Article

A field study of culling and mortality in beef cows from western Canada

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Abstract — The objectives were to describe the pattern of losses through culling, sales of breeding stock, mortality, and disappearance, and to characterize the causes of mortality of cows and replacement heifers of breeding age from Western Canadian beef herds. Cows and replacement heifers from 203 herds were observed for a 1-year period starting June 1, 2001. Veterinarians examined dead animals on-farm using a standard postmortem protocol. The incidence of culling in cows and replacements heifers was 14.3 per 100 cow-years at risk, and the frequencies of sales for breeding stock, mortality, and cows reported missing per cow-years at risk were 4.0, 1.1, and 0.4, respectively. During the study, 355 animals died or were euthanized, 209 were examined postmortem, and the requested tissues were submitted for histopathologic examination from 184. A cause of death was determined for 70% (128/184) of the cows with complete gross postmortem and histopathologic examinations. Hardware disease (traumatic reticuloperitonitis), malignant neoplasia (cancer), calving-associated injury, rumen tympany (bloat), myopathy, and pneumonia accounted for 56% (72/128) of the animals where a cause of death was determined. Twenty-three other causes of death accounted for the remaining 44% (56/128). Factors relating to cow nutrition accounted for 25% of the deaths, emphasizing the importance of feeding management as a determinant of cow health in western Canada.

Résumé — Étude sur le terrain de la réforme et de la mortalité chez les bovins de l'Ouest canadien. Les objectifs étaient de décrire les tendances des pertes par la réforme, la vente de reproducteurs, la mortalité et la disparition et de caractériser les causes de la mortalité des vaches et des génisses de remplacement en âge de se reproduire dans les troupeaux de bovins de l'Ouest canadien. Les vaches et les génisses de remplacement provenant de 203 troupeaux ont été observées pendant une période de un an à partir du 1er juin 2001. Les vétérinaires ont examiné les animaux morts à la ferme en utilisant un protocole d'autopsie standard. L'incidence de la réforme chez les vaches et les génisses de remplacement était de 14,3 par 100 vaches-années à risque et la fréquence de la vente pour les reproductrices, la mortalité et les vaches signalées absentes par vaches-années à risque étaient de 4,0, de 1,1 et de 0,4, respectivement. Durant l'étude, 355 animaux sont morts ou ont été euthanasiés, 209 ont été examinés par autopsie et des tissus ont été soumis à un examen histopathologique pour 184 animaux. Une cause de mortalité a été déterminée pour 70 % (128/184) des vaches par une autopsie complète rudimentaire et des examens histopathologiques. La réticulo-péritonite traumatique, les tumeurs malignes (cancer), les blessures attribuables à la mise bas, le tympanisme du rumen (ballonnement), les myopathies et les pneumonies représentaient 56 % (72/128) des animaux pour lesquels une cause de mortalité a été déterminée. Vingt-trois autres causes de mortalité expliquaient la proportion restante de 44 % (56/128). Les facteurs se rapportant à l'alimentation des vaches représentaient 25 % des mortalités, signalant ainsi l'importance de la gestion de l'alimentation en tant que déterminant de la santé d'une vache dans l'Ouest canadien.

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Introduction

Veterinarians are frequently asked to determine the cause of death in livestock to address disease outbreaks, questions of liability, and herd owner curiosity. These opinions are frequently requested without the veterinarian having the benefit of a timely postmortem examination. Even when a complete examination is possible, the results can be difficult to interpret in the absence of information on the typical pattern of losses in the industry. While there have been some limited reports on the causes of loss in beef calves (1–5), there is little information from either laboratory or field studies on the frequency of cow losses in beef herds and the reasons for these losses. Such data are needed for herd heath benchmarking and to increase our understanding of the pattern of cow losses in western Canada.

In western Canada, mature animal deaths are rarely investigated in a systematic manner to determine cause. Producers may perceive that the expense associated with the investigation are too high relative to the benefit as the cause of death is often assumed based on history and the external appearance of the animal, losses are often sporadic, and when postmortem examinations are performed the results are frequently inconclusive. Postmortem examinations are typically only requested in the case of the death of valuable animals, abnormally high death loss, for insurance investigations, or where there is the potential for litigation.

A large on-farm survey of factors affecting cow-calf herd productivity in 2001 provided a unique opportunity to examine losses from inventory in beef herds from western Canada. The first objective of this study was to document losses from herd inventory — categorized as culls, sales of breeding stock, mortalities, and disappearances — in a cohort of breeding age females for 1 calendar year, by tracing individual cows and replacement heifers from the start of one breeding season to the beginning of the next. The second objective of this study was to characterize causes of mortality on-farm by having veterinarians examine dead animals using a standard postmortem protocol, which included submitting a specified set of fixed tissues for histopathologic evaluation.

Methods and materials

Recruitment of study participants

Herds were recruited through private veterinary clinics as a part of a comprehensive study of factors affecting beef cattle productivity in western Canada (6). Veterinarians from clinics across Alberta, Saskatchewan, and northeastern British Columbia were asked to participate. Within each practice, herds were enrolled based on selection criteria that considered herd size (minimum of 50 cows), completeness of animal identification, existing calving records, presence of animal handling facilities, and a relationship with a local veterinary clinic. Only herds using a winter or spring calving season were enrolled in the study. One of 6 project veterinarians regularly visited each herd to collect samples and data, and to monitor the quality and consistency of on-farm records.

Collection of field data and laboratory analysis

Information was collected on risk factors potentially associated with loss from inventory. These data included animal age, breed, and source (born on the farm or purchased). All cow ages were reported throughout this summary as they should have been at the end of the study period during calving season in the spring of 2002 to simplify presentation. For example, a replacement heifer from the spring of 2001 that was born in 2000, and should have had her first calf in calving season 2002, was consistently referred to as a 2-year-old in all summaries and tables in this document. A cow born in 1999, that should have had her 2nd calf in 2002, was referred to as a 3-year-old. The other categories used in the analysis included 4-year-old cows (born in 1998), mature cows (born 1992 to 1997), and old cows (born before 1992).

Herd inventory was verified by manually checking each animal's identification against herd lists during processing for vaccination, parasite treatment, and pregnancy testing. Body condition score (BCS) was determined using a 9-point scale (7) before the 2001 breeding season, at pregnancy test in the fall of 2001, prior to calving in 2002, and after calving in 2002.

Data collection and postmortem examinations for the productivity study were carried out between March 1, 2001 and July 1, 2002. Only data for the 1-year period between June 1, 2001 and May 31, 2002 were described in this summary due to inconsistent reporting by herd owners at the very start of and the very end of the period.

The number of cows present in each herd was determined on June 1, 2001 and May 31, 2002. Herd inventory losses during the period were categorized as culling, sales of breeding stock, mortality (death due to natural causes or euthanasia), or disappearance (where the cow was reported missing from inventory). Losses from inventory were summarized by category for each month along with the number of cows purchased each month. Data were verified by checking that the starting inventory less reported losses plus reported purchases equaled the ending inventory in all herds. The crude incidence rate for each category of loss from inventory was calculated as the number of occurrences during the time period of interest divided by the animal-time-units at risk. The animal-time-units at risk was approximated by the number of animals at the start of the period less half the number of total losses from inventory during that period plus half the number of animals purchased during the period (8).

All dead or euthanized animals of breeding age were eligible for a postmortem examination by the licensed veterinarian who normally provided veterinary services to the herd owner. The veterinarians were asked to conduct postmortem examinations according to a standard protocol and submit formalin-fixed tissues to a private veterinary laboratory (Prairie Diagnostic Services, Saskatoon, Saskatchewan), where one pathologist (EGC), certified by the American College of Veterinary Pathologists, examined all tissues. Tissues requested from adult animals included: skin, trachea, tracheobronchial lymph node, lung, heart, esophagus, duodenum, jejunum, ileum, spiral colon, mesenteric lymph node, liver, spleen, kidney, endometrium, diaphragm, large skeletal muscle, brain, spinal cord, and sciatic nerve.

Statistical analysis

Generalized linear mixed models were used to estimate the proportion of total variation explained by herd effects [σ^2_h/σ^2_h +

Table 1. Summary of individual herd losses from inventory[a] for beef cows and replacement heifers in 203 herds in western Canada from June 1, 2001 through May 31, 2002 reported as incidence per 100-cow years at risk

	Incidence of culling	Incidence of sales of breeding stock	Incidence of mortality	Incidence of disappearance	Incidence of loss from inventory for any reason
Mean *(s)*[b]	14.1 (7.9)	4.0 (8.1)	1.2 (1.8)	0.4 (1.2)	19.6 (11.2)
Median	12.7	0.0	0.9	0.0	17.1
5th percentile	4.0	0.0	0.0	0.0	7.3
25th percentile	8.8	0.0	0.0	0.0	12.4
75th percentile	17.2	3.8	1.6	0.0	23.3
95th percentile	30.4	22.1	3.1	2.2	41.7

[a] Incidence rate reported here represents total number of occurrences of each outcome per 100 cows and replacement heifers at risk in each herd for the 1-year study period. Includes all breeding females born in 2000 or earlier.
[b] Calculated as crude incidence based on descriptive summary of raw data where number of animals at risk is the average number of cows and replacement heifers (born in 2000) present in the herd at the beginning and end of the study period. Not adjusted for clustering by herd.

$\pi^2/3$)] for total losses from inventory, culling, and mortality (8). Models used a Poisson distribution and log link function with an offset equal to the log of the animal time units at risk for each herd in each period. The variance accounted for by herd (σ^2_b) was determined from a null model (intercept only) for each outcome using penalized quasi-likelihood estimates (2nd order PQL) (MLwiN version 2.0; Centre for Multilevel Modeling, Institute of Education, London, United Kingdom).

All other statistical analyses used generalized estimating equations (GEE) to adjust for clustering within herds (PROC GENMOD, SAS for Windows ver 9.1; SAS Institute, Cary, North Carolina, USA). Unless otherwise stated, an exchangeable correlation structure was used. The herd adjusted incidence of culling, sales of breeding stock, mortality, and disappearance were estimated with robust confidence intervals for the period June 1, 2001 to May 31, 2002. Models examined the total number of occurrences of each outcome in each herd relative to the natural log of the animal-time-units at risk during this period (offset) using a Poisson distribution and log link function.

To describe time-related differences in losses from inventory during the study, the 1-year period was divided into 4 quarters, hereafter referred to by season and year: Summer 2001 (June to August, 2001), Fall 2001 (September to November, 2001), Winter 2001–2002 (December 2001, January and February 2002), and Spring 2002 (March to May 2002). The difference in the incidence of each category of loss from inventory across seasons was examined with GEE; the model specifications outlined previously and an autoregressive correlation structure were used to account for the repeated measurements on each herd. The total number of occurrences for each category of loss from inventory and the animal-time-units at risk were determined for each season. Differences in the incidence of loss from inventory due to culling and mortality across seasons were reported as relative rate ratios (RR) with 95% confidence intervals (CI).

The association between age and the odds of culling or mortality were also examined. Models included a logit link function and used a binomial distribution. The strength of the association was reported as an odds ratio (OR) with 95% CI. Additionally, potential differences in age at death, breed, body condition score (BCS), and time of year between animals that were and were not examined postmortem, or animals for which tissues were or were not submitted, were examined to evaluate the potential for bias in the cases where a diagnostic evaluation was reported.

The results of the postmortem examinations were summarized over the entire 1-year period and for each season. The immediate cause of death was determined for each animal where histologic evaluation was completed. Where there was evidence of more than one disease contributing to death [Dietary Atypical Interstitial Pneumonia (AIP) progressing to heart failure, for example], the last reported event was interpreted to be the immediate cause of death (in the above example, heart failure/cor pulmonale). A cause of death was reported in each case where clear consistent evidence from the history, gross postmortem findings and histological findings suggested an immediate cause for the animal's death or where an injury or disease was identified that would logically contribute to the decision to euthanize the animal. For those cases where these criteria were not met, cause of death was classified as "Unknown."

Results

Study population and losses from inventory

On June 1, 2001, there were 34 665 adult cows and replacement heifers in the 203 study herds. In the fall of 2001, 33 280 cows had pregnancy test records, 29 775 cows calved in the spring of 2002, and there were 29 450 cows present in these herds (excluding heifers born in 2001) at the end of the study on May 31, 2002. The average herd size at the start of the study was 171 cows and replacement heifers [standard deviation *(s)*, (79)], and average herd size at the end of the study, before the replacement heifers for the 2002 breeding season were added to the herd, was 145 cows [*(s)*, (67)].

During the study, 6338 cows and replacement heifers were removed from inventory due to culling, sales of breeding stock, mortality, and disappearance, and 1123 cows and bred replacement heifers were purchased. The average population-at-risk for the study period was 32 059 cow-years. The crude incidence of culling across all breeding females in the study herds was 14.3 per 100 cow-years at risk (4578/32 059), the incidence of sold as breeding stock was 4.0 (1280/32 059), the incidence of mortality was 1.1 (355/32 059), and the incidence of disappearance was 0.4 (125/32 059).

Table 2. Summary of incidence of losses from herd inventory per 100 cow-years at risk for cows and replacement heifers from 203 beef herds in western Canada for June 1, 2001 through May 31, 2002

	Incidence of loss from herd inventory			
Categories of loss from herd inventory	Summer 2001[a]	Fall 2001[b]	Winter 2001–2002[c]	Spring 2002[d]
Culling	4.9[e]	27.8[e]	14.1[e]	10.3[e]
Sales of breeding stock	1.9	5.2	6.0	2.9
Mortality	0.8	1.0	1.1	1.6
Disappearance	0.1	0.6	0.7	0.1
Total losses	7.8	34.7	21.8	15.0

[a] Summer 2001: June 1, 2001 to August 31, 2001; number of animals at risk = 34 346.
[b] Fall 2001: September 1, 2001 to November 30, 2001; number of animals at risk = 32 858.
[c] Winter 2001–2002: December 1, 2001 to February 29, 2002; number of animals at risk = 31 112.
[d] Spring 2002: March 1, 2002 to May 31, 2002; number of animals at risk = 29 993.
[e] Incidence rate was converted to 100 cow-years at risk (× 100 × 12 months/3 months) for consistency in comparison to other tables.

Table 3. Age distribution of cows and replacement heifers in beef herds from western Canada in the fall of 2001 and spring of 2002 (N = 203 herds)

Age group[a]	Pregnancy testing Fall 2001[b]	Calving season Spring 2002[c]
Replacement heifer — 2-year-old Birth year: 2000	16%	17%
First calf heifer — 3-year-old Birth year: 1999	15%	16%
4-year-old Birth year: 1998	12%	12%
Mature Birth year: 1992 to 1997	45%	44%
≥ 10 years old Birth year: before 1992	9%	8%
Unrecorded	3%	3%

[a] Age is reported as it would have been during calving season in Spring 2002. For example, 2-year old cows include replacement heifers from the spring of 2001 born in calving season 2000.
[b] Number of animals tested = 33 280.
[c] Number of animals present at calving = 29 775.

Table 4. Summary of incidence of losses from herd inventory[a] by age group for cows and replacement heifers in beef herds in western Canada from June 1, 2001 to May 31, 2002 (inclusive) (N = 203 herds)

Age Group[b]	Incidence of culling	Incidence of sales of breeding stock	Incidence of mortality	Incidence of disappearance	Incidence of loss from inventory for any reason
2-year-old	12.6 (663/5252)	6.1 (320/5252)	0.9 (48/5252)[a]	0.1 (6/5252)	19.7 (1037/5252)
3-year-old	11.4 (560/4907)	3.8 (188/4907)	0.8 (42/4907)	0.2 (11/4907)	16.3 (801/4907)
4-year-old	11.6 (451/3899)	3.3 (129/3899)	0.7 (27/3899)	0.4 (14/3899)	15.9 (621/3899)
Mature	13.4 (1895/14 151)	3.7 (527/14 151)	1.1 (157/14 151)	0.5 (64/14 151)	18.7 (2643/14 151)
> 10 years old	28.8 (805/2795)	3.8 (107/2795)	2.0 (56/2795)	0.4 (10/2795)	35.0 (978/2795)
Unrecorded	19.3 (204/1055)	0.9 (9/1055)	2.4 (25/1055)	1.9 (20/1055)	24.5 (258/1055)
Total	14.3 (4578/32 059)	4.0 (1280/32 059)	1.1 (355/32 059)	0.4 (125/32 059)	19.8 (6338/32 059)

[a] Incidence rate for each category of loss from herd inventory reported as number of occurrences per 100 cow-years at risk.
[b] Age is reported as it would have been during calving season in Spring 2002. For example, 2-year-old cows include replacement heifers from the spring of 2001 born in calving season 2000.

All but one herd owner culled cows during the study period. Almost half of the herd owners (47.3%, 96/203) sold cows or replacement heifers for breeding stock. Most herd owners (74.4%, 151/203) had at least one cow die during the study and 16.7% (34/203) had at least one cow that went missing. The proportion of variation accounted for by the herd was 6.9% for disposal for any reason, 6.4% for culling, and 11.6% for mortality.

There was substantial variation in inventory losses among the study herds (Table 1). The predicted incidence rate for loss from inventory for any reason after accounting for clustering by herd was 19.8 per 100 cow-years at risk (95% CI: 18.2 to 21.4). For each category describing removal from the herd, the herd-adjusted predicted incidences mirrored the crude incidence reported above and mean of the incidence for each herd (Table 1). The predicted herd-adjusted culling rate was 14.3 per 100 cow-years at risk (95% CI: 13.2 to 15.4), the herd-adjusted rate for sales of breeding stock was 4.0 (95% CI: 3.0 to 5.3), the herd-adjusted mortality rate was 1.1 (95% CI: 1.0 to 1.3), and the herd-adjusted rate of disappearance was 0.4 (95% CI: 0.2 to 0.6).

Effect of season on loss from inventory

The incidence of disposal for different reasons also varied during the study period (Table 2). The incidence of culling was greatest in Fall 2001, followed by Winter 2001–2002, then Spring 2002, and Summer 2001. The incidence of culling was significantly higher in Fall 2001 ($P < 0.0001$) than in any other period ($RR_{\text{Summer 2001}}$: 5.6, 95% CI: 4.0 to 7.8; $RR_{\text{Winter 2001–2002}}$: 2.0, 95% CI: 1.5 to 2.6; $RR_{\text{Spring 2002}}$: 2.7, 95% CI: 2.2 to 3.3). The incidence of culling was also higher ($P < 0.0001$) in Winter 2001–2002 (RR: 2.8, 95% CI: 1.9 to 4.1) and Spring 2002

Table 5. Summary of all significant ($P < 0.05$) unconditional associations between age and the odds of culling and the odds of mortality for cows and replacement heifers from beef herds in western Canada

Association between age and odds of culling[a]		Association between age and odds of mortality[b]				
		2-year-old[c]	3-year-old[c]	4-year-old[c]	Mature cow[c]	> 10 years[c]
	2-year-old[c]		—	—	—	2.1 (1.4–3.2)
	3-year-old[c]	—[d]		—	—	2.3 (1.5–3.5)
	4-year-old[c]	—	—		1.6 (1.0–2.4)	2.8 (1.7–4.5)
	Mature cow[c]	—	1.2 (1.0–1.3)	1.2 (1.0–1.3)		1.8 (1.3–2.3)
	> 10 years[c]	2.6 (2.0–3.2)	2.8 (2.4–3.4)	2.8 (2.4–3.3)	2.4 (2.1–2.8)	

[a] The numbers above the diagonal represent the odds ratios for death (95% confidence intervals are in parenthesis).
[b] Numbers below the diagonal represent the odds ratios of culling (95% CI).
[c] Age is reported as it would have been during calving season in Spring 2002. For example, 2-year-old cows include replacement heifers from the spring of 2001 born in calving season 2000.
[d] — = indicates that no statistically significant association was detected ($P > 0.05$).

(RR: 2.1, 95% CI: 1.5 to 3.0) than in Summer 2001, and finally, the incidence in Winter 2001–2002 was higher ($P = 0.02$) than in Spring 2002 (RR: 1.4, 95% CI: 1.0 to 1.8). The incidence of mortality was higher in Spring 2002 than in Summer 2001 (RR: 2.0, 95% CI: 1.5 to 2.9, $P < 0.0001$), Fall 2001 (RR: 1.6, 95% CI: 1.2 to 2.1, $P = 0.001$), and Winter 2001–2002 (RR: 1.5, 95% CI: 1.1 to 2.0, $P = 0.01$).

Effect of cow age on loss from inventory

The age distribution of the cows present in the study herds was similar in Fall 2001 at pregnancy testing and Spring 2002 during calving (Table 3). The age at culling [median: 6 y, inter-quartile range (IQR): 3 to 9 y] was similar to the age at death in these herds (median: 6 y, IQR: 3 to 9 y). The risk of loss from inventory was summarized for the average population at risk in each age group (Table 4).

Age was a significant predictor of the odds of culling (Table 5). Cows greater than 10 y, summarized as of calving season 2002, had higher odds of being culled than cows in any other age category ($P < 0.0001$). The difference in the odds of culling was less pronounced between mature cows and 3-year-old ($P = 0.04$) and 4-year-old cows ($P = 0.02$). There was no difference in the odds of culling between 2-year-old and mature cows ($P = 0.65$) or among 2-, 3-, and 4-year-old cows ($P > 0.37$).

The relative change in the odds of mortality among age categories showed a similar pattern to culling (Table 5). For cows present in these herds at the start of the study, the odds of mortality were higher in cows greater than 10 y of age than in 2-year-old ($P = 0.0004$), 3-year-old ($P = 0.0002$), 4-year-old ($P = 0.0001$), and mature cows ($P = 0.0001$). The odds of mortality were also higher in mature cows than in 4-year-old cows ($P = 0.04$). There were no other difference in the odds of mortality among 2-, 3-, and either 4-year-old or mature cows ($P > 0.16$).

Postmortem examination results

A total of 355 breeding female cattle (Tables 4 and 6) were reported to have died or have been euthanized on 151 farms in the 1-year study period. Of these, 209 animals on 118 farms were examined postmortem (Table 6). Cows that died in Spring 2002 were more likely to be examined postmortem than cows that died in Fall 2001 (OR, 2.0; 95% CI, 1.0 to 3.6; $P = 0.03$). There were no other differences in animals that were and were not examined postmortem, based on the period during which they died ($P > 0.13$), age ($P > 0.19$), breed ($P > 0.15$), and if BCS was ever less than 5 out of 9 ($P = 0.83$).

Of the 209 cows with gross postmortem examinations, tissues were submitted for histopathologic examination from 184 cows in 112 herds (Tables 6 and 7). For the remaining 25 animals, either only a gross examination was reported or the submitted tissues were inadequate in either number (carcass had been scavenged) or quality (tissues were too autolyzed) for satisfactory histopathologic examination. Date of death was the only significant predictor of having adequate samples submitted for histology. Cows that died in Spring 2002 were more likely to have adequate samples submitted for complete histopathologic examination than cows that died in Summer 2001 (OR, 2.3; 95% CI, 1.1 to 4.5; $P = 0.02$) and Fall 2001 (OR, 3.2; 95% CI, 1.7 to 5.9; $P = 0.001$). Cows that died in Winter 2001–2002 were also more likely to have tissues submitted for histopathologic examination than cows that died in Fall 2001 (OR, 2.8; 95% CI, 1.2 to 6.4; $P = 0.01$). There were no other differences in animals that did and did not have tissues submitted for histopathologic examination based on the period during which they died ($P > 0.10$), age ($P > 0.16$), breed ($P > 0.08$), and if body condition was ever less than 5 out of 9 ($P = 0.86$).

Ten or more animals died of traumatic reticuloperitonitis (hardware); malignant neoplasia (cancer); skeletal, muscle, or nerve injuries related to calving trauma; rumen tympany (bloat); myopathy; and pneumonia (Table 7). A diagnosis of hardware disease, calving injury, and bloat was based on the gross diagnosis by the local veterinarian and the absence of another apparent cause of death from histopathologic examination of submitted tissues.

Neoplasia accounted for more than 7% of examined cow deaths. There were 13 cases of cancer that occurred in 13 separate herds. The types of cancer diagnosed included:

Table 6. Description of cows and replacement heifers that died or were euthanized and those that were examined postmortem (PM) from June 1, 2001 to May 31, 2002, inclusive

	All cows that died or were euthanized (n = 355, N = 151 herds)	Cows with gross PM examination (n = 209, N = 118 herds)	Cows with histopathologic evaluation (n = 184, N = 112 herds)
Cows with gross PM examination	59% (209/355)	—	—
Cows with histopathologic evaluation	52% (184/355)	88% (184/209)	—
Date of death			
1. Summer 2001[a]	19% (68/355)	18% (38/209)	16% (29/184)
2. Fall 2001[b]	23% (83/355)	19% (40/209)	16% (29/184)
3. Winter 2001–2002[c]	23% (83/355)	25% (53/209)	27% (50/184)
4. Spring 2002[d]	34% (121/355)	37% (78/209)	41% (76/184)
Age group			
1. 2-year-old (born 2000)	14% (48/355)	14% (30/209)	15% (28/184)
2. 3-year-old (born 1999)	12% (42/355)	13% (27/209)	12% (22/184)
3. 4-year-old (born 1998)	8% (27/355)	9% (19/209)	9% (17/184)
4. Mature cow (born 1992–1997)	44% (157/355)	44% (92/209)	45% (82/184)
5. > 10 years old (born 1991 or earlier)	16% (56/355)	14% (30/209)	14% (25/184)
6. No record	7% (25/355)	5% (11/209)	5% (10/184)
Breed			
1. British	46% (162/355)	45% (95/209)	44% (81/184)
2. Continental	45% (160/355)	44% (93/209)	46% (84/184)
3. Cross	8% (29/355)	10% (21/209)	10% (19/184)
4. Other	1% (4/355)		
BCS at pre-Breeding (2001)			
1. Less than 5 out of 9	15% (49/334)	14% (27/199)	14% (25/174)
2. 5 or greater out of 9	85% (285/334)	86% (172/199)	86% (149/174)
3. Not available	6% (21/355)	5% (10/209)	5% (10/184)
BCS at pregnancy testing (2001)			
1. Less than 5 out of 9	19% (44/227)	19% (26/136)	18% (23/131)
2. 5 or greater out of 9	81% (183/227)	81% (110/136)	82% (108/131)
3. Not available	36% (128/355)	35% (73/209)	29% (53/184)
BCS at pre-calving (2002)			
1. Less than 5 out of 9	20% (33/165)	20% (20/100)	21% (20/96)
2. 5 or greater out of 9	80% (132/165)	80% (80/100)	79% (76/96)
3. Not available	54% (190/355)	52% (109/209)	48% (88/184)

[a] Summer 2001: June 1, 2001 to August 31, 2001.
[b] Fall 2001: September 1, 2001 to November 30, 2001.
[c] Winter 2001–2002: December 1, 2001 to February 29, 2002.
[d] Spring 2002: March 1, 2002 to May 31, 2002.

lymphosarcoma (3 cases), ocular squamous cell carcinoma (3 cases), malignant mesothelioma (2 cases), intrapulmonary and pleural scirrhous carcinoma or adenocarcinoma (1 case), metastatic fibrosarcoma (lung, mediastinum and intrathoracic lymph nodes) (1 case), metastatic adenocarcinoma (lung, pericardium, diaphragm, and serosal surfaces of the thorax) (1 case), intestinal adenocarcinoma, and bile duct carcinoma (1 case).

All myopathy-associated losses were reported during Spring 2002. No herd had more than one death due to myopathy.

Pneumonia was diagnosed in 10 cows; 7 of these cases were classified as atypical interstitial pneumonia (AIP) consistent with 3-methyl-indole toxicity. There was 1 case of AIP thought to be due an allergic reaction, and 1 case of acute and 1 case of chronic aspiration pneumonia.

The diagnoses summarized above that were reported in 10 or more animals accounted for 56% (72/128) of the animals for which an immediate cause of death was determined. Twenty-three other causes of death were each identified in 7 or fewer animals and accounted for the other 44% (56/128). There were 56 of the 184 cases where histologic evaluation was completed and a cause of death was not determined.

Heart failure was considered the primary cause of death in 7 cows. Dietary AIP or lung fibrosis was present in 3 cows, 2 had evidence of myopathy (one of these cows also had a prolapsed uterus), and there were 2 cases where the cause of the heart failure was not determined.

The 7 deaths associated with non-calving related injury included skeletal and muscle trauma such as fractures (2 legs, 1 pelvis), hip dislocations (2 cases), 1 torn obturator muscle, and 1 unspecified injury.

Of the 6 cows with pyelonephritis, 4 had treatments recorded for either an unknown condition or metritis prior to death. Of the cows with pyelonephritis, 5 of 6 died between March and May 2002; the other 1 died in June 2001 after being treated for metritis earlier in the year.

The diagnoses of bacterial toxemia were based on histological findings and gross postmortem observations. Two cases involved the uterus as the site of a bacterial infection along with changes in the liver, spleen kidney and lung (pulmonary congestion) consistent with a toxemia. The third case involved coliform mastitis with a "jaundiced" carcass and changes in the liver (acute degeneration and early lipidosis of periportal hepatocytes).

Table 7. Summary of postmortem (PM) findings for natural mortality and euthanasia in beef cows and replacement heifers where tissues were submitted for histopathologic evaluation from June 1, 2001 to May 31, 2002, inclusive (N = 115 herds)

	Summer 2001[a]	Fall 2001[b]	Winter 2001–2002[c]	Spring 2002[d]	June 1, 2001 to May 31, 2002
All animals with gross PM examination	38	40	53	78	209
Animals with histopathologic evaluation	76% (29/38)	73% (29/40)	94% (50/53)	97% (76/78)	88% (184/209)
Summary of diagnoses for immediate cause of death:	% of 29	% of 29	% of 50	% of 76	% of 184
1. Hardware	10 (3)[e]	14 (4)	6 (3)	7 (5)	8 (15)
2. Malignant neoplasisa (cancer)	14 (4)	14 (4)	4 (2)	4 (3)	7 (13)
3. Calving-associated injury	0 (0)	0 (0)	12 (6)	8 (6)	7 (12)
4. Rumen tympany (bloat)	10 (3)	7 (2)	6 (3)	4 (3)	6 (11)
5. Myopathy	0 (0)	0 (0)	0 (0)	14 (11)	6 (11)
6. Pneumonia	10 (3)	7 (2)	4 (2)	4 (3)	5 (10)
7. Heart failure	3 (1)	0 (0)	2 (1)	7 (5)	4 (7)
8. Non-calving related skeletal or muscle injury	3 (1)	10 (3)	2 (1)	3 (2)	4 (7)
9. Pyelonephritis	3 (1)	0 (0)	0 (0)	7 (5)	3 (6)
10. Intestinal accident	0 (0)	0 (0)	2 (1)	4 (3)	2 (4)
11. Paratuberculosis (Johne's disease)	0 (0)	7 (2)	0 (0)	3 (2)	2 (4)
12. Posterior vena cava syndrome	3 (1)	0 (0)	6 (3)	0 (0)	2 (4)
13. Bacterial toxemia	0 (0)	0 (0)	4 (2)	1 (1)	2 (3)
14. Positional bloat (cast)	0 (0)	0 (0)	0 (0)	4 (3)	2 (3)
15. Bovine viral diarrhea virus	0 (0)	0 (0)	4 (2)	0 (0)	1 (2)
16. Clostridial disease	0 (0)	0 (0)	4 (2)	0 (0)	1 (2)
17. Endocarditis	0 (0)	3 (1)	2 (1)	0 (0)	1 (2)
18. Asphyxia	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)
19. Chronic lung disease	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)
20. Drowning	3 (1)	0 (0)	0 (0)	0 (0)	1 (1)
21. Lightning strike	3 (1)	0 (0)	0 (0)	0 (0)	1 (1)
22. Lung abscess	0 (0)	0 (0)	2 (1)	0 (0)	1 (1)
23. Mastitis	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)
24. Metritis	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)
25. Nitrate toxicity	0 (0)	0 (0)	2 (1)	0 (0)	1 (1)
26. Peritonitis	0 (0)	0 (0)	2 (1)	0 (0)	1 (1)
27. Pleuritis	0 (0)	0 (0)	2 (1)	0 (0)	1 (1)
28. Polioencephalomalacia	3 (1)	0 (0)	0 (0)	0 (0)	1 (1)
29. Septic thrombosis	0 (0)	3 (1)	0 (0)	0 (0)	1 (1)
30. Unknown	31 (9)	34 (10)	34 (17)	26 (20)	30 (56)

[a] Summer 2001: June 1, 2001 to August 31, 2001.
[b] Fall 2001: September 1, 2001 to November 30, 2001.
[c] Winter 2001–2002: December 1, 2001 to February 29, 2002.
[d] Spring 2002: March 1, 2002 to May 31, 2002.
[e] Number of animals.

There were 3 cases of "positional bloat" (cast); those diagnoses were based on history ("found dead"), gross postmortem findings (found with "back down hill" or "in a hole"), with or without gross postmortem findings consistent with bloat (anterior congestion, for example) and no significant histological findings. These cases were considered separate from bloat because feeding or feeding management did not cause these losses.

There were 2 animals that were reported to have died from clostridial disease; in both cases the uterus was the site at which clostridia-like organisms were seen and in both cases the cow had recently aborted or calved.

The diagnosis in the single case of nitrate poisoning was based on the history (respiratory distress), gross postmortem findings ("brown" carcass) and the absence of other clinical, postmortem, or histological findings sufficient to suggest another cause of death.

Discussion

This is the first on-farm cohort study of culling and death loss in breeding age beef cattle reported in North America, using a standardized protocol for postmortem examination. The study was unique in that all loss data were collected by tracking individual animals through the study period using herd inventory records. Previous reports have described the reasons for culling cows (9–12) and conditions in culled beef cows at slaughter (13), while this study focused on the reasons for death or euthanasia in North American beef cattle. Describing the cause of, and risk factors for, cow disposal provides insight into diseases in this region.

The estimated annual culling and mortality rates in this group of herds were 14.3 and 1.1 per 100 cow-years at risk, respectively. Culling losses were highest in the fall of 2001, the usual season when pregnancy status is checked in western Canada and nonpregnant or cull cows are removed from herds. The odds of culling were highest in cows greater than 10 y of age, but cows between 5 and 10 y of age were also slightly more likely to be culled than cows 3 or 4 y of age. Culling practices by producers in this region are consistent with previously published recommendations that, accounting for pregnancy status, body condition score, and replacement costs, the optimal age for culling is 7 to 8 y of age (9,12). Cows greater than 10 y of age were also most likely to die during the study, and cows between

5 and 10 y of age were slightly more like to die than cows 4 y of age. Longitudinal studies of individual herds have found similar age distributions for death in brood cows (11,14); however, this is the first report to describe the age distribution at death in a large number of herds.

Veterinarians examined 59% of all cows and replacement heifers that died or were euthanized, and tissues were collected for histopathologic evaluation in 88% of all animals examined. The cows that were examined postmortem and had tissue samples collected for histopathologic evaluation were representative of all cows that died with respect to age, breed, and body condition score. However, cows that died during the winter and spring calving period were more frequently subjected to a complete postmortem examination with tissue collection for histopathologic evaluation than cows that died while on pasture. The largest contributing factor to the more frequent postmortem examinations during the winter months is likely the daily observations of the cattle when they are being fed as compared with management during the summer months when cattle may not all be observed daily and are typically dispersed over a larger area.

The factors identified as common causes of death differed substantially from conditions reported in cull beef cattle at slaughter plants in the United States; culled cattle commonly presented with lameness, cancer eye, and lump jaw (13). In contrast, death on farm was usually caused by acute conditions (bloat) or diseases that eliminate salvage value due to condemnation (infectious diseases, hardware). This demonstrates the need to consider reasons for culling and death loss when discussing the prevalence of diseases in this region.

Factors related to nutrition and feeding management were the most common contributors to death loss. The causes of death most directly linked to feeding management included: traumatic reticuloperitonitis (hardware disease), rumen tympany (bloat), myopathy (potentially associated with vitamin E or selenium deficiency), nitrate toxicity, and polioencephalomalacia. Collectively, these represented 21% of all deaths with a histopathologic examination. If AIP and its sequelae are also considered as a nutrition and feed management related disease, then 25% of all deaths examined could potentially be directly or indirectly attributed to feeding management.

Deaths occurred most frequently between March and May, which was in part because the selection criteria for spring calving herds concentrated parturition-related deaths during this period. Myopathy, including the cases where myopathy was present but not the primary cause of death, occurred exclusively in the period between March and May 2002. This is typically the end of the winter feeding period and was the calving season for all herds. Vitamin E is unstable and its activity decreases the longer feed is stored (15). The vitamin E content of feed in western Canada would be substantially depleted by calving season due to storage since the previous growing season. Calving and early lactation are associated with high oxidative stress (16) and exertion. The combination of increased demand and vitamin E degradation in feed could explain the apparent seasonality of these cases. Allison and Laven (16) have suggested that current recommendations (17) for vitamin E supplementation are inadequate.

Cancer accounted for more than 7% of deaths among the cows that were examined. However, several types of cancer were reported and there was no indication of clustering of cases in particular herds. The most common form of cancer was ocular squamous cell carcinoma, which was reported in 2% of all cases examined. This statistic likely underestimates the incidence of this condition in beef cattle as 6% of culled animals in the United States had evidence of cancer eye (13). Presumably, the relatively slow progression of disease allows many producers to cull affected cattle, capturing salvage value. Lymphosarcoma was the next most common type of cancer reported.

Pyelonephritis was another relatively frequent cause of death, with all but one case occurring between March and May. This condition is generally caused by urine and bacterial reflux into the kidney. Although a number of pathogens can be involved, *Corynebacterium renale* is specific for cattle (18). A detailed review of the treatment records from these herds showed that some of the cows diagnosed with pyelonephritis were treated for either an undiagnosed condition or metritis. These cases could have resulted from ascending lower urogenital tract infections. Calving and calving management should be considered as risk factors for this disease.

Paratuberculosis was identified in 2% of all cows examined postmortem. In dairy herds, death loss due to paratuberculosis has been reported to account for approximately 11% of the total direct costs of this disease; other costs included lost production, decreased slaughter value and increased veterinary expense (19). A serological survey of these herds (20) identified 0.7% of cows as positive and 3.6% that were suspicious for this disease. Based on the prevalence of cows with antibodies against paratuberculosis there could be at least 200 infected cows in addition to the 4 that died and were diagnosed between June 1, 2001 and May 31, 2002 in the study population (~32 000). This is consistent with other reports that clinical cases of paratuberculosis often represent a very small fraction of infected animals (21).

This study was unique in that standardized postmortem examinations were done on mature breeding animals. The study covered the cost of the veterinary examinations and laboratory submissions to encourage herd owners to have all death losses examined. However, some animals were not found in sufficient time for a meaningful postmortem examination. Decomposition before discovery of the carcass was most commonly reported during the summer months while the animals were on pasture and, therefore, were more difficult to observe individually on a regular schedule. Because a lower proportion of cow deaths was subjected to examination during the pasture season, this may have biased the proportions of cause of death to causes that have a seasonal distribution in the winter or early spring. However, the information on the numbers of animals dead or lost during each time period is accurate and was verified by on-farm inventory checks.

This study described on-farm losses in a cohort of beef cows in western Canada from the start of the breeding season in 2001 to the end of the calving season in 2002. This study includes unique information on the percentage of animals lost from herd inventory due to culling and death loss, the causes of cow death in these herds, and the age distribution of animals in these herds. However, there have been a number of factors that have affected the beef industry in Canada since these data were collected, including changes in mature cow value and market access associated with the discovery of BSE in 2003. Follow-up studies should be considered to determine if and how these market forces have changed culling management, the age distribution of beef herds, and reasons for loss.

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References

1. Wittum TE, Salman MD, Odde KG, Mortimer RG, King ME. Causes and costs of calf mortality in Colorado beef herds participating in the National Animal Health Monitoring System. J Am Vet Med Assoc 1993; 203:232–236.
2. Wittum TE, Salman MD, King ME, Mortimer RG, Odde KG, Morris DL. Individual animal and maternal risk factors for morbidity and mortality of neonatal beef calves in Colorado, USA. Prev Vet Med 1994;19:1–13.
3. Toombs RE, Wiksie SE, Kasari TR. The incidence, causes, and financial impact of perinatal mortality in North American beef herds. Vet Clin North Am Food Anim Pract 1994;10:137–146.
4. Toombs RE, Grotelueschen DM, Glock RD, Salman MD, Odde KG. Postnatal calf losses in beef herds: Causes and epidemiological characteristics. Large Anim Pract 1998;19:16–23.
5. Gagea MI, Bateman KG, van Dreumel TV, et al. Diseases and pathogens associated with mortality in Ontario beef feedlots. J Vet Diagn Invest 2006;18:18–28.
6. Western Interprovincial Scientific Studies Association (2006). Western Canada study of animal health effects associated with exposure to emissions from oil and natural gas field facilities. Research Appendices. Western Interprovincial Scientific Studies Association, Calgary Alberta. 2006.
7. Rice LE. The effects of nutrition on reproductive performance of beef cattle. Vet Clin N Am Food Anim Pract 1991;7:1–26.
8. Dohoo I, Martin W, Stryhn H. Veterinary Epidemiologic Research. AVC Inc., Charlottetown, PEI, 2003:502–504.
9. Bourdon RM, Brinks JS. Simulated efficiency of range beef production. III. Culling strategies and non-traditional management systems. J Anim Sci 1987;65:963–969.
10. Frasier WM, Pfeiffer GH. Optimal replacement and management policies for beef cows. Am J Agric Econ 1994;76:847–858.
11. Greer RC, Whitman RW, Woodward RR. Estimation of probability of beef cows being culled and calculation of expected herd life. J Anim Sci 1980;51:10–19.
12. Tronstad R, Gum R. Cow culling decisions adapted for management with CART. Am J Agric Econ 1994;76:237–249.
13. Roeber DL, Mies PD, Smith CD, et al. National market cow and bull beef quality audit — 1999: A survey of producer-related defects in market cows and bulls. J Anim Sci 2001;79:658–665.
14. Schons D, Hohenboken WD, Hall JD. Population analysis of a commercial beef cattle herd. J Anim Sci 1985;61:44–54.
15. Anonymous. Vitamin Nutrition Compendium [CD-ROM]. Cambridge Ontario: Hoffman-LaRoche, 2000.
16. Allison RD, Laven RA. Effect of vitamin E supplementation on the health and fertility of dairy cows: A review. Vet Rec 2000;147: 703–709.
17. National Research Council. Nutrient requirements of beef cattle, Update 2000. Washington DC: National Acad Pr, 2000.
18. Confer AW, Panchera RJ. The urinary system. In: McGavin MD, Carlton WW, Zachary JF, eds. Thomson's Special Veterinary Pathology, 3rd ed. St. Louis: Mosby, 2001:235–277.
19. Chi J, VanLeeuwen JA,Weersink A, Keefe GP. Direct production losses and treatment costs from bovine viral diarrhoea virus, bovine leucosis virus, *Mycobacterium avium* subspecies paratuberculosis, and *Neospora caninum.* Prev Vet Med 2002;55:137–153.
20. Waldner CL. Serological status for *N. caninum,* bovine viral diarrhea virus, and infectious bovine rhinotracheitis Virus at pregnancy testing and reproductive performance in beef herds. Anim Reprod Sci 2005;95:219–242.
21. Whitlock R. Johne's disease (paratuberculosis), In: Smith BP, ed. Large Animal Internal Medicine. 3rd ed. St. Louis: Mosby, 2002:779–783.