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THE EFFECT OF RISK FACTORS, AS DETERMINED BY LOGISTIC REGRESSION, ON HEALTH OF BEEF FEEDLOT CATTLE

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Each fall, approximately 300,000 recently weaned spring calves are transported 2-3,000 km, from pastures in western Canada to feedlots in Ontario, for growing and fattening prior to slaughter. Outbreaks of disease, chiefly shipping fever pneumonias, commonly occur within three weeks of arrival leading to increased treatment costs, poor productivity, death and other economic losses. In 1978, a three year study, the Bruce county beef project, was initiated to identify factors associated with morbidity and mortality in the five to six week period after arrival. Initial results of this study are presented elsewhere (Martin et al 1980, 1981).

The previous analyses were performed using least squares regression and/or linear discriminant analysis techniques. Although useful exploratory devises, standard regression techniques can lead to predicted disease rates of less than zero and greater than 100%. Since most of the independent variables were binary, the assumption of multivariate normality is not met and the use of discriminant analysis to differentiate between outcomes of a binary response variable is at best approximate. Logistic analysis provides a better and more unified approach to the analysis of data of this kind and can accommodate both categorical and continuous independent variables (Breslow and Day, 1980). Logistic regression routines are readily available and relatively easy to use. Computing costs are quite reasonable for stepwise selection providing the number of variables is limited.

This study presents a re-analysis, using logistic regression, of a subset of the data from the Bruce county beef project. The variables selected for this study appeared to be important, according to results of previous analyses.

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METHODS

Data were available on 311 groups of calves. Two hundred and six of these had complete daily treatment, mortality and health cost records. Of these, 174 groups of western Canadian calves that were not allowed access to pasture, in Ontario, were selected for analysis. Data for the variables shown in tables 1 and 2 were obtained by inspection of each calf group, personal interview of the feedlot owner, owner records, and post mortem files. Approximately 75% of all dead calves were examined at the Ontario Veterinary College, in Guelph, Ontario. (Martin et al 1980, 1981).

The data were analyzed using stepwise logistic regression, BMDP PLR, (Engelman, 1982). In the initial analysis, the 15 independent variables (Table 1) were available for entry into a main effects model; i.e. no interaction terms were entered. YEAR and SICKGR were forced into the equation as potential confounders, in all analyses. All variables selected to enter the equation with a significance level at or below $p = 0.10$ were retained and a second analysis containing all possible two-way interaction terms, plus the main effects of these variables was performed.

RESULTS

The odds ratios for factors related significantly (at $p \leq 0.10$) to the dependent variables are shown in Table 3. The standard errors may be used to calculate confidence intervals for the odds ratio or as a means of testing the significance of each variables' contribution to the regression equation. No two-way interactions were present, thus the effects of each significant factor were considered to be the same at all levels of other variables. All models appeared to fit the data quite well, as judged by Hosmer's chi-square in BMDP PLR, but departures from the model were noted when probability plots and residuals were examined.

As an example of one model; namely, MORT, the logistic equation asserts that the effects of SIZE, SIL2 and RESPVAC on the risk of mortality are independent. The odds ratio contrasting groups with more than 110 calves to smaller groups was 2.36. The odds ratio contrasting silage-fed to dry-hay-fed groups was 2.48 and for vaccinated versus nonvaccinated groups the odds ratio was 2.41. Hosmer's chi-square was 4.81, with 5 degrees of freedom, indicating an excellent overall fit. Nonetheless, apparent outliers were noted when the observed and predicted proportions of groups with mortality were plotted. Examination of observed and expected values (see Table IV) indicated some discrepancies in the vaccinated, large, dry hay fed groups; the expected number of groups with mortality being somewhat higher than observed. Four groups of cattle with the largest differences between observed and predicted proportions of groups with mortality were investigated further. All groups were on different farms and there were no apparent common factors.

Groups of cattle that arrived in poor condition, or had deaths in the first week were at increased risk of excess morbidity and mortality - crude and cause specific - subsequently. Having greater than 110 calves per group, feeding silage within two weeks of arrival, using prophylactic antimicrobials in the water supply, and vaccinating against respiratory disease were associated with increased disease problems. Feeding silage as the major component of the ration within two weeks of arrival, using antimicrobial containing starter rations, implanting with growth promotants, not mixing groups of calves, and buying calves direct from the source farm were associated with decreased disease problems.

DISCUSSION

The major reasons for veterinarians using logistic analysis, on data similar to those presented here, are to predict the future likelihood of disease (or other outcome) and/or to identify factors that appear to influence the outcome. In this study, our general objective was to identify some appropriate ways of managing highly stressed calves in the first few weeks after arrival in the feedlot. As a side benefit, the study also identified areas of feedlot management and disease prophylaxis requiring future research.

The general logistic model of the probability of disease (p) may be represented as:

$$\text{logistic (p)} = \log p/(1-p) = \beta_o + \Sigma \beta X_i,$$

where β_o is the intercept (i.e. the logit of the risk of the outcome in the absence of all of the putative risk (sparing) factors) and the β_i are the log odds ratios representing the strength of association between the ith variable and the outcome (Breslow and Day, 1980). In this study, stepwise selection models were used. At each step, the variable which adds most to the likelihood ratio statistic is selected and all variables in the model are re-evaluated to see if they still contribute significantly to the model. The procedure continues until none of the variables, not yet in the model, adds significantly to the likelihood ratio. For significance, at $p = .05$, the Z statistic obtained by dividing the log odds ratio (β_i) by its standard error. should be 1.96 or more. Other procedures for selecting variables are possible and may yield different models that describe the data equally as well. Thus one must be cautious with causal interpretations based on any given model.

To reduce the possible number of models, we used the heirarchical principle; that models including two-way interactions (second order) with the outcome should include the one-way interactions (first order or main effects) of these variables with the outcome. Only models containing variables with a first order interaction significant at or below $p = 0.10$ were considered, and since none of the second order interaction terms were significant, in any model, no higher order models were considered.

Different statistics for assessing the goodness of fit of a particular model are available (Engelman, 1981) and have been discussed by Lemeshow and Hosmer 1982 and by Breslow and Day, 1980. Global tests may be insensitive, to some departures from the model. If there are a limited number of risk categories, relative to the sample size, examination of the standardized residuals and/or comparing predicted verus observed odds can be helpful in detecting areas of departure from the model. All the models in this study provided a reasonable overall fit, but specific departures were notes also.

A summary interpretation of the findings in this study support our previously published results. Based on these we conclude that calves should be kept in groups of less than 110 and that calves from different sources or those arriving on different days should not be mixed. We recommend that silage not be introduced into the ration within two-weeks of arrival. (We believe the negative coefficient of SILM2 is due to a feedback between the groups response to silage and the amount of silage fed. Some groups of calves adapt to silage based rations readily, but most do not.)

The use of vaccines against respiratory disease is contraindicated in the first two weeks after arrival. Owners rarely vaccinate sick groups of calves and thus the increase in risk of death, crude or cause specific, is attributed to the vaccines and not vice-versa.

The practice of using prophylactic antimicrobials in water or feed appears to produce disparate results. We recommend that owners not use antimicrobials via the water and are hesitant to recommend their inclusion in starter rations. Cohort studies are planned to elaborate and validate our findings with regard to antimicrobial use.

Groups of calves that arrived in poor condition and/or had deaths during the first week after arrival (SICKGR = 1) had significantly higher morbidity and mortality in weeks two through five than more healthy groups. There did not however, appear to be an interaction between SICKGR and other variables, in the logistic model.

In conclusion, formal epidemiologic studies, including rigorous analyses with appropriate methods, should be an integral part of devising strategies to prevent disease and death losses in domestic animals.

REFERENCES

1. Breslow, N.E., and N.E. Day. 1980. Statistical methods in Cancer Research. Vol. I. The analysis of case-control studies. IARC, Ag. Res. Can. Switzerland 338 p. ISBN 92 832 11324.

2. Engelman, L. 1981. Stepwise logistic regression in Biomedical Computer Programs, P-Series. Univ. of California Press, pp. 330-344.

3. Lemeshow, S., and D.W. Hosmer. 1982. A review of goodness of fit statistics for use in the development of logistic regression models. Am. J. Epidem. 115: 92-106.

4. Martin, S.W., A.H. Meek, D.G. Davis, R.G. Thomson, J.A. Johnson, A. Lopez, L. Stephens. R.A. Curtis, J.F. Prescott, S.Rosendal, M. Savan, A.J. Zubaidy and M.R. Bolton. 1980. Factors associated with mortality in feedlot calves: The Bruce county beef cattle project. Can. J. comp. Med. 44: 1-10.

5. Martin, S.W., A.H. Meek, D.G. Davis, J.A. Johnson and R.A. Curtis. 1981. Factors associated with morbidity and mortality in feedlot calves. The Bruce county beef project, year two. Can. J. comp. Med. 45: 103-112.

Table 1: Variables used in the study of factors associated with morbidity and mortality in feedlot calves.

Variable[a]	Definition
YEAR	The year of study; 1978,79,80.
UNMIXED	The group was unmixed if the calves came from one source or if they were not mixed with cattle from other sources after one day following arrival?
SIZE	The group was considered small if it contained less than 110 calves.
SIL2	Were the calves fed silage (corn or hay) in the first two weeks after arrival?
SILM2	Was silage the major component of the ration in the first two weeks after arrival?
GRAINFED	Was grain fed in the first two weeks?
ANTIFEED	Was antimicrobials fed in a commercial starter ration in the first week?
ANTIWATER	Were antimicrobials included in the water supply in the first week after arrival?
RESPVAC	Was this group of calves vaccinated against respiratory diseases, within two weeks of arrival?
IMPLANTED	Was this group of calves implanted with growth promotants in the first two weeks after arrival?
DEWORMED	(as per IMPLANTED)
VITAMINS	(as per IMPLANTED, given by injection)
SICKGR	The group was considered sick if there were deaths in the first week or if the owner said they were in poor condition on arrival.
DIRECT	Did the group come directly from the ranch of origin?
LIMITFED	Were the calves kept slightly hungry during the first two weeks after arrival?

[a] Coded as 1 if variable met definition, or answer positive, 0 otherwise.

Table 2: Dependent Variables used in the study of factors associated with morbidity and mortality in feedlot calves.

Variable[a]	Definition
MORB	Considered high if: over the first five weeks after arrival a) Incidence rate of treatments greater than 0.273 (27.3%) or b) Prevalence rate of treatments greater than 0.683. (Total calf days of treatment divided by the number of calves in the group).
MORT	Considered high if any deaths occurred in weeks two through five post arrival.
FIBPNEU	Did any of the calves die from fibrinous pneumonia in weeks 2-5?
OTHPNEU	Did any calves die from other types of pneumonia in weeks 2-5?
ITEME	Did any calves die from Infectious Thromboembolic Meningo-encephalitis in weeks 2-5?

[a] Coded as 1 if level was high or if answer was affirmative, 0 otherwise.

Table 3: Log odds ratios and standard errors between significant ($p \leq 0.10$) independent variables and health status of groups of feedlot calves in Southern Ontario, 1978 - 1981.

Variables	Dependent Variables				
Selected	MORB	MORT	FIBPNEU	OTHPNEU	ITEME
UNMIXED	-0.56/0.34		-0.81/0.50		
SIZE		0.86/0.34			
SIL2	1.24/10.50	0.91/0.36	0.98/0.48		
SILM2	-1.98/0.60				
ANTIFEED	-2.70/1.11				
ANTIWATER	2.18/1.47				
RESPVAC		0.88/0.36	1.14/0.48	1.55/0.56	1.38/0.56
IMPLANTED				-1.52/0.92	
DIRECT	0.76/0.23				
SICKGR	0.96/0.56			1.71/0.64	
CONSTANT (β_0)	-0.16	-0.23	-1.56	-2.42	-2.09

Table 4: Observed (O) and Expected (E) numbers of cattle groups according to SIZE, SILAGE, RESPVAC and MORT[a].

			MORT			
	SILAGE	RESPVAC	1		0	
SIZE = 0			O	E	O	E
	0	1	5	4.25	7	7.75
		0	9	8.73	38	38.27
	1	1	4	3.84	3	3.16
		0	4	5.53	10	8.47
SIZE = 1	0	1	7	9.26	9	6.74
			16	14.76	24	25.24
	1	1	14	12.65	4	5.35
		0	13	12.99	10	10.01

[a] See tables I and II for coding and definition of variables. The expected numbers are based on the predicted proportion of successes (mortality) available from BMDP PLR.