitable endeavor regardless of herd size. Conversely, Options A and B were only sparingly profitable regardless of herd size. The market cost of purchasing pregnant replacement females, the cost of maintaining open females in the herd, and the cost of maintaining recently bred females through the winter months heavily influenced the estimates of Options A, B, and C, respectively. Based upon the confines of this model, these data suggest that regardless of evaluated herd size, the economic value of these open-female management options differ highly and are influenced by multiple factors. Therefore, the influential parameters of the outcome estimates, along with the management limitations of individual herds, should be considered when attempting to implement open-female management strategies among cow-calf herds.

Key words: beef cows, open cows, non-pregnant cows

Résumé

La vente de femelles non gestantes est une source appréciable de revenus annuels pour les producteurs de troupeaux de bovins allaitants (vache-veau). C'est pourquoi il est important d'évaluer les diverses possibilités de gestion des femelles non gestantes. Nous avons élaboré un modèle stochastique pour comparer la valeur économique de trois pratiques de gestion courantes des femelles non saillies, dans des troupeaux de bovins de boucherie à vêlage printanier comptant 50, 300 et 600 têtes. Ces modèles étaient les suivants : A) la réforme des femelles non gestantes et le remplacement par l'achat de femelles gestantes, B) le maintien des femelles non gestantes dans le troupeau et C) le transfert des femelles non gestantes dans un troupeau d'automne. Les limites temporelles de chaque modèle vont du diagnostic de la non-gestation des femelles à la vente des veaux de première génération. Selon les postulats du modèle, l'option C, en moyenne, s'est avérée rentable peu importe la taille du troupeau. À l'inverse, les options A et B n'étaient que modérément rentables, peu importe la taille du troupeau. Certains paramètres ont fortement influencé l'estimation des options A, B et C, à savoir, respectivement : le coût d'achat des femelles gestantes de renouvellement, le coût du maintien des femelles non gestantes dans le troupeau et le coût du maintien des femelles récemment saillies tout au long de l'hiver. Dans les limites de ce modèle, ces données suggèrent que, peu importe la taille du troupeau évalué, la valeur économique de ces diverses options de gestion des femelles non gestantes varie significativement et dépend de plusieurs facteurs. Par conséquent, avant de choisir un type de gestion des femelles non gestantes, les propriétaires de troupeaux de bovins allaitants doivent considérer les paramètres qui influencent ces estimations ainsi que les limites de gestion de leur troupeau.

Introduction

Determining how to maximize profitability of non-pregnant (open) females among cow-calf herds is an ongoing question faced by both producers and practicing veterinarians. Despite constant efforts aimed at maximizing the number of pregnant cows, well-managed beef herds consistently have an average proportion of open cows or heifers ranging from 5 to 10%.[13-23] The inability of a cow or heifer to become pregnant and maintain the pregnancy may be due to multiple factors including genetic influence, nutritional status, bull fertility and management, and disease.[11] Since the cow-calf sector of the beef industry is sustained by producing live calves, the obvious issue posed by open females is the inability to produce a calf and the subsequent loss of revenue that will be incurred by the producer from the upcoming calf crop. In addition to not providing a calf, retained open females impose additional expense to the producer. Conversely, replacing open females with either home-raised or purchased females demands a large financial investment. Therefore, economically viable and practical open-female management is crucial in order to avoid this sub-population of the herd from becoming a significant economic drain to the producer.

Management of open females begins with identification of this cohort by the herd veterinarian. Once identified and managed accordingly, income generated from culled females constitutes 10 to 20% of the annual revenue of typical production systems. Therefore, producers intimately engaged in cow-calf production are behooved to maximize the value of open females. Traditional advice has been that open females within spring-calving herds should be either culled at the time of the fall pregnancy examination in order to reduce winter feed costs, or retained for a short time to add body condition and subsequent value.[1,8,12] However, culled females obviously must be replaced in order to sustain (or expand) herd size. Despite historical recommendations, recent data suggests that simply culling open females and replacing them with either home-raised or purchased heifers may not maximize long-term economic value for the producer.[2,3,6] Therefore, it is logical to explore additional avenues of open-female management.

The spring-calving herd owner has several management options for open females. In this study, three alternatives will be evaluated: 1) cull open females and replace with purchased pregnant females; 2) maintain open females in the herd and attempt to rebreed them the following spring with the remainder of the herd; and 3) transfer open females into a fall herd. The objective of this study was to generate a stochastic model to estimate the relative economic value of each of these three open-female management options among 50, 300, and 600 head spring-calving cow-calf herds from the time point of initial pregnancy diagnosis (i.e. determination of the initial number of open females) to the point at which first-generation calves produced from females in each management option are sold.

Materials and Methods

Three different herd sizes were evaluated in this study (50, 300, and 600 head) in order to extrapolate findings to the herd size distribution within the United States.[26] Additionally, three different open-female management strategies (Table 1) were evaluated for each of the modeled herd sizes and were determined based upon the author's own clinical experience and reported survey outcomes.[26] One model was constructed for each of these open-female management options (Table 2). Each model commenced upon calculation of the pregnancy percentage generated in October of year one, subsequently defining the number of open females entering the model (Figure 1). The economic value of each management option was the outcome variable in each model. This estimate was generated at the time point of marketing first-generation calves produced by females within each respective open-female management option. The figure was calculated by subtracting estimated costs from estimated income generated within each model (Table 2).

Model assumptions

For the respective herd in all three models, it was assumed that cows/heifers (referred to collectively as "females" from here onward) gave birth in the spring; additionally, it was assumed that pregnancy diagnosis occurred in October when the herd was 120 days in gestation (on average). Subsequent parturition was assumed to occur in March of the following year (i.e. a 280-day gestation period). Conversely, open females transferred from the original spring-calving herd into a fall-calving herd (management Option C) were assumed to have been rebred in November (i.e. immediately following the October pregnancy evaluation), pregnancy status determined in March of the following year (120 days of gestation), and parturition subsequently occurring in August.

Daily maintenance costs specific to the cow herd, but not general farm costs, were based upon estimates that included total feed costs, operating costs, depreciation, capital charges, hired labor, and family/operator labor charges.[13-23] These costs (head/day) were calculated in each model from the day at which the original open diagnosis was made (i.e. October of year 1) to the day at which the female was either culled (due to the inability

Table 1. Management options for open females in a spring-calving beef herd evaluated in the current stochastic model. Each option was evaluated within three distinct herd sizes (50, 300, and 600 head).

Option A	Cull open females and purchase pregnant replacement females
Option B	Retain original open females in the existing spring herd
Option C	Transfer open females into a fall-calving herd

Table 2. Tabulated description of model flow for each replacement female management strategy. Note that the respective relative time frames reflect that displayed in Figure 1 for each respective management option.

Option A: Cull open females and purchase pregnant replacement females			
Node 1: Determination of the number of open females			
Cell label	**Variable**	**Parameter**	**Calculation**
1A	Herd size at the time of pregnancy diagnosis[a]	Static	NA
1B	Pregnancy %	Stochastic[b]	NA
1C	Number of pregnant females	Calculated	1A*1B
1D	Number of open females	Calculated	1A-1C
Node 2: Estimation of the monetary value received from culling non-pregnant females			
1D	Number of open cows/heifers	Calculated	1D
2A	Market price received per pound for culled females	Stochastic	NA
2B	Weight of open females (lb)	Static	NA
2C	Price received per head	Calculated	2A*2B
2D	Market value of the group of culled open females	Calculated	1D*2C
Node 3: Estimating the cost of replacement females from purchase to calving			
3A	Number of bred replacement females needed (plus additional 10%)	Calculated	1D*(1D*0.1[c])
3B	Market price of pregnant replacement females (per head)	Stochastic	NA
3C	Cost of purchasing bred replacement females	Calculated	3A*3B
3D	Cost of housing bred replacement females from purchase to calving	Stochastic	NA
3E	Days from purchase until calving	Static	NA
3F	Cost of replacement females from purchase until calving	Calculated	3C+(3A*(3D*3E))
Node 4: Estimating the cost and production of retained females (from calving to weaning)			
4A	Number of purchased bred replacement females	Calculated	3A
4B	Calving success among bred replacement females	Stochastic	NA
4C	Number of live calves by the replacement females	Calculated	4A*4B
4D	Cost of housing replacement females (per head per day) from calving to weaning	Calculated	3D
4E	Days from calving until weaning	Static	NA
4F	Weaning % among calves born to replacement females	Stochastic	NA
4G	Number of calves weaned by the replacement females	Calculated	4C*4F
4H	Weaning weight of calves weaned by replacement females (lb)	Stochastic	NA
4I	Market price received for weaned calves by replacement females (per lb)	Calculated	Price slide
4J	Market price received for open replacement females (per lb)	Calculated	2A
4K	Value of weaned calves	Calculated	4G*(4H*4I)
4L	Value of open replacement(s) (females that failed to wean a calf)	Calculated	(4A-4G)*(4J*1000[d])
4M	Cost of housing replacement females from parturition until weaning	Calculated	((4A-4G)*(4D*90[e]))+(4G*(4D*4E))
Final output	**Value of purchasing bred replacement females up to the point of selling the first generation of calves**	Calculated	(2H+4K+4L)-(3F+4M)

[a]Herd sizes evaluated include 50 head, 300 head, and 600 head herds.
[b]Stochastic parameters refer to distributions outlined in Table 3 for each respective variable.
[c]This calculation includes an additional 10% of replacement females.
[d]This calculation assumes that the open replacements averaged 1000 lb at the time of commerce.
[e]This calculation assumes that the females that had a calf, but failed to wean that calf, were culled 90 days after parturition.

Table 2. Tabulated description of model flow for each replacement female management strategy (continued).

Cell label	Variable	Parameter	Calculation
Option B: Retain original open females in the existing spring herd			
Node 1: Estimation of the cost of retained open females from the original open diagnosis until subsequent parturition			
1A	Number of open females	Calculated	1D in Option A
1B	Daily cost of housing replacement females until next pregnancy exam (per head per day)	Stochastic	NA
1C	Days until next pregnancy exam	Static (365 days)	NA
1D	Cost of housing open retained heifers until next pregnancy exam one year later	Calculated	1A*(1B*1C)
1E	Pregnancy %	Stochastic	NA
1F	Number of pregnant females (who were originally open)	Calculated	round down(1A*1E)
1G	Number of open females (i.e. open a second time)	Calculated	1A-1F
1H	Market price received for open replacement females (per lb)	Stochastic	NA
1I	Value of open females	Calculated	1G*(1H*1000)
1J	Daily cost of housing retained open females from preg check to parturition	Calculated	1B
1K	Days until parturition	Static (160 days)	NA
1L	Cost of housing retained females from preg check until subsequent parturition	Calculated	(1F*(1J*1K))-1I
1M	Total cost of retaining open females from previous year until subsequent parturition	Calculated	1D+1L
Node 2: Estimating the production of retained open females			
2A	Number of pregnant females (originally open but retained in the spring herd)	Calculated	1F
2B	Calving success among pregnant females	Stochastic	NA
2C	Number of live calves by the replacement females	Calculated	round down(2A*2B)
2D	Weaning %	Stochastic	NA
2E	Number of calves weaned by the replacement females	Calculated	round down(2C*2D)
2F	Weaning weight of calves weaned by replacement females (lb)	Stochastic	NA
2G	Market price received for weaned calves by retained females (per lb)	Calculated	Price slide
2H	Market price received for open replacement females (per lb)	Stochastic	NA
2I	Value of weaned calves	Calculated	2E*(2F*2G)
2J	Value of open female(s)	Calculated	(2A-2E)*(2H*1000)
2K	Daily cost of housing retained open females from parturition to weaning	Calculated	1B
2L	Days from calving until weaning	Static (205 days)	NA
2M	Total cost of housing retained open females from parturition to weaning	Calculated	((2C-2E)*(2K*90))+(2E*(2K*2L))
Final output	**Value of retaining original open females until the subsequent year up to the point of selling the first generation of calves from that cohort**	Calculated	(2I+2J)-(2M+2M)

to get rebred, have a live calf, or wean a calf; Figure 1) or when a calf was successfully weaned and sold (Figure 1).

Baseline distributions for pregnancy percentage,[13-23] market price of culled females,[24] market price of replacement females,[7] daily maintenance costs (described above), calving percentage,[16-21,25] weaning percentage,[16-21] and weaning weight[26] are displayed in Table 3. Market prices for spring and fall calves were based upon a 10-year average (2000-2010) for 550 lb (250 kg) October steers ($110/cwt) and February-March steers ($116/cwt), respectively.[7] For both weaned-calf markets, a $0.05/lb price slide was used to adjust sale price based

Table 2. Tabulated description of model flow for each replacement female management strategy (continued).

Cell label	Variable	Parameter	Calculation
Option C: Transfer open females into a fall-calving herd			
Node 1: Estimating the cost of retaining open females through the winter until the pregnancy exam in March			
1A	Number of open females	Calculated	1D in Option A
1B	Daily cost of housing replacement females until next pregnancy exam (per head per day)	Stochastic	NA
1C	Days until next pregnancy exam	Static (150 days)	NA
1D	Cost of housing open retained females until the March pregnancy exam	Calculated	1A*(1B*1C)
Node 2: Determining the cost of keeping open females from March pregnancy exam until parturition			
2A	Pregnancy %	Stochastic	NA
2B	Number of pregnant retained females that were rolled into the fall herd (who were originally open)	Calculated	round down(1A*2A)
2C	Number of open females (i.e. open a second time)	Calculated	1A-2B
2D	Market price received for open replacement females (per lb)	Stochastic	NA
2E	Value of open females	Calculated	2C*(2D*1000)
2F	Daily cost of housing retained open females from preg check to parturition	Calculated	1B
2G	Days until parturition	Static (130 days)	280-1C
2H	Cost of housing retained females from pregnancy exam until subsequent parturition	Calculated	(2B*(2F*2G))-2E
2I	Total cost of retaining open females from previous year until subsequent parturition	Calculated	1D+2H
Node 3: Estimating the production and the cost of retained open females from parturition until weaning			
3A	Number of pregnant females now in the fall herd (who were originally open)	Calculated	2B
3B	Calving success among pregnant females	Stochastic	NA
3C	Number of live calves by the replacement females	Calculated	round down(3A*3B)
3D	Weaning %	Stochastic	NA
3E	Number of calves weaned by the replacement females	Calculated	round down(3C*3D)
3F	Weaning weight of calves weaned by replacement females (lb)	Stochastic	NA
3G	Market price received for weaned calves by retained females (per lb)	Calculated	Price slide
3H	Market price received for open replacement females (per lb)	Calculated	2D
3I	Value of weaned calves	Calculated	3E*(3F*3G)
3J	Value of open female(s)	Calculated	(3A-3E)*(3H*1000)
3K	Daily cost of housing retained open females from parturition to weaning	Calculated	1B
3L	Days from calving until weaning	Static (205 days)	NA
3M	Total cost of housing retained open females from parturition to weaning	Calculated	((3C-3E)*(3K*90))+(3E*(3K*3L))
Final output	**Value of rolling open females into a fall herd up to the point of selling the first-generation calves from that cohort**	Calculated	(3I+3J)-(2I+3N)

upon the calf's weight. Market prices for cull cows were based upon a 10-year average for 1000 lb (455 kg) utility grade cows ($41/cwt) regardless of the time of year.[7] Time frames of culling females were dependent upon the management option and are displayed in Figure 1. Additionally, all females that produced a live calf but failed to wean it were assumed to have been culled 90 days post-calving in order to account for added expense

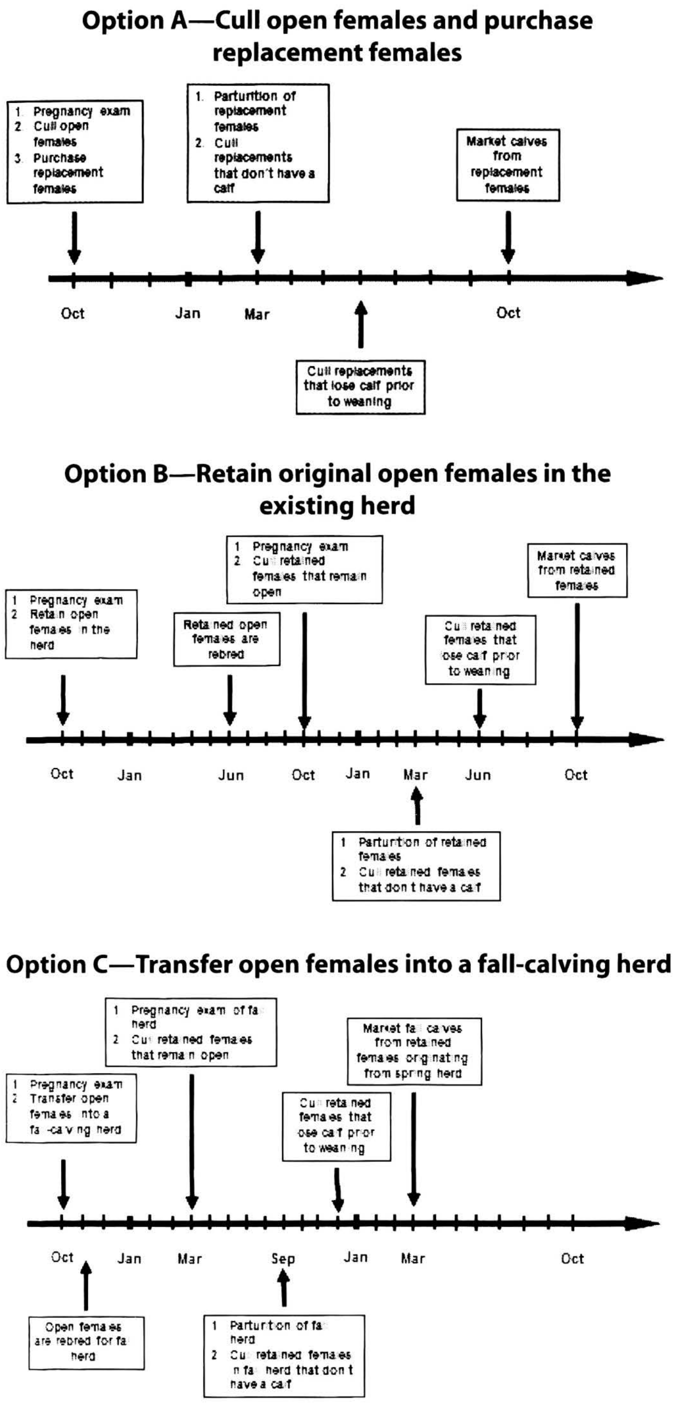

Figure 1. The timeline of each respective open-female management option is displayed above. Each Option begins with the initial pregnancy exam in October and ends when the first calf crop is marketed from the respective cohort of replacement females. Note that this duration of time is dependent upon the open-female management option. Additional timepoints of significance (e.g. calving, culling of open females) are denoted on each respective timeline.

(i.e. daily maintenance costs) that the female generated while on the farm post-calving (Figure 1).

Model structure

Templates for the three models are displayed in Table 2. Management Option A consisted of open cows being identified and immediately culled from the herd. Based upon the number of open females, it was assumed that the same number of pregnant replacement females (plus an additional 10% to accommodate for potential pregnancy loss among the replacement females) were immediately purchased and brought into the herd to calve in the upcoming spring along with the remainder of the original herd.[5] The replacement female subpopulation was followed throughout the remainder of gestation (October to March), through parturition (March), and up to the point of weaning and marketing of the subsequent calf crop (October; Figure 1, Option A).

For all model iterations, the number of open cows entering the model for management Option B was forced to be the same as that of management Option A. However, in Option B, open females were not culled; rather, they were maintained as open females in the herd, allowed to be rebred at the same time as the remainder of the herd (June), and pregnancy tested again the following October (Figure 1, Option B). At this point in the model, if the original open females were found to be open a second time at pregnancy evaluation, they were culled from the herd. The remaining pregnant females, those originally open in year one, stayed with the herd until parturition (i.e. in March of year two). These respective females were then followed from parturition (March of year two) to weaning (October of year two). Therefore, females originally identified as open in the first year of this model did not produce a calf ready to sell until approximately two years after the initial pregnancy diagnosis.

As in Option B, the number of open females entering the model for management Option C equaled that in management Option A. In this model, females found to be open at pregnancy diagnosis were maintained on the farm, but were transferred to a fall-calving herd. In general, it was assumed that open females were immediately removed from the spring herd after pregnancy diagnosis (October), held for 30 days, and then rebred (November). The females were then followed for 120 days until pregnancy evaluation of the fall-calving herd took place (March). Females originally open in October and found to still be open at this time point (i.e. a second time) were then culled from the herd. The remaining pregnant females were then followed from pregnancy diagnosis (March) until parturition (September) and up to the point of weaning and marketing the subsequent calf crop (March; Figure 1, Option C).

Table 3. Distributions of production parameters implemented to estimate the relative value of open female management options among beef cow-calf herds.

Parameter	Distribution	Truncated values	References
Pregnancy % (at the time of initial pregnancy diagnosis)	Pert (75%, 91%, 97%)[a]	(75%, 97%)c	SPA, 1994-1998 ISU summary SPA, 2000-2005 ISU summary
Herd maintenance costs ($/head/day)	Pert ($0.85, $1.10, $1.55)	($0.85, $1.55)	SPA, 1994-1998 ISU summary SPA, 2000-2005 ISU summary
Market price of pregnant replacement females ($/head)	Normal ($1,466, $313)[b]	($725, $2000)	Superior Livestock Auction http://www.superiorcountrypage.com/index.cfm?action=catalog&lottype=breed (Accessed on September 11, 2011)
Calving %	Normal (92%, 3%)	(85.5%, 97.7%)	SPA 2000-2005 summary NAHMS 1997 (western herds) NAHMS 1997 (north-central herds) NAHMS 1997 (south-central herds) NAHMS 1997 (central herds) NAHMS 1997 (southeast herds)
Weaning %	Pert (80%, 87.4%, 92%)	(80%, 92%)	SPA 2000-2005 summary
Weaning weight (lb)	Normal (528, 92.4)	(299, 658)	USDA, 2008, Part I: Reference of beef cow-calf management practices in the United states; 2007-2008.
Market price of open female cattle from 2000 to 2010 ($/cwt)	Normal ($41, $7.60)	($25, $60)	ISU Extension-Ag Decision Maker: Utility Cow Price http://www.extension.iastate.edu/agdm/livestock/pdf/b2-12.pdf

[a]A Pert distribution is comprised of three values: a minimum value, a most-likely value, and a maximum value. It is subsequently displayed in the following manner: Pert (min, most-likely, max).
[b]A normal distribution is composed of the mean and the standard deviation. It is subsequently displayed as Normal (mean, standard deviation).
[c]Truncated values are stipulated by the user (via the software) in order to place a minimum and maximum value on the potential outcomes generated by the respective distribution. A failure to truncate a distribution may lead to nonsensical outcomes.

Application of the model

Each open-female management option was modeled in succession (i.e. A through C) and (as spoken above) was dependent upon the number of open females initially generated by the model in Option A. Therefore, each model iteration estimated the outcome variable (i.e. Final Output; Table 2) based upon the same number of open females, which ensured that the herd inventory stayed consistent across each open-female management option. All remaining parameters (stochastic, static, and calculated) were independent for each of the three models in order to derive independent sensitivity analyses for each management option. The models were evaluated by a commercial simulation program,[a] an add-in for a commercial software package.[b] Each simulation was composed of 10,000 iterations using a fixed number random seed of one and utilizing Monte Carlo sampling methods.

A sensitivity analysis was performed for each herd size-management option permutation. This analysis reflects the magnitude of variation that each stochastic (i.e. probabilistic) parameter dictates on the outcome of each model. In general, parameters with greater coefficient values (positive or negative) exert a larger influence on the outcome of the model compared to parameters with lesser values.

Results

The objective of the present study was to estimate the relative value of three different open-female management strategies for each of three different cow-calf herd sizes. For each of the three management options within the assumptions and temporal confines of this model, Option C, on average, was always a profitable endeavor regardless of herd size (Table 4). Conversely, Options A and B were not profitable, on average, for each of the three herd sizes evaluated in this model. Furthermore, based upon the assumptions of the current model, Option A, on average, was always the most expensive management option, regardless of herd size, observed in this study (Table 4).

Distributions reflecting the overall economic value for each management option among the three herd sizes are further characterized in Table 5. Although the maximum values for both Options A and B are positive, the probability of actually observing this outcome during the specified time frames (and within the additional assumptions of this model) is extremely low given the negative estimates for each of the 95 percentile (95%) values in each management option. These findings suggest that the likelihood of observing a profitable outcome from Options A or B in the first year after implementation is less than 5%. Conversely, the probability of losing money upon implementing Option C during the specified time frame (Figure 1; Option C) is relatively low as the 25[th] percentile value is positive. Further analysis reveals that the 10[th] percentile is also a positive value in all model scenarios (data not shown). Therefore, this suggests that on average implementation of Option C will be a profitable endeavor ~ 90% of the time during the first year after implementation.

Results of the sensitivity analysis are displayed in Table 6. For Option A, the correlation coefficients for the number of open females (0.682) and the market price of pregnant replacement females (-0.652) were the two main parameters shown to profoundly impact the model outcome for each of the three herd sizes in this model. For Option B, pregnancy percentage was also shown to be a large factor in the relative value of this open-female management strategy (0.650). However, and as expected, the cost of maintaining open females on site for an additional year was shown to be negatively correlated (-0.580) with the relative value of Option B. For Option C, the cost of maintaining open females through the winter (i.e. the winter after the initial pregnancy diagnosis in October and rebreeding in November) was negatively correlated with the relative value of this management strategy. However, the market price received for open females (if they did not get rebred) and the weaning weights of calves generated from this cohort (0.520 and 0.410, respectively) were positively correlated with the relative value of Option C.

Discussion

Based upon the temporal confines and the assumptions of this model, the relative value of open-female management among spring-calving cow-calf herds was, on average, maximized when transferring open females from the spring-calving herd to a fall-calving herd (management Option C), regardless of the herd size examined in this study. Conversely, purchasing pregnant replacements (Option A) and retaining open females in the spring-calving herd (Option B) were only sparingly observed to provide a positive relative value within the chronological and managerial stipulations of this model and were, on average, of negative economic value (Tables 4 and 5).

Although Option A has previously been shown to be a secondary source of replacement females when compared to adding home-grown heifers to the herd, it is still regarded as a relatively popular management practice to replace open females within cow-calf production systems.[26] In addition, it is conceivable that purchasing replacement females may garner more demand in the future due to rising land values, high costs of concentrate feeds needed for efficient growth of young heifers, and high weaned-calf values. All of these factors may motivate cow-calf producers to sell heifer calves rather than retain them for future herd replacements. Although Option A does pose a potential biosecurity hazard (not evaluated in this model) by exposing the herd to outside sources of cattle, this risk is accepted and can be managed. Generally, producers can identify cohorts that conform to their current herd's production timeline,

Table 4. Average relative economic value estimates for each open-female management strategy among each of the three herd sizes evaluated in this study. Estimates with parentheses indicate negative monetary values. These values do not convey the entirety of potential outcomes that could be observed for each of the three management strategies; rather, these data indicate the economic outcome that a producer could expect, on average, for each of the herd size-management strategy permutations when evaluated within the confines (e.g. time frames) of the model.

Herd size	Open female management strategy		
	Option A	Option B	Option C
50 hd	$ (5,256.27)	$ (1,169.34)	$ 578.27
300 hd	$ (26,820.26)	$ (7,272.24)	$ 2,553.52
600 hd	$ (52,638.98)	$ (14,580.46)	$ 4,939.01

Table 5. Distributions of relative economic value estimates for each open female management strategy among each of the three herd sizes evaluated in this study. Estimates with parentheses indicate negative monetary values.

Herd size	Descriptive statistics[a]	Open cow management strategy		
		Option A	Option B	Option C
50 hd	Max	$ 717.22	$ 235.13	$ 2,605.48
	95%	$ (1,696.19)	$ (237.45)	$ 1,409.46
	75%	$ (3,467.70)	$ (634.08)	$ 837.17
	Mean	$ (5,256.27)	$ (1,169.34)	$ 578.27
	Median	$ (4,897.87)	$ (1,032.47)	$ 537.39
	25%	$ (6,760.85)	$ (1,571.21)	$ 278.97
	5%	$ (9,899.98)	$ (2,560.58)	$ (103.13)
	Min	$ (18,077.01)	$ (5,148.60)	$ (1,647.39)
300 hd	Max	$ (10,824.09)	$ 754.36	$ 14,363.83
	95%	$ (7,154.27)	$ (1,893.75)	$ 7,470.55
	75%	$ (15,843.52)	$ (4,141.66)	$ 4,113.66
	Mean	$ (26,820.26)	$ (7,272.24)	$ 2,553.52
	Median	$ (24,481.44)	$ (6,442.64)	$ 2,299.36
	25%	$ (35,234.52)	$ (9,618.54)	$ 813.32
	5%	$ (54,896.72)	$(15,414.50)	$ (1,408.32)
	Min	$ (93,731.80)	$(33,094.84)	$(10,332.10)
600 hd	Max	$ 27,542.42	$ 1,454.58	$ 28,759.62
	95%	$ (13,819.05)	$ (3,817.34)	$ 14,751.92
	75%	$ (31,300.25)	$ (8,306.36)	$ 8,053.28
	Mean	$ (52,638.98)	$(14,580.46)	$ 4,939.01
	Median	$ (47,964.77)	$(12,932.52)	$ 4,452.61
	25%	$ (69,657.31)	$(19,262.60)	$ 1,456.98
	5%	$ (107,810.23)	$(30,866.35)	$ (3,032.71)
	Min	$ (198,710.92)	$(66,508.88)	$(20,862.12)

[a]Percentile values indicate the percentage of data at or below that specific point. For example, in 50-head herds utilizing Option A, 95% of the time that producer will lose $1,696.19 or more in this model. Therefore, these producers would only be profitable ~ 5% of the time when evaluated within the confines of this model. Conversely, given that the 25th percentile estimate is positive (and the 5th percentile is negative) in 50-head herds utilizing Option C, this suggests that these producers will be profitable ≥ 75% of the time based upon the confines of this model.

fit their herd's breed status needs and desires, are less labor intensive, and may require a reduction in overall forage demands compared to home-grown replacements. This strategy is also of potential value as it provides an opportunity to improve upon the genetics of the herd in a relatively short time frame. Nonetheless, based upon the assumptions and the temporal confines of this model, this management strategy was shown to be of negative economic value, on average, among all evaluated herd sizes. Based upon the sensitivity analysis, this outcome is highly driven by the number of open females and the expense that is incurred when purchasing replacement females (Table 6). This suggests that as the pregnancy percentage declines and the cost of purchasing replacement females increases, the relative economic value of this management option is reduced, and vice versa.

Nonetheless, these findings for Option A should not be extrapolated beyond the studied time frame (Figure 1; Option A); therefore, one cannot implement this model to predict how long it may possibly take for Option A to achieve profitability. Bohling *et al* recently reported that among four different non-pregnant cow management strategies—retainment of home-grown heifers, purchasing bred heifers, purchasing bred cows,

Table 6. Sensitivity analysis for each open-female management strategy for each herd size evaluated in this model. Positive and negative values indicate direct and indirect relationships, respectively, with the relative economic outcome of each option. Larger coefficients indicate parameters that exert a greater influence on the relative economic value of each management option. Therefore, the rank of each parameter is based upon the magnitude of its respective correlation coefficient.

Herd size	Rank	Open female management strategy					
		Option A		Option B		Option C	
		Parameter	Correlation coefficient	Parameter	Correlation coefficient	Parameter	Correlation coefficient
50 hd	1	Pregnancy % that initially determines the number of open females	0.682	Pregnancy % that initially determines the number of open females	0.650	Cost of maintaining open females until the subsequent pregnancy exam (150 days)	-0.560
	2	Market price of pregnant replacement females	-0.652	Cost of maintaining open females until the subsequent pregnancy exam (365 days)	-0.580	Market price received for open females culled from herd	0.520
	3	Market price received for open females culled from herd	0.154	Weaning weight of calves from this cohort	0.240	Weaning weight of calves from this cohort	0.410
	4	Weaning weight of calves born to replacement females	0.105	Market price received for open females culled from herd	0.200	Pregnancy % that initially determines the number of open females	-0.290
300 hd	1	Pregnancy % that initially determines the number of open females	0.731	Pregnancy % that initially determines the number of open females	0.651	Cost of maintaining open females until the subsequent pregnancy exam (150 days)	-0.594
	2	Market price of pregnant replacement females	-0.610	Cost of maintaining open females until the subsequent pregnancy exam (365 days)	-0.602	Weaning weight of calves from this cohort	0.568
	3	Market price received for open females culled from herd	0.135	Weaning weight of calves from this cohort	0.340	Pregnancy % that initially determines the number of open females	0.327
	4	Weaning weight of calves born to replacement females	0.112	Market price received for open females culled from herd	0.110	Market price received for open females at second pregnancy evaluation	0.294
600 hd	1	Pregnancy % that initially determines the number of open females	0.730	Pregnancy % that initially determines the number of open females	0.651	Cost of maintaining open females until the subsequent pregnancy exam (150 days)	-0.594
	2	Market price of pregnant replacement females	-0.615	Cost of maintaining open females until the subsequent pregnancy exam (365 days)	-0.616	Weaning weight of calves from this cohort	0.581
	3	Market price received for open females culled from herd	0.128	Weaning weight of calves from this cohort	0.368	Pregnancy % that initially determines the number of open females	-0.325
	4	Weaning weight of calves born to replacement females	0.116	Market price received for open females culled from herd	0.110	Market price received for open females at second pregnancy evaluation	0.261

and retaining open cows—purchasing replacement heifers resulted in the lowest economic return when evaluated over a five-year period.[3] However, this same study demonstrated that purchasing replacement cows was typically a viable option when evaluated over the course of five years.[3] As spoken above, the purchase price of replacement females was a major determinant in the outcome of the model. The negative value of the correlation coefficient for this variable suggests that as the market price for pregnant replacements decline, the relative value of management Option A will increase. Therefore, despite the perceived benefits of acquiring pregnant replacement females (described above), the lack of profitability in the short-term modeled in this study suggests that producers should critically evaluate the desired/needed number of replacement females, the magnitude of that initial expense, and the standard overhead of maintaining those females to determine if this practice is a viable long-term investment.

Admittedly, Option B can either be classified as a "strategy" or simply poor management on the part of the producer. Veterinarians in private practice are regularly frustrated in knowing that producers retain open females through the winter months despite having conveyed to the client the costs associated with the practice. Nonetheless, it was surprising to observe that although this management option was not found to provide a profitable outcome (on average), it was typically shown to be of higher value than Option A (within the temporal limitations of the model). Nonetheless, in this model, the sensitivity analysis suggested that the cost of retaining open females in the spring herd was negatively correlated to relative value of this management practice; specifically, as costs to keep females rise the value of that practice is reduced. Although Option B was not shown to be profitable within the time limitations of this model, prior data has shown that retaining open females in the herd may be a profitable endeavor over a five-year time frame, which is approximately three years longer than the present model.[3] Bohling *et al* observed the retainment of open females to be a profitable endeavor when the proportion of open females was 30% or more and when cull female prices were $40/cwt ($40/45.5 kg) or less. However, one of the limitations of that study, and the present model, is the assumption that open females and the remaining herd mates that actually generated a calf possessed the same probability of becoming pregnant the following year. Although most infertility issues can be addressed in order to increase the likelihood of future pregnancy, such as nutritional status/body condition, bull fertility and management, and implementation of vaccine protocols, other parameters may be present among the female population that cannot be effectively improved upon, and thereby permanently reduce the likelihood of pregnancy, including dentition, genetic or physiologic traits, and chronic disease. Therefore, if these factors are present, the model outcomes for Option B may be overly inflated in the present study, possibly indicating that this management strategy may have even less value in the given time frame (Figure 1; Option B) than currently reported. Given these data, veterinarians and producers must continue to be highly critical of open females and thoroughly evaluate that cohort in order to estimate the probability of future pregnancy. Additionally, based upon this study, producers should also be aware that this management option will not likely be profitable in the short term.

On average, Option C provided a positive relative economic value among the herd sizes assessed in this model. This finding contrasts with a previous study that determined that transferring open females to a fall herd was inferior to culling all open females.[1] However, a subsequent study identified that the cost differentials between open females and replacement heifers highly impacts the value of retaining open females in the spring-calving herd.[6] Building upon that finding, the present model suggests that additional value can be added to open females by transferring open spring-calving females to a fall herd. This practice may enable producers to reduce production expenses by maintaining overall herd numbers while avoiding the costs of purchased replacement females (as in Option A); reducing the amount of time needed to produce a calf compared to maintaining open females in the spring herd (as in Option B), thereby maintaining cash-flow; and taking advantage of higher average market calf prices for fall calves compared to spring calves. However, in Option C, as in Option B, the same assumption was made regarding the future fertility of open females. Therefore, it is possible that the estimates generated by this model may be slightly high. Nonetheless, the current outcome distribution (skewed heavily towards the positive; Tables 4 and 5) suggests that this open-female management strategy may be a viable option for cow-calf producers. Most importantly, within the confines of this model, these data also suggest that, on average, Option C provides high relative value during the first year of implementation.

Despite the findings in the model for Option C, veterinarians and producers must discuss the many factors demanded by a fall-calving herd. Specifically, the unique features of spring-calving and fall-calving herds make separation between the two cohorts necessary for most stages of production. Therefore, producers must possess either multi-site facilities and/or reliable fences to ensure that the spring and fall cohorts remain as independent entities. A fall herd demands its own health management program, such as breeding season, timing of pregnancy exams, semen evaluations, and vaccinations, as well as more intense winter feeding programs and possibly even additional bull batteries. This being said, some producers may not possess resources available to implement a fall-calving herd. In addition to these points, generation of a fall herd may simply be impractical if a small number of open females are identified among the spring herd, such as in the 50-head herd. Therefore, an initial discussion with the producer regarding the potential of creating a fall herd or adding open females to a pre-existing fall herd is of value in order to plan accordingly.

Like any form of research, this study has limitations that should be addressed and taken into account when interpreting these findings. Outcome validity in a stochastic model, like feed ration formulation, is dependent on the quality of data used in the model. Therefore, the "garbage in, garbage out" concept does apply; consequently, the empirical data and the subsequent distributions should be evaluated for external validity. The distributions displayed in Table 3 are based upon contemporary data, and were critically evaluated for accuracy and external validity. When necessary, distributions based upon limited data were widened to provide conservative estimates. Additionally, great care was provided to ensure that all possible parameters were accounted for in all models and that mathematical equations were accurate. Despite these efforts, the author acknowledges that one potential limitation of this model is that it was evaluated over a relatively short time frame, from the time point of initial pregnancy examination to the time point of production of one calf after implementation of each specific management option. This specific time frame was selected for analysis in order to provide veterinarians with a greater knowledge of economic expectations, targeted specifically in the short term, for each of the replacement-female management options evaluated in this study. This information is of value as it provides clientele more data to make informed decisions regarding replacement of open females and/or expansion of the current herd. Nevertheless, as discussed above with regard to Options A and B, it is likely that economic outcomes may differ from these current findings if the model is assessed for a greater duration of time, such as five years or more. Therefore, more work is needed to determine the long-term viability of these replacement-female strategies.

In addition to replacement-female Options A, B, and C the author acknowledges that other open-female management strategies exist, such as home-grown replacement heifers and combinations of Options A and B, in addition to those evaluated in the current model. These cannot be compared to Options A, B, and C at this time. One obvious limitation of this study is the inability to decipher between the values of purchasing/retaining heifers and/or mature cows since both classes were combined into a "female" category. It is plausible that Option A may be a more viable opportunity when purchasing pregnant mature cows, compared to pregnant heifers, as cows may demand a reduced market price. As discussed above, Bohling *et al* observed that the purchase of replacement cows was a more economically valid approach compared to purchasing heifers when evaluated over five years.[3] Additionally, pregnant mature cows may be easier to identify and procure, compared to pregnant heifers. However, the purchase of pregnant cows does increase the age of the herd, which should be taken into account prior to purchase.

In addition to alternative open-female management options, it is unlikely that all possible economic and management parameters implemented in these models reflect all cow-calf production systems. Other factors, such as feeding culled females through the winter in order to add value, retaining females that either don't produce a calf (despite being pregnant earlier in gestation) or lose a calf prior to weaning, are routinely implemented and may change the landscape of the model outcomes.[4,9,10] One final parameter worth mentioning is that although differences in weaned calf market prices in the fall versus spring were included in this model, one potential limitation of the study was that daily cow costs were based on average annual values and not season-dependent values. Therefore, compared to true costs, it is likely that these modeled costs may be slightly high in some scenarios and lower in others. Therefore, given the variability between herds, logistical and management concerns, and seasonal differences, veterinarians are encouraged to critically evaluate the assumptions built into the present stochastic models when attempting to extrapolate these data to their clientele's production systems.

Conclusion

Within the assumptions of this model, transferring open females from a spring-calving herd to a fall-calving herd (Option C) was, on average, the most economically viable open-female management strategy for each of the three herd sizes (50, 300, and 600 head) evaluated in this study. The outcomes of each model were driven by multiple production parameters that must be critically evaluated prior to implementing any of the three modeled strategies. Additionally, veterinarians should be aware of the management demands necessary for successful implementation of Option C. Furthermore, alternative open-female strategies not included in this study and long-term economic outcomes for those strategies modeled in this study cannot be evaluated at this time or compared to the current outcomes. Nonetheless, even in well-managed herds, a certain percentage of females within a cow-calf production system will be open on an annual basis. Therefore, it is imperative for veterinarians to provide economically valid and practical options to their clientele.

Endnotes

[a]@Risk® 5.5, Palisade Corp., Ithaca, NY
[b]Microsoft Excel® 2010, Microsoft Corp., Redmond, WA

Acknowledgement

The author declares no conflict of interest.

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Injectable

Baytril® 100

(enrofloxacin)

100 mg/mL Antimicrobial Injectable Solution

For Subcutaneous Use In Beef Cattle, Non-Lactating Dairy Cattle And Swine Only

Not For Use In Female Dairy Cattle 20 Months Of Age Or Older

Or In Calves To Be Processed For Veal

BRIEF SUMMARY:

Before using Baytril® 100, please consult the product insert, a summary of which follows:

CAUTION:

Federal (U.S.A.) law restricts this drug to use by or on the order of a licensed veterinarian.

Federal (U.S.A.) law prohibits the extra-label use of this drug in food-producing animals.

PRODUCT DESCRIPTION:

Each mL of Baytril® 100 contains 100 mg of enrofloxacin. Excipients are L-arginine base 200 mg, n-butyl alcohol 30 mg, benzyl alcohol (as a preservative) 20 mg and water for injection q.s.

INDICATIONS:

Cattle - Single-Dose Therapy: Baytril® 100 is indicated for the treatment of bovine respiratory disease (BRD) associated with *Mannheimia haemolytica, Pasteurella multocida, Histophilus somni* and *Mycoplasma bovis* in beef and non-lactating dairy cattle; and for the control of BRD in beef and non-lactating dairy cattle at high risk of developing BRD associated with *M. haemolytica, P. multocida, H. somni* and *M. bovis*.

Cattle - Multiple-Day Therapy: Baytril® 100 is indicated for the treatment of bovine respiratory disease (BRD) associated with *Mannheimia haemolytica, Pasteurella multocida* and *Histophilus somni* in beef and non-lactating dairy cattle.

Swine: Baytril® 100 is indicated for the treatment and control of swine respiratory disease (SRD) associated with *Actinobacillus pleuropneumoniae, Pasteurella multocida, Haemophilus parasuis* and *Streptococcus suis*.

RESIDUE WARNINGS:

Cattle: Animals intended for human consumption must not be slaughtered within 28 days from the last treatment. This product is not approved for female dairy cattle 20 months of age or older, including dry dairy cows. Use in these cattle may cause drug residues in milk and/or in calves born to these cows. A withdrawal period has not been established for this product in pre-ruminating calves. Do not use in calves to be processed for veal.

Swine: Animals intended for human consumption must not be slaughtered within 5 days of receiving a single-injection dose.

HUMAN WARNINGS:

For use in animals only. Keep out of the reach of children. Avoid contact with eyes. In case of contact, immediately flush eyes with copious amounts of water for 15 minutes. In case of dermal contact, wash skin with soap and water. Consult a physician if irritation persists following ocular or dermal exposures. Individuals with a history of hypersensitivity to quinolones should avoid this product. In humans, there is a risk of user photosensitization within a few hours after excessive exposure to quinolones. If excessive accidental exposure occurs, avoid direct sunlight. For customer service or to obtain product information, including a Material Safety Data Sheet, call 1-800-633-3796. For medical emergencies or to report adverse reactions, call 1-800-422-9874.

PRECAUTIONS:

The effects of enrofloxacin on cattle or swine reproductive performance, pregnancy and lactation have not been adequately determined.

The long-term effects on articular joint cartilage have not been determined in pigs above market weight.

Subcutaneous injection can cause a transient local tissue reaction that may result in trim loss of edible tissue at slaughter.

Baytril® 100 contains different excipients than other Baytril® products. The safety and efficacy of this formulation in species other than cattle and swine have not been determined.

Quinolone-class drugs should be used with caution in animals with known or suspected Central Nervous System (CNS) disorders. In such animals, quinolones have, in rare instances, been associated with CNS stimulation which may lead to convulsive seizures. Quinolone-class drugs have been shown to produce erosions of cartilage of weight-bearing joints and other signs of arthropathy in immature animals of various species. See Animal Safety section for additional information.

ADVERSE REACTIONS:

No adverse reactions were observed during clinical trials.

ANIMAL SAFETY:

In cattle safety studies, clinical signs of depression, incoordination and muscle fasciculation were observed in calves when doses of 15 or 25 mg/kg were administered for 10 to 15 days. Clinical signs of depression, inappetance and incoordination were observed when a dose of 50 mg/kg was administered for 3 days. An injection site study conducted in feeder calves demonstrated that the formulation may induce a transient reaction in the subcutaneous tissue and underlying muscle.

In swine safety studies, incidental lameness of short duration was observed in all groups, including the saline-treated controls. Musculoskeletal stiffness was observed following the 15 and 25 mg/kg treatments with clinical signs appearing during the second week of treatment. Clinical signs of lameness improved after treatment ceased and most animals were clinically normal at necropsy. An injection site study conducted in pigs demonstrated that the formulation may induce a transient reaction in the subcutaneous tissue.

U.S. Patent No. 5,756,506

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Baytril® 100 17120

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