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A Retrospective Analysis of Risk Factors Associated with Johne's Disease in Pacific Northwest Dairy Herds

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Abstract

Data from 407 dairy risk assessments completed as part of the United States Department of Agriculture's Voluntary Bovine Johne's Disease Control Program in Washington and Oregon from November 2003 to August 2007 were evaluated to determine what management practices were associated with herd Johne's disease status, and what range of these management practices were in use in Pacific Northwest dairies. Overall, assessment scores between Johne's disease-positive and Johne's disease-negative herds did not significantly differ. A multivariate logistic regression analysis of the 32 individual management practices and two herd-level variables included in the overall risk assessment score found nine factors significantly associated with whether the assessment veterinarian reported at least one case of Johne's disease in the previous year. These nine factors were: 1) herd size, 2) addition of new animals during the previous year, 3) stocking density of the calving area, 4) degree of manure build-up in the calving area, 5) presence of Johne's disease suspects in the calving area, 6) degree of manure soiling of udders and legs of cows in the calving area, 7) exposure of bred heifers to adult cow manure, 8) pasture-sharing by bred heifers and adult cows, and 9) degree of contamination of adult cow feed with manure.

Key words: bovine, dairy, Johne's disease, risk analysis

Résumé

Des données provenant de 407 évaluations de risque dans des fermes laitières, dans le cadre du programme volontaire de contrôle de la paratuberculose bovine du United States Department of Agriculture à Washington et en Oregon de novembre 2003 à août 2007, ont été évaluées afin de déterminer quelles pratiques de régie étaient associées à la prévalence de paratuberculose au niveau du troupeau et la fréquence d'utilisation de ces pratiques de régie dans les fermes laitières du Nord-Ouest Pacifique. Généralement, les scores d'évaluation ne différaient pas significativement entre les troupeaux avec ou sans paratuberculose. Une analyse de régression logistique multivariée des 32 pratiques de régie et de deux variables de troupeau incluses dans le score d'ensemble de l'évaluation de risque a permis d'isoler neuf facteurs significativement associés à l'identification d'au moins un cas de paratuberculose au courant de l'année précédente par le médecin vétérinaire évaluateur. Ces neuf facteurs étaient: 1) la taille du troupeau, 2) l'ajout de nouveaux animaux au courant de l'année précédente, 3) la densité des animaux dans l'aire de vêlage, 4) le degré d'accumulation du fumier dans l'aire de vêlage, 5) la présence d'individus soupçonnés d'avoir la paratuberculose dans l'aire de vêlage, 6) le degré de souillure du pis et des pattes de vaches par le fumier dans l'aire de vêlage, 7) l'exposition des taures inséminées ou saillies au fumier de vaches adultes, 8) le partage des pâturages par les taures inséminées ou saillies et les vaches adultes, et 9) le degré de contamination de la nourriture des vaches adultes par le fumier.

Introduction

Johne's disease is an incurable intestinal disease of cattle caused by *Mycobacterium avium* subspecies *paratuberculosis*, which is present in more than two-thirds of dairies and a large number of beef operations in the United States.[12] The major route of infection of the disease is by fecal-oral transmission. Without an efficacious vaccine against this disease, control has focused on instituting management practices that reduce disease transmission. In 2002, the United States Department of Agriculture (USDA) created the Voluntary Bovine Johne's Disease Control Program (VBJDCP) as a means to reduce the national prevalence of Johne's disease in cattle. The program has three components: education, risk assessments, and testing. Under the program, dairies are eligible for federal funding only if they have an official VBJDCP risk assessment performed each year by a program-certified veterinarian that has gone through approved training. Herd-level testing may be performed by the program-certified veterinarian, who is then compensated with program funds, but testing is not required. Program approved tests at the time of these assessments were serum ELISA, fecal culture, and fecal PCR.

Several studies have evaluated the management (risk) factors associated with Johne's disease and its control.[1,2,3,6,8,9,10,12] Two of these studies were based on the USDA National Animal Health Monitoring Service dairy surveys of 1996[12] and 2002,[1] and became the basis of the VBJDCP dairy risk assessment system.[4,11] Many different factors have been evaluated in these studies, ranging from exposure of cattle to wildlife to potential contact with contaminated manure to the sources of new herd additions to a dairy. The overall objectives of this study were to: 1) determine the range of control practices in use by dairies participating in the VBJDCP and 2) identify which of these control practices were most closely associated with the presence of Johne's disease in a herd.

Materials and Methods

A total of 407 Johne's disease risk assessments submitted to the Washington State Department of Agriculture or Oregon Department of Agriculture as part of the VBJDCP from November 1, 2003 to August 31, 2007 were considered for the study. In this assessment, certified veterinarians were asked to assign numeric scores (higher scores indicating greater Johne's disease risk) for 32 management criteria for participating dairies. Of these assessments, 199 were submitted to the state of Washington while 208 were submitted to the state of Oregon. Because herds could submit more than one assessment (at most one per year), these assessments represented 312 herds, 160 from Washington and 152 from Oregon, with 95 assessments being follow-ups to a previous year's submission.

For the multivariate logistic regression model, these 95 follow-up assessments were excluded from the analysis. For each assessment, two different Johne's disease status variables were calculated. For the first status variable, assessments for herds that reported at least one clinical cow, as defined by the program veterinarian, or one positive test, as reported by the program veterinarian, in the previous 12 months were considered positive. All other assessments were considered Johne's disease-negative. For the second status variable, assessments for herds where the program veterinarian reported at least one positive cow (either by a program-approved test or clinical signs) at any point in their history, including more than 12 months previously, were classified as Johne's-positive, while all other assessments were classified as Johne's-negative. Of the original 312 herds, 294 (165 Johne's disease-positive, 129 Johne's disease-negative) could be classified for Johne's status.

Potential risk factors were derived from the 32 management factor scores included in the VBJDCP risk assessment guide.[4] These 32 management factor scores include eight scores relative to calving area management practices, with a maximum score of 10 points each; six scores relative to pre-weaned calf management practices, with a maximum score of 10 points each; five scores relative to post-weaned calf management practices, with a maximum score of seven points each; five scores relative to bred heifer management practices, with a maximum score of five points each; four scores relative to cow and bull management practices, with a maximum score of four points each; and four scores relative to sources of new additions, with a maximum score of 60 points; for a total maximum score of 276 points. In this assessment system, higher scores are associated with higher risk of Johne's disease transmission.

For the multivariate logistic regression analysis, each management score was transformed into a dichotomous variable, with scores higher than the median value being assigned a value of 1 and scores equal to, or lower than, the median value being assigned a value of 0. Two additional dichotomous independent variables were created: herd size (0 for herds $\leq$ 500 cows, 1 for herds > 500 cows) and whether the herd had received new additions in the last 12 months (0 if no, 1 if yes). The choice of the 500-cow cutpoint for different herd sizes was based on rounding the mean herd size (487 cows) to a multiple of 50. These factors were modeled against the Johne's disease status variable based on the herd status in the last 12 months.

Statistical Analysis

All statistical analyses were conducted using the Statistix software package.[a] Multivariate logistic regression was conducted using the approach of Hosmer and Lemeshow.[5] This approach consists of five steps: 1) a preliminary screening of all independent variables for univariate associations, 2) selection of variables with P values less than 0.25 for construction of the full multivariate logistic regression model, 3) stepwise removal of non-significant variables from the full model while comparing the reduced model to the previous model for model fit and confounding, 4) evaluation of interaction among the remaining variables, and 5) assessment of model fit using the Hosmer-Lemeshow statistic. Model fitting was continued until all main effects or interaction terms were statistically significant by the Wald statistic at the $P \leq 0.10$ level. This higher level of significance was used in the multivariate logistic regression analysis to assure that potentially important risk factors would not be excluded from the model (hypothesis generation) while the conventional $P \leq 0.05$ level was used for comparisons (hypothesis testing). For each factor identified in the final multivariate logistic regression model, the population attributable rate (PAR), calculated as the estimated effect of a factor multiplied by the prevalence of the factor, was reported. PAR is a direct estimate of the rate of disease in a population due to a factor and can be interpreted as the reduction in rate that would be expected if the factor were eliminated.[6] Therefore, factors with the largest PAR will have the most impact on Johne's disease herd prevalence in a group of herds if the factor is eliminated.

Results

The percentage of herds with at least one Johne's disease case in their history was 72.4%, while the practitioner estimated Johne's disease cow-level prevalence was 3.0%. The 312 herds in this study were quite different in herd size (range = 25 to 9,300 cows) and milk production (range = 30 to 100 lb [13.6 to 45.5 kg] per cow per day); however, herds from Washington and Oregon were very similar. Table 1 shows a comparison of the 160 Washington and 152 Oregon herds for size, production, and management scores. Washington dairies had significantly higher milk production, had higher cow and bull scores, and scored higher on sourcing for new additions.

Table 2 shows the descriptive statistics for the 32 individual management factor scores across all farms. Scoring for these management factors was performed by the herd veterinarian in consultation with the dairy manager. Values indicate the estimated level at which that factor occurs with 0 representing the best case scenario (i.e. "never") and the highest value indicating the worst case scenario (i.e. "always"). The VBJDCP assessment is designed to weight the factors earlier in life with higher scores, such that the highest value differs by area of interest.

Figure 1 shows the distribution of overall assessment scores for the 163 Johne's disease-positive and 149 Johne's disease-negative herds. No statistical difference (at $P \leq 0.05$) was found in average score between positive and negative herds; Johne's disease-positive herds averaged 74.2 points and Johne's disease-negative herds averaged 70.9 points. The lowest overall score for Johne's disease-positive herds was 23 points, while the lowest overall score for Johne's disease-negative herds was 13 points. The highest overall score for Johne's disease-positive herds was 194 points, while the highest overall score for Johne's disease-negative herds was 149 points.

Table 3 shows a comparison of the subcategory scores for the 163 Johne's disease-positive and 149 Johne's disease-negative herds. Positive herds scored significantly higher in cow/bull scores than did negative herds ($P < 0.01$). All other subcategory scores did not statistically differ ($P \geq 0.05$) between positive and negative herds. Positive herds were significantly larger than negative herds, with positive herds averaging 673 cows compared to 250 cows for negative herds ($P < 0.01$).

For 95 pairs of assessments, consecutive years were scored on the same herds. Table 4 shows the change in scores for each management factor between consecutive years. The "% Down" column indicates the percentage of

Table 1. Comparison of Washington and Oregon study herds on herd demographics and assessment score categories.

Herd level statistic	Washington*	Oregon*
Herd size (cows)	541 (56)	450 (90)
Milk production (lb/cow/day)	71.9 (1.1)[a]	64.0 (1.2)[b]
Herds receiving new additions in last year (%)	41.2 (4.2)	27.7 (3.7)
Herds with Johne's diagnosis in last year (%)	53.1 (4.0)	51.3 (4.1)
Herds with Johne's diagnosis in herd history (%)	72.1 (3.7)	73.3 (3.6)
Estimated Johne's disease cow prevalence (%)**	3.2 (0.3)	2.6 (0.3)
Calving area score (points)	26.0 (0.9)	24.2 (0.9)
Pre-weaned heifer score (points)	15.4 (0.8)	13.1 (0.7)
Post-weaned heifer score (points)	7.6 (0.5)	5.9 (0.4)
Bred heifer score (points)	9.0 (0.6)	7.7 (0.5)
Cow and bull score (points)	7.4 (0.2)[a]	6.0 (0.2)[b]
Sourcing for new additions score (points)	16.2 (0.5)[a]	11.7 (1.3)[b]
Overall risk assessment score (points)	81.5 (2.4)[a]	68.5 (2.3)[b]

* Values indicate mean and standard error (in parenthesis).
** Cow prevalence estimated by the program-certified veterinarian.
*** Lettered superscripts indicate values significantly differ at $P \leq 0.05$ level.

Table 2. Descriptive statistics for 32 management factor scores used in Voluntary Bovine Johne's Disease Control Program (VBJDCP) assessment.

Management factor	Mean (S.E.)	Range	25*	50*	75*
Calving area, stocking density	4.28 (0.13)	0 - 10	2	4	6
Calving area, manure buildup	3.40 (0.12)	0 - 10	2	3	5
Calving area, area used for sick cows	2.51 (0.10)	0 - 10	0	1	5
Calving area, presence of Johne's suspects	1.76 (0.12)	0 - 10	0	1	2
Calving area, manure-soiled udder or legs	2.65 (0.09)	0 - 10	1	2	4
Calving area, calves born in other areas	1.95 (0.08)	0 - 10	1	1	3
Calving area, time calves stay with dam	3.68 (0.12)	0 - 10	2	3	5
Calving area, calves ability to nurse dam	4.15 (0.15)	0 - 10	1	4	6
Pre-wean area, fed pooled colostrum	2.55 (0.15)	0 - 10	0	1	5
Pre-wean area, fed colostrum from > 1 cow	3.66 (0.15)	0 - 10	1	3	5
Pre-wean area, fed unpasteurized pooled milk	3.96 (0.17)	0 - 10	0	3	8
Pre-wean area, contaminated colostrum or milk	1.40 (0.07)	0 - 7	0	1	2
Pre-wean area, contaminated feed or water	1.38 (0.08)	0 - 9	0	1	2
Pre-wean area, contact with adult cow manure	1.40 (0.10)	0 - 10	0	1	2
Post-wean area, contact with adult cow manure	1.49 (0.09)	0 - 7	0	1	2
Post-wean area, contaminated feed	1.49 (0.09)	0 - 7	0	1	2
Post-wean area, contaminated water	1.15 (0.09)	0 - 7	0	0	2
Post-wean area, shared pasture with adult cows	0.84 (0.09)	0 - 7	0	0	1
Post-wean area, manure spread on forage	3.19 (0.14)	0 - 7	1	2	6
Bred heifer area, contact with adult cow manure	1.77 (0.09)	0 - 5	0	1	3
Bred heifer area, contaminated feed	1.50 (0.08)	0 - 5	0	1	3
Bred heifer area, contaminated water	1.29 (0.07)	0 - 5	0	1	2
Bred heifer area, shared pasture with adult cows	1.78 (0.10)	0 - 5	0	1	3
Bred heifer area, manure spread on forage	3.07 (0.09)	0 - 5	2	3	5
Cow/bull area, contaminated feed	1.53 (0.05)	0 - 4	1	1	2
Cow/bull area, contaminated water	1.44 (0.06)	0 - 4	1	1	2
Cow/bull area, access to stored manure	0.90 (0.06)	0 - 4	0	0	1
Cow/bull area, manure spread on forage	2.85 (0.06)	0 - 4	2	3	4
Additions from Level 2-4 herds	0.80 (0.10)	0 - 8	0	0	0
Additions from Level 1 herds	1.20 (0.18)	0 - 14	0	0	0
Additions from single source, untested herds	4.10 (0.44)	0 - 40	0	0	0
Additions from multiple source, untested herds	7.40 (0.71)	0 - 40	0	0	26
Herd size	487 (43.4)	25 - 9300	95	240	461
Calving area, total score	24.6 (0.57)	0 - 63	15	23	32
Pre-wean area, total score	13.4 (0.46)	0 - 49	6	12	19
Post-wean area, total score	6.6 (0.28)	0 - 28	2	6	10
Bred heifer area, total score	8.3 (0.32)	0 - 25	3	7	13
Cow/bull area, total score	6.6 (0.14)	0 - 15	4	6	8
Additions and replacements, total score	13.3 (0.85)	0 - 60	0	0	26
Overall total score	72.8 (1.47)	13 - 194	50	69	91

* 25th, 50th (median) and 75th percentile values

follow-up assessments in which the score in the second year was less than the first year. The "% Same" column indicates the percentage of follow-up assessments in which the score in the second year was the same as the first year. The "% Up" column indicates the percentage of follow-up assessments in which the score in the second year was greater than the first year. In most cases, the % Down was larger than the % Up, but the % Up was greater than zero for all management factors.

Figure 2 shows the average overall assessment score for all 407 assessments from the first quarter (January, February, March) of 2004 to the fourth quarter (October, November, December) of 2006. There was no significant ($P \geq 0.05$) difference in average score during this time period. Error bars on this figure indicate the standard error of the average assessment score.

Table 5 shows the final multivariate logistic regression model for factors significantly associated (*P*

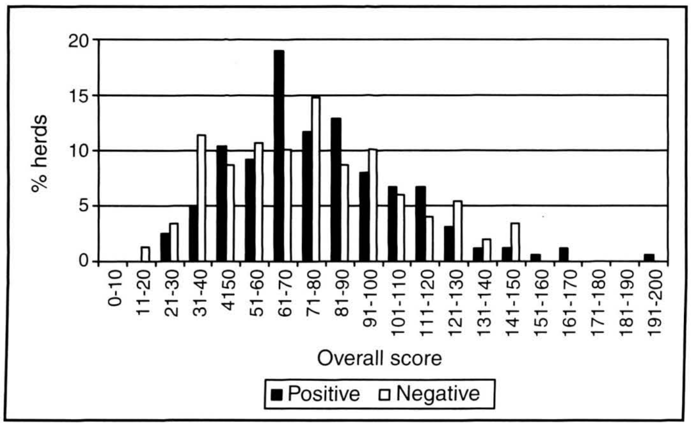

Figure 1. *Distribution of assessment scores for 312 Johne's disease-positive and negative herds.*

≤ 0.10) with herd Johne's disease status. Seven of the nine factors were associated with an increase in Johne's disease risk when present (a detrimental effect), while two of the nine factors were associated with a decrease in Johne's disease risk when present (a protective effect). The seven factors associated with a detrimental effect were: 1) herd size greater than 500 cows, 2) addition of new animals in last 12 months, 3) a calving area stocking density score of greater than four, 4) a calving area presence of Johne's disease suspects score of greater than one, 5) a calving area manure soiling of udder or leg score greater than two, 6) a bred-heifer manure spread on forage score greater than three, and 7) a cow/bull area contaminated feed score greater than one. The two factors associated with a protective effect were: 1) a calving area manure buildup score greater than three, and 2) a bred-heifer area contact with adult cow manure score greater than one. Population attributable rate for each factor in the final regression model is shown as the last column in Table 5.

Discussion

The prevalence of Johne's disease in this study was similar to previous reports. The percentage of herds with at least one Johne's disease case in their history was 72.4%, compared to 68.1% of herds with at least one positive environmental sample in the most recent USDA study.[12] Likewise, the estimated Johne's disease cow-level prevalence of 3.0% was very similar to the rate of 3.4% reported by Wells and Wagner.[13] The similarity in Johne's disease prevalence between Washington and Oregon was not unexpected, as these states have very similar dairies in management style, size, and environmental conditions. Significantly higher assessment scores in Washington herds can be explained by Washington having higher milk production, higher cow and bull scores, and greater likelihood of receiving new animals than Oregon herds. The lack of significantly different Johne's rates between the states suggests that these factors may not have large effects on herd prevalence, or that other factors may be more important determinants.

Management factor scores in this study tended to be low (less than four points per question) and were generally lower than the scores reported by Berghaus *et al.*[1] This suggests that dairy herds have been more readily adopting practices that may be important in the control of Johne's disease and other diseases transmitted by the fecal-oral route. Exceptions to the general improvement in adopting management practices assumed to reduce Johne's disease risk were increases in scores relative to calving area use for either sick or Johne's disease suspect cattle, and the practice of spreading manure on fields with growing forage prior to harvest. The increased use of these practices may be the result of the large and expanding herd sizes in the study herds as space is at a premium both for housing animals and for dealing with the associated manure on a limited

Table 3. Comparison of subcategory scores for 312 Johne's disease-positive and negative herds.

Score area	Johne's (+) herds*	Johne's (-) herds*	All herds*
Calving area	25.4 (0.7)	23.4 (0.9)	24.6 (0.6)
Pre-weaned area	13.6 (0.6)	13.1 (0.7)	13.4 (0.5)
Post-weaned area	6.3 (0.4)	7.0 (0.4)	6.6 (0.3)
Bred heifer area	8.0 (0.4)	8.8 (0.5)	8.3 (0.3)
Cow/bull area	7.2 (0.2)[a]	6.0 (0.2)[b]	6.6 (0.1)
Additions	13.8 (1.2)	12.7 (1.2)	13.3 (0.9)
Herd size	673 (76)[a]	250 (23)[b]	487 (45)
Overall score	74.2 (2.0)	70.9 (2.3)	72.8 (1.5)

*Values indicate mean and standard error (in parenthesis).
[a,b] Indicate values significantly differ at $P \leq 0.05$ level.

Table 4. Change in scores from previous assessment for 95 follow-up assessments.

Management factor	% down	% same	% up
Calving area, stocking density	23.2	60.0	16.8
Calving area, manure buildup	21.1	56.8	22.1
Calving area, area used for sick cows	22.1	58.9	18.9
Calving area, presence of Johne's suspects	17.9	64.2	17.9
Calving area, manure-soiled udder or legs	23.2	56.8	20.0
Calving area, calves born in other areas	29.5	53.7	16.8
Calving area, time calves stay with dam	22.1	50.5	17.9
Calving area, calves ability to nurse dam	32.6	56.8	10.5
Pre-wean area, fed pooled colostrum	22.4	65.3	7.3
Pre-wean area, fed colostrum from > 1 cow	36.8	49.5	13.7
Pre-wean area, fed unpasteurized pooled milk	39.4	52.1	8.5
Pre-wean area, contaminated colostrum or milk	25.3	62.1	12.6
Pre-wean area, contaminated feed or water	21.1	64.2	14.7
Pre-wean area, contact with adult cow manure	25.3	63.2	11.6
Post-wean area, contact with adult cow manure	18.9	71.6	9.5
Post-wean area, contaminated feed	20.0	66.3	13.7
Post-wean area, contaminated water	14.7	76.8	8.4
Post-wean area, shared pasture with adult cows	13.7	74.7	11.6
Post-wean area, manure spread on forage	21.1	61.1	17.9
Bred heifer area, contact with adult cow manure	17.9	66.3	15.9
Bred heifer area, contaminated feed	21.1	66.3	12.6
Bred heifer area, contaminated water	12.6	74.7	12.6
Bred heifer area, shared pasture with adult cows	11.6	76.8	11.6
Bred heifer area, manure spread on forage	21.1	66.3	12.6
Cow/bull area, contaminated feed	15.8	66.3	17.9
Cow/bull area, contaminated water	14.7	69.5	15.8
Cow/bull area, access to stored manure	13.7	72.6	13.7
Cow/bull area, manure spread on forage	17.9	75.8	6.3
Calving area, total score	40.0	29.5	34.5
Pre-wean area, total score	50.5	34.7	14.7
Post-wean area, total score	35.8	45.3	18.9
Bred heifer area, total score	28.4	51.6	20.0
Cow/bull area, total score	25.3	53.7	21.1
Additions and replacements, total score	31.6	47.4	21.1
Overall total score	53.8	14.3	31.9

land base. Therefore, dairy producers may view these practices as a necessary tradeoff to operate their dairy within their space constraints.

The similarity in assessment scores between Johne's disease-positive and negative herds was a surprising result. There are three plausible reasons for this. First, it is possible that factors are included in the assessment that have little or no bearing on herd status, and these lead to a dilution effect of important factors. These factors may be included because there are very few epidemiologic studies of risk factors for Johne's disease, and control recommendations have historically been based on biologic plausibility, rather than empirical evidence.[1] Support for this hypothesis has been found in other studies[1,2,3,7,13] where analysis of a reduced set of factors performed just as well as a more complete set in predicting herd Johne's disease status. Second, classification of a herd's status was based on a subjective measure (veterinarian's opinion) rather than on a more objective measure such as herd testing; thus, there was more chance for misclassifying herds and more biased estimates of the effects of various management factors.[6] Despite the potential for misclassification, any misclassification would bias the estimates toward the null such that measured effects would be smaller than those estimated with more appropriate classification, and potentially important risk factors may be left out. However, misclassification is unlikely to influence the relative magnitude of the effects, and the significantly important factors found in this study are likely to be the largest predictors of Johne's disease status. Third, due to the nature of Johne's disease as a chronic condition, it

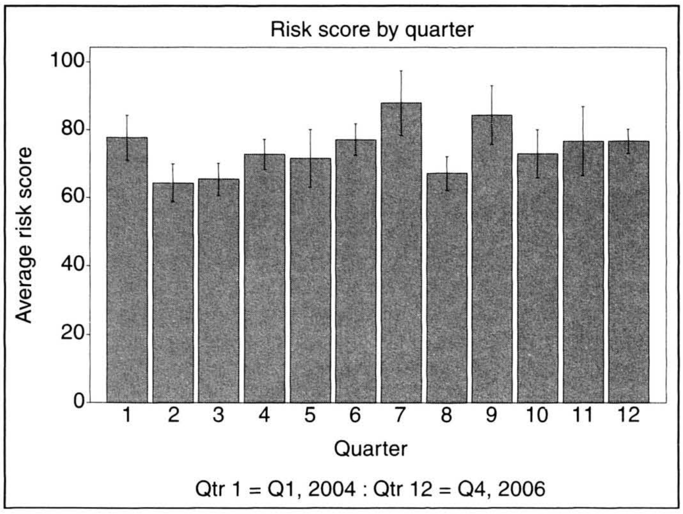

Figure 2. Trends in average risk score by quarter from first quarter 2004 to fourth quarter 2006.

may take years to see changes in prevalence after changing management practices. Since the USDA VBJDCP was not started until 2002 and the risk assessment does not contain a question regarding how long a herd has been on a control program, it is possible that insufficient time has elapsed to see a change in prevalence.

Larger dairies in this study were more likely to be Johne's disease-positive, which has been reported previously.[1,3,12,13] This association may be partially explained by our case definition of a positive herd being a herd with at least one positive cow or test. Given this definition, larger herds are more likely to be positive just because they have more animals. A second possible reason for this association is that larger dairies are more likely to purchase replacement animals, thus increasing the probability of exposing their herds to infected cows.

The finding that a large percentage of follow-up assessment scores did not change or had higher scores than previous assessments (Table 4) was disappointing. This may be occurring for several reasons. First, there is loose control on how assessments are performed, and several follow-up assessments were "copied" from the previous year's assessment. This could be due to failure of veterinarians conducting the assessment to appreciate its value, and that it is a means to qualify for program funding. Second might be a perception that Johne's disease control is less important than other management strategies. Evidence for this is provided by Wells and Wagner,[13] in which the authors found that knowledge of Johne's disease by the herd manager did not necessarily lead to implementing effective control measures. A third possible explanation is that most dairies will only make a few changes at a time due to economic and other constraints. As a result, only a handful of scores will change from assessment to assessment, and factors that change are likely to be either the ones perceived to have the most impact or the easiest to do. Examples in this study include reducing the ability of calves to nurse their dams, reducing the number of calves born outside the calving area, and avoiding feeding of unpasteurized pooled milk. In this study, these factor scores were the most likely to decline in follow-up assessments, and all of these factors have been reported to have an effect on Johne's disease transmission.[1] Finding summary scores less likely to stay the same in follow-up assessments was not unexpected since they include multiple factors, and any single change would be reflected as a summary score change.

The lack of a detectable trend in Johne's disease assessment scores across herds over time is of interest (Figure 2). We must be careful interpreting this, however, because the data represent different herds over time. Nonetheless, repeat assessments in herds did not change between successive years (Table 4), suggesting

Table 5. Final logistic regression model for factors associated with herd Johne's disease status.

Management factor	Odds ratio*	P	PAR**
Herd size > 500 cows	2.15 (1.12, 4.13)	0.02	63
Added animals in last 12 months	1.73 (0.99, 3.01)	0.05	42
Calving area, stocking density score > 4	1.97 (1.03, 3.74)	0.04	72
Calving area, manure buildup score > 3	0.37 (0.19, 0.73)	<0.01	-11
Calving area, presence of Johne's suspects score > 1	2.68 (1.54, 4.68)	<0.01	96
Calving area, manure-soiled udder or legs score > 2	1.69 (0.94, 3.02)	0.08	53
Bred heifer area, contact with adult manure score > 1	0.42 (0.23, 0.74)	<0.01	-69
Bred heifer area, manure spread on forage score > 3	1.72 (0.97, 3.35)	0.06	3
Cow/bull area, contaminated feed score > 1	1.38 (1.11, 1.71)	0.02	85

* Values in parenthesis indicate 95% confidence interval.

** PAR (population attributable rate) is the estimated reduction in number of positive herds per 1,000 herds if factor was eliminated.

that efforts to reduce the prevalence of Johne's disease in Pacific Northwest dairy herds have not been very successful. One possible explanation is that dairy producers perceive Johne's disease control as a low priority. This apparent lack of concern may arise for three reasons: 1) control of Johne's disease is difficult due to the hardiness of the agent, the long time period from infection to clinical disease, and the difficulty in detecting positive cows;[1] 2) producers don't understand the impact of Johne's disease on their herds, as there is a relative lack of scientific studies demonstrating the economic impact of Johne's disease on a dairy; and 3) producers don't understand what they can do about Johne's disease if present in the herd since there are relatively few studies that describe the efficacy of alternative control strategies.

The multivariate logistic regression analysis identified nine factors associated with herd-level status for Johne's disease. These nine factors were: 1) herd size greater than 500 cows, 2) adding new animals to the herd in the last 12 months, 3) calving area stocking density score, 4) calving area manure buildup score, 5) presence of Johne's disease suspects in the calving area, 6) level of manure soiling on maternity cow udders and legs, 7) bred-heifer contact with adult cow manure, 8) application of manure to forage fields harvested for bred heifers, and 9) manure contamination of adult cow feed.

The positive association of Johne's disease with calving area stocking density, the presence of Johne's disease suspects or clinicals in the calving area, and manure soiling of maternity cow udders and legs is not surprising as Johne's disease is thought to be primarily transmitted by the fecal-oral route,[1] and these factors would increase the likelihood of manure from an infected cow being ingested by newborn calves. The combined population attributable rate of 221 per 1,000 herds (72 per 1,000 herds for calving area stocking density, 96 per 1,000 herds for presence of Johne's disease suspects, and 53 per 1,000 herds for manure soiling of maternity cows) suggests that the herd prevalence of Johne's disease could be reduced as much as 22.1% if these three risk factors were eliminated.

The negative association of Johne's disease risk to the level of manure build-up in the calving area and contact with cow manure for bred heifers may seem paradoxical at first, but while a significant association does not necessarily indicate causality, it can indicate a response to the outcome or confounding by an unmeasured factor. For example, herds diagnosed with Johne's disease may be more conscientious of manure contamination, and therefore have lower scores as a consequence of implementing management practices that reduce manure exposure.

Exposure of adult cattle to contaminated manure has not been considered a significant source of Johne's disease transmission in past studies. However, the positive association of Johne's disease status with herds that score higher on contaminated feed scores for adult cattle in this study might suggest that this may be a significant risk under certain circumstances, or that this is a spurious result. Further investigation is needed in a hypothesis testing study to resolve this discrepancy. The population attributable rate of 85 per 1,000 herds in this study suggests that, if confirmed, this could be a major risk factor for Johne's disease control.

Conclusion

This study demonstrates there are no detectable differences in Johne's disease assessment scores between positive and negative herds. It is possible that factors included in the assessment are not significantly associated with Johne's disease status as we found only nine of the 32 factors considered to be predictive of Johne's status. A second possible explanation is that the case definition used in these assessments is prone to misclassification bias. Finally, the chronic nature of Johne's disease on a herd-wide basis and the relative newness of the USDA Johne's disease program may require more time to detect improvements in Johne's disease control. The four most important risk factors in this study, based on population attributable rate, were: 1) the presence of Johne's disease suspects or clinicals in the calving area, 2) calving area stocking density, 3) manure soiling of maternity cow udders and legs, and 4) exposure of adult cattle to contaminated manure. Assessment scores did not improve over time across farms and did not improve over time within farms, suggesting that opportunities exist to improve Johne's disease control practices on Pacific Northwest dairies or that sufficient time for improvement to occur has not elapsed.

Endnote

[a]Statistix version 9, Analytical Software, P.O. Box 12185, Tallahassee, FL

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