Characterization of the risk of deer-cattle interactions in Minnesota by use of an on-farm environmental assessment tool

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Objective—To characterize the risk of interactions that may lead to the transmission of *Mycobacterium bovis* between cattle and white-tailed deer (*Odocoileus virginianus*) on farms in northern Minnesota.

Sample—53 cattle farms in northwestern Minnesota adjacent to an area where bovine tuberculosis–infected cattle and deer were detected.

Procedures—A semiquantitative deer-cattle interaction assessment tool was used for the 53 cattle herds. Farm risk scores were analyzed on the basis of deer damage to stored feed.

Results—27 (51%) farms reported deer damage to stored cattle feeds within the year previous to the farm visit. A strong association was found between increases in the percentage of land that could serve as deer cover and deer damage to stored feeds on a farm. The total risk score was significantly associated with the probability of a farm having deer damage. By use of a logistic regression model, the total risk score and proportion of nonagricultural land around a farm could be used to predict the likelihood of deer damage to stored feeds.

Conclusions and Clinical Relevance—Management practices on many farms in northwestern Minnesota allowed potential deer-cattle interactions. The on-farm risk assessment tool served as a valuable tool for prioritizing the biosecurity risks for farms. Continued development of biosecurity is needed to prevent potential transmission of bovine tuberculosis between deer and cattle, especially on farms that have a higher risk of deer damage. (*Am J Vet Res* 2011;72:924–931)

Mycobacterium bovis, the causative agent of bovine tuberculosis, was an important cause of illness in humans in the United States until the first part of the 20th century. In 1917, the United States introduced a cooperative state-federal program to eradicate bovine tuberculosis from cattle through testing and restrictions on movement of cattle from herds with positive test results.[1] By the 1970s, bovine tuberculosis was uncommonly reported in much of the US cattle population, and every state had achieved tuberculosis-free status by the 1990s. Similar programs have been introduced in many other countries, which makes bovine tuberculosis a rare disease for both cattle and humans in many parts of the world.

However, it is erroneous to assume that *M bovis* is no longer a pathogen of concern. By establishing infections in wildlife and cattle populations, *M bovis* has staged a comeback in several parts of the world, including the United Kingdom, New Zealand, and the United States.[2] In each location, the epidemiological aspects of the disease differs, which indicates the ability of *M bovis* to survive and cause infection in a variety of species.

In parts of Michigan, the white-tailed deer (*Odocoileus virginianus*) population is infected with *M bovis* and apparently serves as a maintenance host for the organism.[3] It has been hypothesized that the provision of supplemental feed and increases in deer densities contribute to the spread of infection through the deer population[4]; 1 study[5] revealed that *M bovis* can be effectively transmitted between deer through shared feeds. In several studies,[6–8] investigators found that *M bovis* can survive while suspended in manure for 1 to 7 months in a number of environmental conditions, although persistence increases when the bacilli are protected from sunlight and kept at lower temperatures. Several types of feedstuffs (apples, corn, carrots, sugar beets, potatoes, and hay) are able to harbor viable bacteria for up to 112 days; bacteria stored in colder temperatures had the longest survival times.[9]

In 2005, tuberculous lesions were identified at slaughter in a cow from Minnesota. The subsequent epidemiological investigation resulted in depopulation of 12 infected herds, all of which were located in northwestern Minnesota. Epidemiological investigations of cattle movements identified movement of cattle between farms for most of the infected herds, although

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2 farms were not connected by verified movements of cattle. Infected deer have been found within 3.2 km of both those farms.[a] Surveillance of free-ranging white-tailed deer has identified test-positive deer in the area of the infected cattle herds, with recent estimates for the apparent prevalence of 0.33% in a small clustered area around the locations of the infected herds.[10] One hypothesis is that cattle were the initial source of infection in this outbreak in Minnesota; cattle movement then led to spread of infection to other herds of cattle, and the disease spilled over into a small percentage of the free-ranging deer, which may have in turn been a source of infection for some cattle herds.

An eradication program for bovine tuberculosis in both cattle and deer populations has been implemented in Minnesota. Eradication of *M bovis* in identified infected cattle and deer populations has been rapid and aggressive, with expanded disease surveillance, removal of all cattle in infected herds, bans on feeding of deer, and reduction of the deer population through public hunting and selective culling via the use of sharpshooters. Mitigations for disease transmission include a ban on feeding of deer and elk as well as use of deer-proof fencing for cattle farms located in the area where infected deer and cattle have been identified.

A strategy for minimizing contact between cattle and deer to eliminate potential transmission of *M bovis* between species is considered important for disease control. This strategy depends on understanding transmission pathways between affected species and identifying high-risk interspecies interactions on cattle farms. Specifically for the area of interest (northwestern Minnesota), the following 4 factors are unknown: type or types of feed storage on cattle operations, frequency of deer damage to stored feeds, location of cattle herds in proximity to deer populations, and time of year deer are most commonly present on a farm. We hypothesized that the burden of deer-cattle interactions would not be evenly dispersed among cattle farms. This may be attributable to a number of factors, including feed management, cattle housing, and land type around a farming operation. The purpose of the study reported here was to characterize the risk of interactions between cattle and white-tailed deer in northwestern Minnesota by use of a semiquantitative on-farm assessment tool.

Materials and Methods

Sample—Dairy and beef farms located in northwestern Minnesota were eligible for inclusion in the on-farm risk assessment. Inclusion criteria were that a farm had a minimum of 20 cattle and was located in northwestern Minnesota proximate to the area where bovine tuberculosis was diagnosed but outside of a core area where farm deer-cattle assessments and mitigations (such as deer removal and use of deer fencing) had already been performed as part of the state's response efforts (**Figure 1**). Estimating that the mean ± SD prevalence of deer damage to feed on farms was 20 ± 10%,[11] the goal sample size was set at 61 farms on the basis of results of a survey[12] of Minnesota dairy farms for which 23% to 26% of respondents indicated deer-cattle interactions on a regular basis. Postal codes of towns and areas adjacent to the core area were used to define the research area. Names and addresses of dairy and beef producers were accessed from multiple sources, including lists of cattle farms participating in cooperative extension educational programs and state disease control programs. A recruitment letter and postage-paid response card were mailed to producers of eligible farms to inform them about the study and request that they express their interest in participating by returning the postage-paid card. A farm visit was scheduled with producers who expressed a willingness to participate and whose farm met the inclusion criteria.

Development of a wildlife-interface risk assessment tool for use in Minnesota—A qualitative survey was developed by USDA APHIS Wildlife Services personnel in Michigan.[b] That survey was modified for use in Minnesota by introduction of a scoring method to evaluate the areas of highest risk for potential deer-cattle interactions. This type of quantitative on-farm risk assessment tool has been used to evaluate cattle herds for transmission risk of paratuberculosis (Johne's disease) caused by *Mycobacterium avium* subsp *paratuberculosis*.[13] The on-farm assessment tool was developed with the intent to evaluate dairy farms and beef operations in winter, which is a time when producers in this region typically use stored feeds and house cattle more intensively and deer may be more motivated to come to farms in search of feed sources.

To assign scores for potential deer-cattle interactions, 4 categories of evaluation were used: feed storage, feeding practices, cattle housing, and water management. Once the management areas and items for risk scoring were identified, available literature and subject matter experts were consulted to determine the maximum score each item should receive. The greater the risk a particular item had for potential deer-cattle interactions, the higher the maximum risk score. As a result, 18 items were scored in the on-farm assessment tool. The maximum possible total risk score for a farm was 180 (feed storage, 75 possible points; feeding practices, 75 possible points; cattle housing, 15 possible points; and water management, 15 possible points).

For the feed storage category, separate scores were assigned for all feeds on the farm on the basis of the type of storage used and ease with which deer could access the stored feed. Hay was scored on the basis of the relative content of alfalfa (second- or third-cutting hay) or grass (first-cutting hay). For feeding practices, cattle housing, and water management, a separate score was assigned for each of 3 separately housed groups of cattle (adult cattle, yearlings, and calves) on the farm. Scores were assigned on the basis of location of the feeding site, housing, or water source and ease with which deer could access them. Additionally, scores were assigned for the rapidity of feed consumption by the cattle and location where minerals were provided to cattle. Scoring guidelines were created with suggested score ranges for various management practices (**Appendix**).

In addition to quantitative scores, the on-farm assessment included qualitative questions regarding herd demographics and presence of deer on the farm. These questions were asked during the on-farm assessment and included closed-ended or numeric questions regarding type and number of cattle on the farm, number of cattle purchased within the past year and the source or sources of those cattle, number of fence-line contacts with other cattle herds, approximate percentage of various land types within a 1.6-km radius around the main farm operation, deer damage to stored feed within the past 12 months, whether congregations of > 10 deer were seen around feed during winter months, whether hunting was allowed or dogs were used on the premises, and type of fencing used. Land types were classified as deer cover if they consisted of woods, swamp, or Conservation Reserve Program land, as opposed to open pasture or cropland.

On-farm risk assessment—Two evaluators (BMK and PCW) completed all deer-cattle risk assessments. When visiting a farm, each evaluator separately reviewed all management areas on the farm, performed a risk assessment, and assigned scores. As much as possible, all sources of feed and all cattle groups on a farm were directly observed by the evaluators. Special attention was given to visible evidence of deer or deer activity around the management areas, and characteristic signs of deer (hair, tracks, urine, and fecal material) were recorded. Evidence of deer damage to stored feeds was assessed by the evaluators at the time of the visit, and the particular kinds of feed damaged were recorded. Feeds were classified as having deer damage when characteristic signs of deer were observed in concert with obvious signs of feed consumption by the deer (eg, nose holes in bales of hay and feces of deer on silage or beet pulp piles) or by directly observing deer feeding from feed stores during the visit. A farm was classified as having had deer damage to feeds on the basis of direct observation made by the evaluators at the time of the visit or on the basis of a report from the farm manager that there had been deer damage to feeds within the past 12 months. Management areas were scored on the basis of the potential for deer-cattle interactions via the aforementioned criteria. Once risk scores for a farm were recorded, the evaluators devised a herd management plan on the basis of the management areas that had the highest scores and had the greatest risk for the herd.

Data analysis—Farm assessment data were recorded into a computerized spreadsheet,[c] and statistical tests were performed by use of a commercial statistical program.[d] Qualitative questions, quantitative scores, and herd management recommendations were summarized via descriptive analysis and reported as simple frequencies. Between-observer variability for risk scores was evaluated by use of the Spearman correlation. Significance for tests was set at values of $P < 0.05$.

By use of univariate analyses, question responses and risk scores were compared (use of *t* tests for continuous variables and χ^2 analysis for binomial variables) between farms with deer damage to stored feeds and farms with no reported deer damage to stored feeds. A multivariate logistic regression model was created to predict the probability of a farm having deer damage to stored feeds. Risk assessment variables found to be significantly ($P < 0.05$) associated with deer damage via univariate analyses were included in the logistic regression model by use of a backward stepwise elimination procedure. Independent variables were assessed for interaction. Goodness of fit was assessed by use of the Hosmer-Lemeshow χ^2 test statistic.[14]

Results

Sample—Of 857 producers contacted by recruitment letter, 191 (22%) responses were received. Sixty-four (7%) producers agreed to participate, and 127 (15%) declined participation in the study. For the 64 producers who indicated an interest in participating, 9 farms were omitted because there were < 20 cattle/farm, and a risk assessment was not completed for 2 additional farms; thus, there were 53 (6%) farms with completed risk assessments.

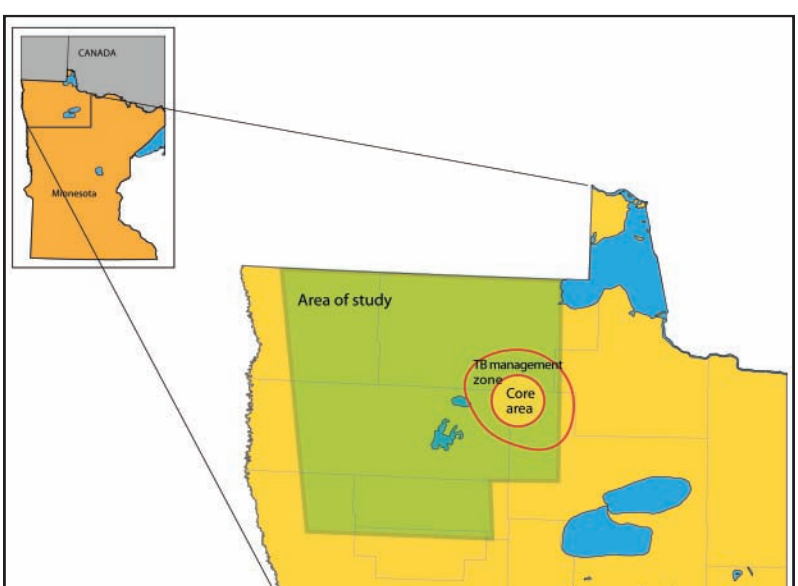

Figure 1—Map of the study area for the 53 farms on which deer-cattle interactions were assessed. TB = Tuberculosis.

On-farm risk assessments were conducted during January and March of 2008. Farms were located in Beltrami, Kittson, Marshall, Pennington, and Roseau counties. The study area was approximately 112 km (north to south dimension) by 64 km (east to west dimension), and it included farms within the tuberculosis management zone but not in the core area (Figure 1). Fifty-one (96%) farms visited were beef cow-calf operations, 1 (2%) was a dairy farm, and 1 (2%) was a farm that raised dairy replacement calves. Of the farms with adult cattle, there was a mean of 73 adult cattle/farm (range, 20 to 250 cattle/farm), whereas the farm that raised dairy replacement calves had 80 calves and no adults at the time of the visit. Eleven producers had > 100 cows/farm. There was a mean of 34 yearlings and calves/farm.

For 14 (26%) farms, there was fence-line contact with at least 1 adjacent herd (mean, 1.3 herds). No cattle had been introduced within the past 36 months on 5 (9%) farms. For the 48 farms that had introduced cattle within the past 36 months, a combination of known and unknown cattle sources was used, with 17 (35%) farms obtaining cattle from unknown sources (auctions and sales barns) and 36 (75%) farms obtaining cattle from known sources. The mean proportion of mature cattle introduced to each farm within the past 36 months was 24%.

Investigators observed that 50 of 53 (94%) farms had adequate cover for deer to inhabit the area immediately surrounding each farm. Producers were asked to describe the land types around the main farm operation within a radius of approximately 1.6 km. For 10 of 53 (19%) farms, < 20% of the land that surrounded each farm consisted of a combination of woods, swamp, or Conservation Reserve Program land (the combination hereafter referred to as deer cover). There were 23 (43%) farms that had between 20% and 50% of the surrounding land as deer cover and 20 (38%) farms that had > 50% of the surrounding land as deer cover. Twenty-seven of 53 (51%) farms had deer damage to stored feeds, as reported by the producer; the damage was verified by observations made at the time of the visit for 23 of the 27 (85%) farms. For those 27 farms, the deer damage to stored feeds was classified as severe for 11 (41%), mild-moderate for 8 (30%), and mild for 8 (30%). Deer were seen throughout the year on 11 of 53 (21%) farms, whereas deer were seen primarily during fall on 11 (21%) farms, during the winter on 6 (11%) farms, and over a combination of seasons on 25 (47%) farms. On 33 (62%) farms, producers reported seeing congregations of > 10 deer at a time on the farm during winter, and 48 (91%) farms allowed deer hunting on farm premises. A dog was located outdoors on the premises of 32 (60%) farms. For 26 (49%) farms, producers indicated that neighbors fed the deer or left field crops or feed plots for the deer. Although a variety of fencing materials was used on farms, all fences were < 3.3 m in height, except for fences on 2 (4%) farms that had 3.3-m-high fences surrounding a feed storage area.

All farms visited fed alfalfa (second- or third-cutting hay), grass (first-cutting hay), or a mixture of both to

Table 1—Risk assessment scores for 53 cattle farms in northwestern Minnesota for which an on-farm assessment for cattle-deer interactions was conducted.

Management area	Maximum possible score*	Mean score†	Spearman coefficient‡	*P* value§
Feed storage				
Alfalfa	20	15.4	0.78	< 0.001
Grass	5	3.4	0.66	< 0.001
Silage (corn)	10	8.5	0.29	0.48
High-moisture corn	10	ND	ND	ND
Grain	10	3.3	0.82	< 0.001
Beet pulp	20	14.9	0.44	0.047
Total feed storage	**75**	**27**	**0.92**	< **0.001**
Feeding practices‖				
Feeding site A	15	10.4	0.77	< 0.001
Feeding site B	15	7.0	0.76	< 0.001
Feeding site C	15	6.6	0.70	< 0.001
Mean feeding site location¶	15 (45)	8.5 (25.5)	—	—
Rapidity with which feed is consumed	15	9.4	0.46	< 0.001
Location at which minerals are provided	15	5.1	0.49	< 0.001
Total feeding practices	**75**	**33**	**0.81**	< **0.001**
Cattle housing ‖				
Cattle housing A	5	3.4	0.68	< 0.001
Cattle housing B	5	2.5	0.48	0.003
Cattle housing C	5	2.3	0.80	< 0.001
Mean cattle housing score¶	5 (15)	2.9 (7.8)	—	
Total cattle housing	**15**	**6.5**	**0.84**	< **0.001**
Water management‖				
Water A	5	1.4	0.76	< 0.001
Water B	5	0.8	0.48	0.003
Water C	5	0.9	0.47	0.009
Mean water source score¶	5 (15)	1.1 (3.3)	—	—
Total water	**15**	**2.4**	**0.74**	< **0.001**
Total risk	**180**	**69**	**0.91**	< **0.001**

Mean number of adult cattle per farm was 73, and the mean proportion of land surrounding the farm that was a combination of woods, swamp, or Conservation Reserve Program land (ie, deer cover) was 34%.

*Maximum possible score for each risk category. †Mean score for the 53 farms visited; the score for each farm was the mean of the scores for the 2 evaluators. ‡Measurement of the agreement of scores between the 2 evaluators. §The *P* value for the Spearman rank correlation score; values were considered significant at $P < 0.05$. ‖For this variable, A, B, and C refer to results for adult cattle, yearlings, and calves, respectively. ¶Mean score calculated for all 3 groups of cattle (ie, adult cattle, yearlings, and calves) on a farm; numbers in parentheses are means of the sum of total mean scores for all 3 housing groups on a farm.

ND = Not determined because high-moisture corn was not fed at any of the farms visited. — = Not applicable.

Table 2—Point estimates of the probability of deer damage to stored feed on a farm as determined by the use of logistic regression analysis of the total risk score for an on-farm assessment and percentage of deer cover.

	Deer cover (%)		
Total risk score	20	50	70
40	0.18	0.41	0.61
70	0.38	0.66	0.81
100	0.63	0.84	0.92

Odds ratio was 1.035 for total risk score and 1.04 for percentage of deer cover. Thus, for every 1-point increase in total risk score or 1% increase in deer cover, the probability of deer damage to stored feed increased by 3.5% or 4%, respectively.

cattle; 50 of 53 (94%) fed alfalfa, and 47 of 53 (89%) fed grass. Thirty-nine of 53 (74%) farms fed grain to cattle, 21 (40%) fed beet pulp, and 7 (13%) fed silage. None of the farms visited fed high-moisture corn to cattle. The highest proportion of deer damage to stored feeds that was directly observed by the evaluators during farm visits was for silage; 5 of 7 (71%) farms that fed silage had evidence of deer damage to the stored silage at the time of the on-farm risk assessment. Eight of 21 (38%) farms that fed beet pulp and 17 of 50 (34%) farms that fed alfalfa had evidence of deer damage to those stored feeds. Farms that fed grain (4/38 [11%]) and grass hay (1/47 [2%]) had the lowest proportions of deer damage to stored feeds.

Risk assessment scores—The risk assessment was originally planned such that the evaluators would calculate a separate score for each group of cattle (adult cattle, yearlings, and calves) housed on a farm. However, because cohousing of these cattle groups was commonly practiced on farms included in the study, these groups were not consistently scored separately. Therefore, a mean score for the 3 groups was calculated for the scores contained within feeding practices, cattle housing, and water management areas.

When agreement between the 2 evaluators was examined, correlation coefficients were > 0.7 for 12 of 21 risk scores, with the highest agreement in scores for total feed storage, total feeding practices, total cattle housing, and total risk **(Table 1)**. Correlation coefficients were < 0.5 for 5 risk scores, which included scores for silage, beet pulp, and the rate at which feed was consumed. The risk assessment score for silage storage was the highest score relative to the maximum possible score (8.5/10).

Management recommendations—Feed storage was the most consistently prioritized risk area; recommendations were made to 34 of 53 (64%) farms that they should fence stored hay to exclude deer. Alterations of feeding practices were frequently recommended. Recommendations were made to 20 (38%) farms to move feeding locations or reduce the amount of feed provided to cattle to minimize the amount of leftover feed that could attract deer. On 8 (15%) farms where severe deer damage was sustained, a recommendation was made to seek a permit to remove deer from the premises. The recommendation was made to 2 (4%) farms that they should discontinue intentionally feeding deer adjacent to facilities used for cattle housing or stored feeds.

Associations between land cover and deer damage—We did not detect a significant ($P = 0.76$) association between deer damage and mean number of adult cattle on a farm (75 adult cattle on farms with deer damage vs 73 adult cattle on farms without deer damage). Compared with farms without deer damage, farms with deer damage had a significantly higher percentage of land surrounding the farm classified as deer cover (28.2% vs 40.6%; $P = 0.01$) and a higher total risk score (62.7 vs 74.7; $P = 0.01$). The risk assessment score for total feeding practices was also significantly (t test statistic = 2.5; $P = 0.02$) associated with deer damage, but total feed storage score was not significantly (t test statistic = 1.84; $P = 0.07$) associated with deer damage. No other demographic or deer-related factors were significantly associated with deer damage.

Fifty farms had complete data for inclusion in the logistic regression model. Because the feeding practices and feed storage scores were part of the total risk score, they were not included in the logistic regression model. Results for a model that incorporated both total risk score and percentage of deer cover as predictors of damage to stored feed were significant (–2 log likelihood $\chi^2 = 7.58$; 2 df; $P = 0.023$). The resulting odds ratio was 1.035 for total risk score and 1.04 for percentage of deer cover; this indicated that for every 1-point increase in total risk score or 1% increase in deer cover, the probability of deer damage increased by 3.5% or 4%, respectively. Results for the Hosmer-Lemeshow goodness-of-fit test revealed that the data points for the actual observations were not significantly different from those for the model predictions, which indicated goodness of fit ($P = 0.43$). A test for interaction between total risk score and percentage of deer cover was not significant (–2 log likelihood $\chi^2 = 7.58$; 3 df; $P = 0.054$). Parameter estimates from the final model were used to estimate the probability of deer damage for specific values of risk score and deer cover **(Table 2)**.

Discussion

To our knowledge, the study reported here is the first in which investigators have quantified factors that may be associated with deer damage of stored cattle feeds on Minnesota farms. Deer-cattle interactions in Minnesota were previously described in a survey[12] conducted to estimate possible transmission of *M avium* subsp *paratuberculosis* between cattle and wildlife, in which 87% of Minnesota dairy producers observed deer on their farms, with 49% reporting at least weekly sightings and 32% reporting the possibility of physical contact between cattle and deer or their feces on at least a weekly basis. Although the evaluators in the study reported here were able to confirm deer damage to stored feed on 23 of 27 (85%) farms for which owners reported such damage, evidence of deer damage was not detected on 4 farms during the evaluator assessment. For each of those 4 farms, this was because the deer had damaged the stored feed during the preceding winter and the feed that was damaged was no longer available for inspection.

It was reported in the present study that deer were most frequently seen in the winter for only 6 (11%)

farms, whereas in a telemetry study[15] in Michigan, radio-collared deer were found to travel to farms most frequently in the spring and fall. The risk assessment tool used in the study reported here did not quantify the time of year that deer most commonly ate stored feeds, although it was assumed that winter was a higher risk than other times of the year because of a lack of other feed sources available to deer.

For the farms that were visited by the evaluators, the most common land types surrounding the farms were estimated by the evaluators with the landowner's input, although this information was not verified by use of objective data, such as satellite imagery. Nevertheless, a strong association was found between increases in the percentage of land that would serve as deer cover and deer damage to stored feeds on the farm. In a Michigan study,[16] satellite data were used to characterize the predominant land types surrounding case and control farms and this was associated with the likelihood that a herd of cattle would have bovine tuberculosis. A higher percentage of open land around a farm had a protective effect.[16] Similarly, land type in Michigan was associated with infected deer, with forested areas having a higher prevalence of deer with bovine tuberculosis and open areas having a lower prevalence of infected deer.[17] In that study,[17] spatial factors were stronger indicators of deer infection than were supplemental feeding factors. In a Canadian study,[18] the proportion of forest cover around a farm was predictive of having elk that grazed on cattle pastures.

When scores from the risk assessment were developed, the maximum scores were assigned to alfalfa (second- or third-cutting hay) and beet pulp because these feeds were expected to have a higher risk of being eaten by deer. Other high-quality forages (such as grain and silage) were assigned middle values for risk scores, and lower-quality forage (grass hay [first-cutting hay]) was assigned the lowest maximum score. Feeding trials support the hypothesis that, in winter, deer prefer high-energy feed sources.[19] However, deer will eat lower-quality feeds if they are the only feeds available. Essentially, there is no stored feed with a zero risk for being eaten by deer. This was the case for the farms visited by the evaluators because every type of stored feed they evaluated was consumed by deer on at least 1 farm.

Both silage and beet pulp had the potential to attract large numbers of deer to cattle operations, likely because of the high nutritional value of such feeds. Beet pulp is frequently fed on farms in this region (21 [39%] farms visited), although it is not widely used as cattle feed in other parts of Minnesota that are more distant from sugar beet agriculture. During the creation of assessment tools, it is important to consider the feeds and management practices that are unique to the area of interest. Both beet pulp and silage were frequently stored in open piles on the farms in the study area. Considering that deer damage was commonly seen for silage, it would be appropriate in future assessment tools to increase the maximum risk score for this feed relative to the scores for other types of feed. Bales of hay were also commonly stored in open unprotected areas. In Michigan, storing hay outdoors or leaving hay bales in fields or fence rows was associated with tuberculosis-positive herds, whereas protecting hay via bagging, wrapping, or indoor storage was associated with tuberculosis-negative herds.[16]

Cattle feeding practices were also found to be a risk factor for deer-cattle interactions; mean scores for location of feeding site and the rapidity with which feed was consumed were worth > 50% of the maximum risk score. Often, the location where cattle were housed could easily be entered by deer. To save time, many producers placed several large, round hay bales in the winter feeding area at 1 time. This practice increased the chance that hay would be leftover after the cattle had finished feeding, and the remaining hay was likely to attract deer. When large quantities of hay are fed at 1 time, cattle may eat initially, leave the remaining hay for a period, and then return to the hay after deer have eaten; the cattle can then be exposed to any potential secretions that may have been left by the deer. In Michigan, farms that had cattle with tuberculosis were significantly more likely to feed loose hay and less likely to house cattle in a barn, feedlot, or barnyard.[16] Feeding hay on the ground on farms in Michigan was associated (but not significantly) with tuberculosis-positive herds.[16]

Bulk or ad libitum feeding of feedstuffs and products other than hay was not frequently observed in the study reported here, although there was evidence that deer ate silage, beet pulp, or grain residues in feeding tubs at a few farms. In most cases, these higher-quality feeds were fed once or twice daily, and cattle would readily consume these feeds within hours after they were provided. However, creep feeders were used on 2 farms to supplement the diets of unweaned calves by providing grain on an ad libitum basis, and there was evidence of deer accessing this feed source.

Although mineral feeders may potentially attract deer, the mean risk scores assigned to this category were < 50% of the maximum possible score. In general, minerals were often made available in protected areas such as covered feeders or adjacent to farm buildings. Similarly, water sources may attract deer, but most types of waterers used during the winter were located adjacent to farm buildings or otherwise protected from freezing and less likely to be accessed by deer. Evaluation of the management practices used during the summer may reveal that those water sources (such as ponds or open water troughs) would pose a higher risk. The presence of ponds or creeks in cattle areas was associated with tuberculosis-positive herds in Michigan.[16]

Comparison of the agreement of risk scores between evaluators revealed that the 2 evaluators had a high degree of agreement for many of the management areas. However, the Spearman rank score was < 0.5 for 7 of 21 scores assigned on farms. Scores from silage and beet pulp storage both had low agreement. For these risk areas, the scoring guidelines were less definitive than for other types of feed, which had higher interobserver agreement. A potential improvement in the assessment tool would be to create more detailed guidelines for use by evaluators.

The likelihood of deer damage to stored feed on farms was predicted by use of logistic regression analysis that used the total risk score for the on-farm assessment and the surrounding land type as variables. Each variable was a significant predictor of deer damage, and the combination described the observed data well (Table 2). There is a possibility that these variables were confounded, considering that proximity to adequate deer cover was taken into account during the scoring process. However, in the logistic regression models, the odds ratio predicting deer damage on the basis of total risk score alone was similar after adjusting for percentage of deer cover (1.039 vs 1.035), which indicated that the 2 variables each provided unique information to the model. Furthermore, there was not a significant interaction between the 2 variables in the logistic regression analysis.

Producers of the farms in this study volunteered to have risk assessments performed; thus, the results have potential volunteer bias. Such a bias can mean the farms evaluated were not necessarily representative of the entire population in the region. Reasons that an owner or producer may have opted to participate in a risk assessment include a preexisting problem with deer damage to stored feeds, proximity to bovine tuberculosis–positive herds, or greater value of cattle. We also did not stratify farms or herds on the basis of size (ie, number of cattle/farm). Larger herds often require more extensive operations, with greater volumes of stored feeds that could attract deer, and this may have affected the results of the study. Furthermore, the target sample size of 61 herds was not attained, and only 53 herds were visited. The fact that we had a lower number of farms in the study may have affected the study's power and may have biased the results toward the null hypothesis.

Despite these limitations, the results of the study reported here revealed that there was deer damage to stored feeds on many farms in the study region and that many herd management practices were conducive to the risk for interspecies interactions. Furthermore, results of the risk assessments indicated that farms were not equal in their risk of deer-cattle interactions. Management practices that placed farms at higher risk of deer-cattle interactions included unprotected feed storage and feeding practices that resulted in cattle feed or leftover feed being readily or easily available to deer.

The transmission rate of bovine tuberculosis from an infected wildlife species to a susceptible domestic species depends on the spatial and temporal distance between the 2 populations, in addition to population densities, prevalence of disease, and factors that affect the survival of the bacterium outside the host.[20] Furthermore, successful transmission of tuberculosis via feed is dependent on the capacity of an infected animal to shed a sufficient amount of bacteria through bodily secretions (respiratory secretions, feces, or urine) and on the organism's ability to survive in the environment long enough for a susceptible animal to eat the feedstuff and become infected.[21] *Mycobacterium bovis* is capable of surviving for weeks to months in a variety of environmental conditions, with the longest persistence in cold temperatures when protected from sunlight. Ambient winter conditions in northwestern Minnesota are likely to be conducive to long-term survival of *M bovis*.

Although the presence of deer on a farm does not imply that deer are infected with a disease transmissible to cattle, it does increase the risk of a sufficient number of contacts between species that could lead to transmission. The flow of infectious disease can travel in either direction through shared feed; white-tailed deer in Minnesota likely became initially infected with *M bovis* by direct or indirect contact with one of the original infected cattle herds, and careful attention to theses interspecific interactions may prevent transmission of infection back to cattle.

Tremendous challenges exist in eradication of a complicated disease such as bovine tuberculosis. Wildlife-cattle interactions are only a small component of the multiple factors that must be considered; improved biosecurity for cattle herds is 1 dimension of the numerous controls that must be effectively implemented. The on-farm risk assessment evaluated in the study reported here has many advantages for use in determining potential biosecurity or management practices that can be used to prevent transmission of bovine tuberculosis. It is a relatively simple tool that can be used to quickly evaluate several risk areas and prioritize the most important risks to a farm. Minor improvements in this tool could make it even more helpful for evaluators and producers as they consider the specific needs for each farm. Wildlife species serve as potential reservoirs for diseases; thus, procedures must be implemented to control disease within affected populations as well as to control transmission of disease between populations.

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Appendix

Guidelines for scoring a risk assessment for cattle-deer interactions during on-farm assessments conducted on cattle farms in northwestern Minnesota.

Risk factor	Scoring guidelines	Risk level	Score
Alfalfa (second- or third-cutting hay)	Uncovered and adjacent to deer habitat	High	20
	Uncovered and near farm buildings	High	15
	Covered and adjacent to deer habitat	Medium	10
	Open building	Medium	8–15
	Enclosed building	Low	0–5
	Completely enclosed by a fence so as to restrict access of deer	Low	0
Grass (first-cutting hay)	Outside, uncovered, and adjacent to deer habitat	High	5
	Outside, uncovered, and near farm buildings	High	1–4
	Open or enclosed building	Low	0–2
	Completely enclosed by a fence so as to restrict access of deer	Low	0
Silage (corn)	Open pile or bunk silo adjacent to deer habitat	High	10
	Open pile or bunk silo near farm buildings	Medium	6–10
	Silage bags or bales	Medium	4–8
	Upright silo or completely enclosed by a fence	Low	0–2
Grain and concentrate	Open containers (eg, bulk bay or corn cribs)	High	8–10
	Closed containers (eg, grain bins or bags)	Low	0–6
Beet pulp	Open pile or bunk adjacent to deer habitat	High	20
	Open pile or bunk near farm buildings	Medium	15
	Completely enclosed by a fence so as to restrict access of deer	Low	0–10
Feeding site (all groups of cattle)	Within or adjacent to suitable deer habitat	High	15
	Located a distance away from farm buildings	High	10–14
	Adjacent to farm buildings	Medium	6–9
	Indoors	Low	0–2
Rapidity of feed consumption	Ad libitum feeding or feed is always available	High	15
	Between 2 and 12 hours	Medium	6–10
	Within 2 hours	Low	0–5
Location where minerals are provided	Pasture in an open feeder	High	10–15
	Pasture in a closed feeder	Medium	6–8
	Dry lot	Medium	4–6
	Barn or cattle housing	Low	0–4
Cattle housing	Outdoor only–pasture	High	5
	Outdoor only–enclosure	Medium	3–4
	Primarily indoors or confinement	Low	0
Source of water	Pond, reservoir, or wetland	High	5
	Creek, stream, or watering tank	Medium	2–4
	Automatic watering system	Low	0–2

Maximum possible total risk score for a farm was 180 (feed storage, 75 possible points; feeding practices, 75 possible points; cattle housing, 15 possible points; and water management, 15 possible points).