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Original Research

Farmer Perceptions of Hay Yard Barrier Fence Effectiveness in Mitigating Bovine Tuberculosis Transmission Risk among Elk (*Cervus canadensis*), White-Tailed Deer (*Odocoileus virgianus*), and Cattle (*Bos taurus*)

Ryan K. BROOK[1]

[1] Department of Animal and Poultry Science & Indigenous Land Management Institute, College of Agriculture and Bioresources, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK, S7N 5E2, Canada. Email: ryan.brook@usask.ca

Abstract

Wildlife diseases such as bovine tuberculosis (TB) can be transmitted among wildlife directly through contact or indirectly via shared feeds; moreover diseases such as TB can also be transmitted between livestock and wildlife. Within the Riding Mountain TB Eradication Area (RMEA) in southwestern Manitoba, Canada, a federal-provincial program provides free 2.4-m-tall game wire barrier fences for stored hay bales with the objective of preventing disease transmission between cattle (*Bos taurus*) and wild cervids. I evaluated farmer perceptions of the effectiveness of the fences using a mail survey to all 1970 rural households (52% response rate) within the RMEA, and interviewing 50 farmers that had a game wire fence for >1 year. Half (52%) of mail survey respondents supported the idea of barrier fencing. The frequency of observing white-tailed deer (*Odocoileus virginianus*) on farms (cumulative AICc weight = 0.80) was the best predictor of support. Level of concern regarding TB was second most important (cumulative AICc weight = 0.56). Of the barrier fence owners interviewed, 76% agreed that fences eliminated damage to hay bales on their farms. Furthermore, 63% agreed that their fence reduced the risk of their cattle getting bovine TB. However, only 38% agreed that their fence eliminated cattle-cervid interaction. Despite some important successes, additional work is needed to address on-going cattle-white-tailed deer-elk (*Cervus canadensis*) interactions on many

Correspondence: Department of Animal and Poultry Science & Indigenous Land Management Institute, College of Agriculture and Bioresources, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK, S7N 5E2, Canada. Email: ryan.brook@usask.ca

farms. Long-term monitoring of farmer satisfaction and compliance is needed to respond to inevitable changes in the mitigation program and evaluate success relative to objectives.

Key Words: Attitudes, Bovine Tuberculosis, Deer, Elk, Farmer, Fencing, Exclosure.

INTRODUCTION

Managing emerging infectious disease issues at the interface between wildlife and agriculture continues to be a critical area of focus in environmental management for both biodiversity conservation and farm sustainability (Daszak *et al.* 2000; Brook and McLachlan 2006, 2009; Brook *et al.* 2012). Indeed, the global costs associated with disease transmission from wildlife to livestock totals billions of dollars annually and present potentially catastrophic economic impacts to livestock trade (Burns *et al.* 2006). Complex interactions between communities of wildlife species and livestock make understanding disease and implementing effective control especially complicated (Brook *et al.* 2012). Ongoing failures in addressing disease at the wildlife-agriculture interface are in part due to the pervasive view of risk that often fails to integrate social aspects when assessing and mitigating these challenges (Brook and McLachlan 2009).

Risks in the field of natural resource management are often characterized as having 'objective' components, sometimes called 'real risk', which are defined as observable and measurable physical elements. Conversely, the 'subjective' components, often called 'perceived risk' focus on human attitudes and perceptions (Slovic 1987; Coleman 1993). Conventional risk studies have focused on the objective aspects (Coleman 1993), but there is an increasing recognition that it is critical to understand the subjective elements as well. Importantly, the subjective aspects of natural resource issues have been shown to directly influence if and how people engage in wildlife management conflicts and ultimately drive the decisions they make. Successful mitigation of wildlife-human conflicts requires commitment and on-going participation by those farmers and other stakeholders that are affected, which is greatly influenced by the subjective aspects of risk (Wilson 1997; Hill 2004; Ferreyra and Beard 2007). At the same time, those directly involved have unique perspectives on the problem and can contribute to evaluating natural resource management interventions (Selin *et al.* 2000). The needs for participatory approaches that incorporate social perspectives are particularly evident in issues of disease transmission at the wildlife-livestock interface.

Bovine tuberculosis (TB) is a bacterial disease of domestic origin that for centuries has infected cattle, humans, and wildlife throughout the world (Davis *et al.* 2010). In North America, the disease now primarily occurs in domestic cattle (*Bos taurus*) and free-ranging elk (*Cervus canadensis*), bison (*Bison bison*), white-tailed deer (*Odocoileus virginianus*), and less commonly in other wild mammals (Nishi *et al.* 2006; Brook and McLachlan 2009; Cosgrove *et al.* 2012). Bovine tuberculosis represents important risks to agricultural production and sustainability of wildlife populations.

Objective measures of risk have been intensively assessed globally for bovine TB in livestock (Humblet *et al.* 2009) and wildlife (Nishi *et al.* 2006; Jenkins *et al.* 2010; Vial and Donnelly 2012). Bovine tuberculosis transmission within and among species occurs either directly through coughing, sneezing, and licking (Sauter and Morris1995), or indirectly via shared hay, grain, silage, or pasture contaminated with TB-infected urine, faeces, or saliva (Hutchings and Harris 1997). Research on subjective aspects of bovine tuberculosis risk, while much less common than objective approaches, has nonetheless identified local perceptions of TB risk (Dorn and Mertig 2005; Brook and McLachlan 2006), evaluated opportunities for integrating local knowledge (Brook and Mclachlan 2009; Brook 2010), perceptions of bovine TB management options (Brook *et al.* 2012), and TB communication best practices (Muter *et al.* 2013). Management of TB requires recognition of the subjective aspects of risk, as the decisions made by farmers and hunters that influence risk are significantly influenced by the actions of these people to reduce on-farm risk, manage baiting and feeding of wildlife, and make land use decisions (Dorn and Mertig 2005; Brook and McLachlan 2006; Walter *et al.* 2012).

Intensive attempts to eradicate TB in livestock have resulted in important successes in some areas and on-going failures in other areas, while efforts to eradicate TB in wildlife have rarely been effective (Brook and McLachlan 2009; Davis *et al.* 2010; Smith 2011). The economic impacts of bovine TB through on-going control efforts and agricultural losses are not well documented but continue to be significant each year globally (Nelson 1999; Butler *et al.* 2010). Worldwide, attempts to prevent the spread of TB from wildlife to livestock have emphasized intensive testing and culling of wildlife and livestock (Jenkins *et al.* 2010; Ramsey and Efford 2010). These efforts have been largely successful for livestock when there is no wildlife reservoir of TB. Attempts at eradicating TB from wildlife through culling have been highly controversial and there is little evidence that they have been effective in reducing or eliminating TB without other risk management approaches (Nishi *et al.* 2005; Jenkins *et al.* 2010; Vial and Donnelly 2012).

Studies of TB in European badgers (*Meles meles*) in the United Kingdom found that culling exacerbates the problem by causing dispersal of infected wildlife, and results in higher prevalence of

TB in cattle (Vial and Donnelly 2012). However, no analogous experiments have been conducted in areas with ungulate hosts. Efforts to reduce white-tailed deer populations infected with Chronic Wasting Disease in North America using hunting have largely been ad-hoc, non-selective culling by hunters that were not conducted as real experiments, so actual effects are poorly understood. Although hunting can decrease wildlife damage and disease risk by reducing wildlife populations and maintaining a climate of fear for wildlife that keeps them away from livestock and human activity, it is unlikely to eliminate contact or disease transmission risk in most cases (Conover 2001). Non-lethal deterrents, including the use of blood meal, frightening devices, and chemical repellents are sometimes effective during the week of implementation, but rarely provide long-term protection (Wagner and Nolte 2001; VerCauteren *et al.* 2006a; Seward *et al.* 2007). Permanent fencing to protect stored hay has been suggested as one of the most effective barriers to TB transmission between ungulates and livestock (Kaneene *et al.* 2002; VerCauteren *et al.* 2006b, Brook 2010). Indeed, Carstensen and DonCarlos (2011) provide evidence suggesting potential eradication of emerging bovine TB in Minnesota through mandatory barrier fencing and reducing deer densities.

Barrier fencing has been used under diverse conditions to prevent cervid damage to stored and standing agricultural crops, and these have included woven wire and electrified wire (e.g., Fitzwater 1972; Hygnstrom and Craven 1988; Curtis *et al.* 1994). Fencing has occasionally been used explicitly to help prevent transmission of cervid and livestock disease including foot-and-mouth (Sutmoller 2002), paratuberculosis (Machackova *et al.* 2001), cattle fever (McAtee 1939), and brucellosis (Meaher 1989), with mixed results. While numerous studies have been conducted to evaluate wildlife fencing (Hygnstrom and Craven 1988; Curtis *et al.* 1994; VerCauteren *et al.* 2006b), of the 11 fencing evaluations that I reviewed, only 1 (Drake and Grande 2007) focused on 'subjective' aspects of risk.

The purpose of this study was to determine farmer perceptions (subjective aspects) of the effectiveness of hay yard barrier fences at mitigating bovine TB transmission risk on their farms within the Riding Mountain Bovine TB Eradication Area in Southwestern Manitoba, Canada. Given the important social and economic impacts of the existing TB problem, there is an important need to evaluate management options.

MATERIALS AND METHODS

This study was conducted within the Riding Mountain TB Eradication Area (RMEA) in southwestern Manitoba (50º 50'N, 100º 07'W), Canada. The RMEA (5,000 km²) was established in 2003 by the Canadian Food Inspection Agency (CFIA) around Riding Mountain National Park (RMNP) as part of an attempt to manage bovine TB through regular testing and movement controls for cattle (Figure 1). At the centre of the RMEA, the federally managed RMNP (3,000 km²) is dominated by trembling aspen (*Populus tremuloides*), mixed, and coniferous forest interspersed with small grasslands and wetlands. Lands within the RMEA were 94% privately owned farmland and 6% was owned by the Manitoba provincial government (Brook 2008). During the study, 48% of all RMEA lands were in cereal, oilseed, or forage crops (Brook 2008). Forest cover was mostly fragmented into small patches on lands unsuitable for agriculture and covered 20% of the RMEA area (Brook 2008). Elk were more abundant within RMNP, but also made extensive use of the RMEA, particularly the area <5 km from RMNP (Brook and McLachlan 2009). White-tailed deer were ubiquitous throughout the RMEA and were observed, at least occasionally, on 99% of all farms (Brook 2008). Mule deer (*O. hemionus*) were rarely observed in my study area and they are listed provincially as 'threatened'. Approximately 1,300 farms were within the RMEA during the study, of which 547 raised cattle (total holdings ≈ 50,000 cattle, CFIA unpublished data).

Several TB outbreaks occurred in cattle herds near RMNP in the 1950s and 1960s, and TB was endemic in cattle in Manitoba until at least 1970 (Lees 2004; Koller-Jones *et al.* 2006; Brook 2009). Over the last 17 years, TB has been found in 40 wild elk, 11 white-tailed deer, and in 12 cattle herds within the RMEA (Shury and Bergeson 2011). In addition, 1 radio-collared elk was confirmed TB positive in the Duck Mountains (20 km north of RMNP); it was initially captured within RMNP (Brook 2008).

Process of stakeholder interactions

To effectively incorporate the local knowledge of stakeholders, accurately reflect their perspectives, and adequately involve them in research, I incorporated on-going communication as part of an iterative and collaborative process throughout the study. This approach has proven successful in effectively engaging communities in research (Brook and McLachlan 2005, 2008; Brook *et al.* 2006). I actively engaged farmers throughout this study, initially through community meetings to discuss research objectives and for input into study design, and later through personal interviews that form the basis of this manuscript. I also included other stakeholders, such as government agency staff, aboriginal communities, and sport hunters in the consultation process, and I participated in meetings and weekly informal discussions with several local stakeholder groups to communicate study findings and obtain input on results interpretation; however, the primary focus of this study was farmers.

Regional scale attitudes assessment (mail questionnaire)

To understand attitudes of farmers toward the potential use of hay yard barrier fencing on their farms, I mailed a self-administered mail-back questionnaire to all 1,970 rural households listed by Canada Post within the RMEA identified as operating a farm (Brook and McLachlan 2006). I sent questionnaires out in late winter 2002 and I sent a follow-up reminder in the spring (Dillman

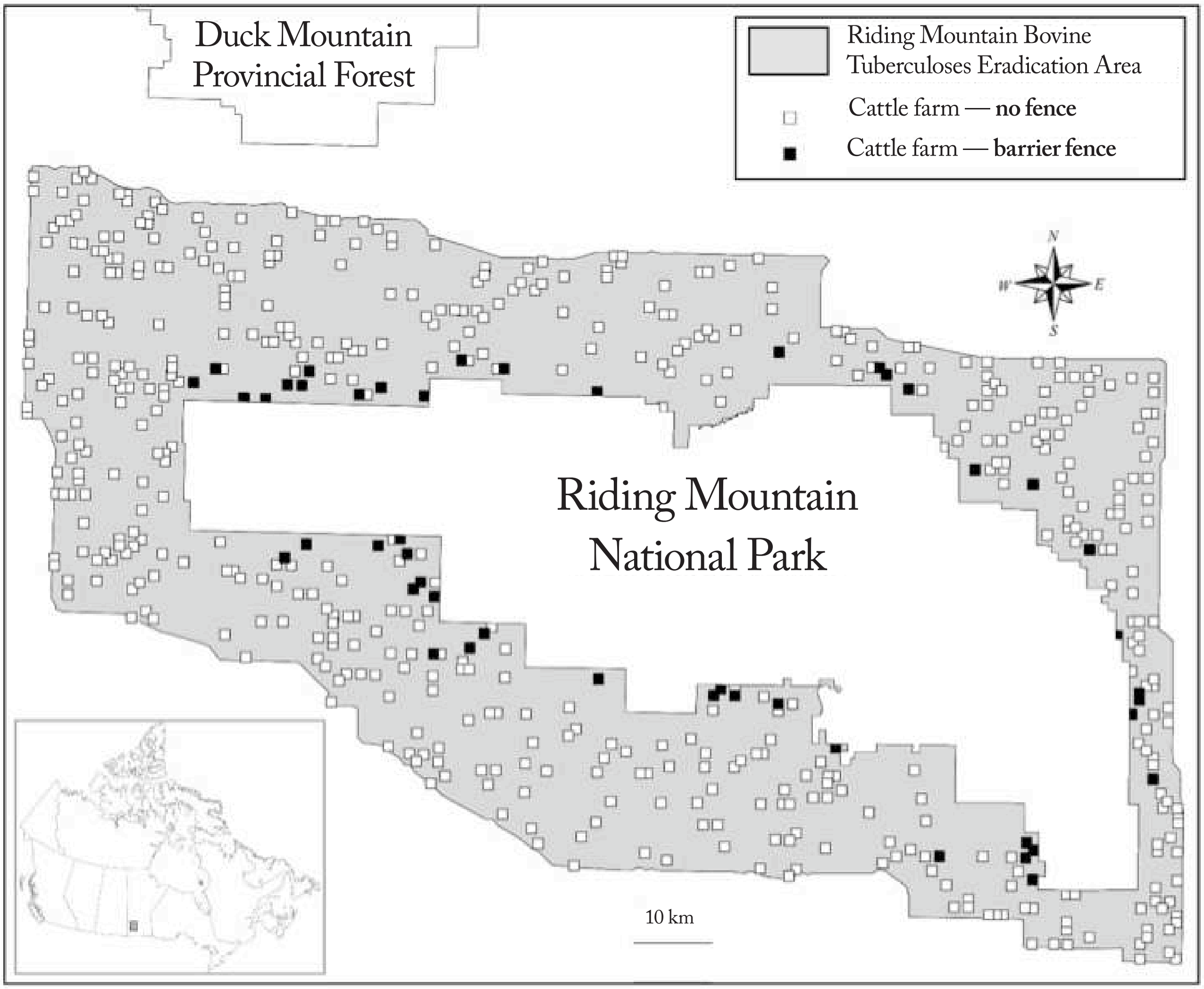

Figure 1. Locations of cattle farms with a hay yard barrier fence (at the time of the study) that were interviewed (n = 50) and all other cattle farms without (n = 497) barrier fencing within the Riding Mountain TB Eradication Area (RMEA) in southwestern Manitoba, Canada.

2007). Adjusted response rate to the mail-out questionnaires was 54% for the RMEA. This was calculated as the number of farmers responding to the questionnaire divided by the number of known farm operations because some rural landowners who received the survey were not farmers or had retired from farming. A random sample of 75 questionnaire recipients (drawn from an agricultural producers phone list) that had not responded to the questionnaire were telephoned and asked a 5-question subset from the original questionnaire to compare respondents with non-respondents. No significant differences were detected (P<0.05) between questions answered by survey respondents and non-respondents. Study design was approved under the authorization of the Joint-Faculty Human Subject Research Ethics Board at the University of Manitoba (Protocol #J2002:043).

Analytical approach

Study design and analysis followed a mixed-methods approach that includes both quantitative and qualitative science. Direct quotes from study participants were included in the results as an important element of the context and tone of the issues discussed and this allows the participants to speak directly to the research (Creswell 1998; Brook 2008).

Interviews with barrier fence owners

All 56 cattle producers within the RMEA that had a hay yard barrier fence for more than 1 year were contacted by telephone in the winter of 2005. They were asked to participate in an interview to document their experiences with the hay yard-fencing program (Brook 2010). Furthermore, I wanted to determine their perceptions of the effectiveness of the fences at reducing hay damage and wildlife-cattle contact, and provide insights into how the program might be adapted or improved in the future. Participants were interviewed over the telephone (n = 41) or in person at the owner's farm (n = 9), as decided by the respondent. I detected no significant differences between the answers obtained using the two methods (P>0.05). I included both quantitative Likert scale questions and open-ended qualitative questions administered using a semi-directive approach (Brook and McLachlan 2006, 2009). Interviews lasted 45 minutes on average. To document and assess the reasons behind farmers refusing barrier fences, 10 of the 18 farmers that declined a hay yard fence were interviewed. The other 8 farmers could not be reached or refused to be interviewed.

Statistical analysis

Analysis of the mail questionnaire and farmer interview data incorporated a mixed methods approach. Qualitative responses were systematically sorted into themes and matched to the outcomes of the quantitative data analysis. Direct quotes of respondents were included in the results to provide important context and affirmation of the quantitative results (Creswell 1998).

For the mail questionnaire data, I examined factors associated with support for page-wire (game wire) fencing using responses to the Likert-scale question about fencing as the dependent variable in binary logistic regression analysis to model the probability that support would be high. Binary logistic regression models were developed using 9 predictor variables (Table 1) derived from the literature and stakeholder consultation.

Factor analysis was used (unweighted least squares methods, Varimax rotation) to reduce all of the questions regarding TB concern into 1 conceptually similar group (SAS Version 9.1, SAS Institute Inc., USA). Items were assigned to the factor if the loading on the factor was at least 0.400. Scale reliability was assessed by calculating coefficient alpha, which was 0.92 for this analysis (Cronbach 1951). In order to examine socio-demographic and environmental variables associated with the factor "TB concern" that was identified in factor analysis, responses were sorted into high, medium, or low disease concern based on 33rd percentiles of factor scores (Brook and McLachlan 2006).

A set of logistic regression models was developed using these variables and Akaike's information criterion difference with small sample bias adjustment (AICc; Anderson *et al.* 1999). Weights were then calculated for each independent variable by summing the AICc weights of every model containing that variable (Burnham and Anderson 2002). Variables with the highest cumulative AICc weights (i.e., near 1.0) were the most important and those that were low (i.e., near 0) were unimportant. The number of farmers refusing a fence was too low for quantitative analysis, so a qualitative summary was conducted.

For the barrier fence owner interview data, I reduced the responses from 8 different questions about fence owner satisfaction into a single variable using factor analysis (Thompson 2004; unweighted least squares method, varimax rotation) (SAS Version 8.3, SAS Institute Inc., USA). I then used the resulting factor scores to sort individual respondents into relatively satisfied and relatively unsatisfied categories and I used these as a binary response variable in logistic regression to model the probability that satisfaction would be high. I anticipated from the literature and additional meetings with fence owners that there might be a wide range of variables influencing satisfaction so I created logistic regression models using twelve predictor variables (Table 2). A set of logistic regression models were again developed using these variables and AICc. Weights were then calculated for each independent variable by summing the AICc weights of every model containing that variable (Burnham and Anderson 2002).

Table 1. Description of the 9 independent variables used to develop logistic regression models to examine overall farmer support for page-wire fencing of hay yards at the regional scale.

Variable	Descripion
ELK USE	Elk Observations on farm over last 5 years (never, rarely, regularly all years)
DEER USE	White-tailed deer observations on farm over last 5 years (never, rarely, regularly all years)
TB CONCERN	Factor score of bovine TB concern from 5 questions about concern
EDUCATION	Level of education (none, grade school, high school, college, university)
HAY	Proportion of farm in hay production (%)
INCOME	Gender of respondent (male, female)
HUNTER	Gender of respondent (male, female)
CATTLE	Size of cattle herd (0, 1-20, 21-40, 41-60, 61-80...... >160)
FARM SIZE	Size of farm (ha)

Table 2. Summary of the independent variables used to develop logistic regression models to examine factors influencing farmer satisfactions with page-wire fencing of their hay yards.

Variable	Descripion
FARMER AGE	Age of farmers interviewed (years)
CATTLE FARMED	Number of beef cattle owned at the time of the survey
YEARS FENCED	Number of years that each farm has had a fence
SEE ELK BEFORE	Frequency of seeing elk before fence was installed
SEE DEER BEFORE	Frequency of seeing white-tailed deer before fence was installed
INCURSIONS	Incursions of elk or white-tailed deer inside the fence
DAMAGE VALUE	Value of hay damage before the fence
SEE ELK AFTER	Frequency of seeing elk after fence was installed
SEE DEER AFTER	Frequency of seeing white-tailed deer after fence was installed
PROXIMITY RMNP	Proximity of each farm to Riding Mountain National Park
DISTANCE TB CATTLE	Distance to the nearest case of TB infected cattle
DISTANCE TO TB WILD	Distance to the nearest case of TB infected wildlife case

RESULTS

Regional scale attitudes assessment (mail questionnaire)

Farmers in the Riding Mountain region had highly variable perceptions of page-wire fencing of hay yards that range from very strong support to very strong opposition, but more than half of all respondents (52%) to the mail questionnaire indicated positive support. At the same time, farmers identified important issues related to fencing. One respondent stated "*barbwire fences don't stop wildlife. Only an eight-foot high page-wire fence will stop* [white-tailed] *deer, elk, and moose. Barb wire and electric fence don't*" (Mail Questionnaire Respondent 2002). Another respondent noted that "f*encing of hay should be done with government* [sponsored, moveable metal] *panels; page-wire fencing is a waste because it cannot be used or moved to another site where needed*" (Mail Questionnaire Respondent 2002). Many hay producers noted the economic value of the damage to hay done by elk and white-tailed deer: "*Farmers should all have elk fences if they have hay damages of $20,000 like myself*" (Mail Questionnaire Respondent 2002). Another producer noted "*it may be wiser for cattle ranchers to put fences up to keep the elk and deer out of their hay yards instead of fencing off the Park. This way the elk and deer and moose* [*Alces alces*] *could still travel between the parks. Nature would eventually take care of this problem (hopefully)*" (Mail Questionnaire Respondent 2002).

At the time of the mail questionnaire in 2002, the hay yard barrier-fencing program was only available to cattle producers, but concerns were raised by other farmers that all hay bales may create important risks even if they are not on a cattle farm. Within the RMEA, 12% of all farmers responding to the questionnaire produced >20 ha of hay per year, but did not own any cattle, and 4% of all farms produced >80 ha of hay but did not own cattle. Of the farms producing hay but having no cattle, 19% reported seeing elk regularly on their farm and 86% reported seeing white-tailed deer regularly. Seven percent of these farmers indicated that they regularly sold hay bales to cattle producers, even after they had been visited by cervids.

Comparison between farmers that supported page-wire fencing of hay yards and farmers that did not support fencing determined that the most important factor influencing support was the frequency of observing deer on their farms (cumulative AICc weight[c] = 0.80; Table 3). The relative level of concern that farmers had about TB risk (cumulative AICc weight[c] = 0.56), the level of education of farmers (cumulative AICc weight[c] = 0.45), and frequency of observing elk on their farms (cumulative AICc weight[c] = 0.38) were less important (Table 3). All of the other variables examined had no effect on support for page-wire fencing.

Interviews with barrier fence owners

The cattle producers who received a hay yard barrier fence responded positively to the interviews and 42% indicated, unprompted, that they were very pleased that an assessment was being done to determine how well the fences were working. Only 1 fence owner refused to participate in the study and 5 could not be reached despite >7 attempts to contact them. In total, 50 fence owners were interviewed (89% of the farms that had a fence for >1 year at the time of interview). Concerns were expressed by some respondents who felt that government agencies were not responsive to farmer concerns or input. Fourteen percent of respondents felt that the interviews were of little value since their input would

Table 3. Cumulative AICc[a] weights (w) for all 9 independent variables hypothesized to influence overall farmer support for page-wire fencing of hay yards around Riding Mountain National Park.

Variable[b]	Cumulative AICc weight[c]
DEER USE	0.80
TB CONCERN	0.56
EDUCATION	0.45
ELK USE	0.38
HAY	0.30
INCOME	0.28
HUNTER	0.28
CATTLE	0.27
FARM SIZE	0.26

[a] AICc = Akaike's Information Criterion with small-sample bias adjustment (Burnham and Anderson 1998).
[b] Variables are described in Table 1.
[c] Cumulative AICc weight of a variable = the percent of weight attributable to models containing that particular variable and is calculated by summing the AICc model weights of every model containing that variable.

be ignored regardless of what was said. Other participants made positive statements about having the opportunity to discuss the fences, and many asked for information about the bovine TB situation and existing management activities. Most participants (89%) felt that their knowledge of the current bovine TB management program was relatively low, while knowledge of wildlife on their own farms was typically very high.

Perceptions of hay damage risk (interviews with barrier fence owners)

From the interviews with fence owners, most felt that the barrier fences effectively protected hay bales, with 76% of all respondents (Table 4) agreeing that the fences eliminated damage:

"*We used to have herds up to 60 elk coming onto our land, now there is zero. Wildlife don't even come to the fence. We used to have lots of damage to bales. The first year the fence was up the elk came and looked at the fence and never came back. Last year, [2004] a couple of bull elk came and walked along the edge of the fence and then went on their merry way*" (Cattle farmer 2005).

However, 23% of respondents were still having some damage to stored hay bales that were not inside the barrier fence. This was most often caused by the farmer not getting the bales inside the fence quickly enough (21%), or in 2% of the cases the fence was not large enough to contain all of the bales produced.

During the initial stages of the program, some farmers (n = 8) expressed concerns that barrier fences might work for small farms but would not be effective for larger operations. However, there was no difference between the responses to the statement 'My fence has eliminated damage by wildlife to baled hay on my farm' for respondents with large (>500 ha; i.e., greater than the mean for all cattle farms) and small farms (<400 ha; i.e., less than the mean for all cattle farms) (t = 1.10, P=0.283).

Perceptions of disease transmission risk (interviews with barrier fence owners)

Interviews with barrier fence owners revealed that while hay bales were generally well protected from elk and white-tailed deer, the fences rarely eliminated concerns regarding TB transmission to cattle. There were mixed responses to the statement "*My fence has eliminated contact between wildlife and my cattle*" (Table 4), with 38% agreeing, 56% disagreeing, and 6% remaining neutral. Respondents felt that contact was occurring directly and indirectly among elk, white-tailed deer, and livestock through shared hay bales, during swath grazing, at mineral supplements, on summer pastures, and through nose-to-nose contact, especially at feed.

Regarding the statement "*My fence has reduced the risk of my cattle getting TB*", 64% agreed, 26% disagreed and 10% remained neutral. Of particular concern are the 12% of respondents that strongly disagreed, and the 2% that moderately disagreed. Livestock contact with wildlife continues to occur and the potential risk of TB transmission remains. Indeed, 4% (n = 2 participants) of farmers were concerned that the fences may have actually placed them at greater risk of TB transmission to their cattle by keeping elk and white-tailed deer out of stored hay and 'forcing' them to feed alongside their cattle:

"*More deer are eating with the cattle now. There hasn't been as many elk coming into the yard in the last 2 to 4 years, so, they are not a problem but they used to be. I used to leave some bales out for the elk during the winters when they were in feeding with the cattle. I would see 40 to 50 elk feeding on the bales that were left out*" (Cattle farmer 2005).

Table 4. Perceptions of farmers who own hay yard barrier fences (n = 50) toward barrier fence effectiveness at eliminating damage by cervids to baled hay on their farms, eliminating contact between cervids and cattle, and reducing the risk of their cattle becoming infected with bovine tuberculosis.

Question	% Strongly Disagree	% Moderately Disagree	% Disagree	% Neutral	% Agree	% Moderately Agree	% Strongly Agree
Since my fence was built, I have noticed an improvement in my farm operation	2	0	13	40	29	10	6
Since my fence was built, I see fewer deer on my land.	18	6	30	26	16	4	0
Since my fence was built, I see fewer Elk on my land.	8	2	24	35	18	4	9
My fence has eliminated damage by wildlife to baled hay on my farm	2	2	8	12	24	8	44
The process of deciding who receives a fence is fair to everyone.	7	2	13	9	43	13	13
My fence has eliminated contact between wildlife and my cattle.	16	6	34	6	28	2	8
My fence meets the needs of my cattle operation.	4	0	4	2	47	14	29
My fence has reduced the risk of my cattle getting TB.	12	2	12	10	37	10	17

Overall satisfaction with barrier fencing (interviews with barrier fence owners)

From the interviews with fence owners, regarding the statement "*My fence meets the needs of my cattle operation*", there was a strong overall positive response, with most (90%) agreeing. This indicates that farmers are generally satisfied with the overall function of the fence on their farm and there were few concerns expressed regarding the design or function of the fences. Farmers were particularly supportive of the approach that the government agencies took in consulting with each participant extensively to design the barrier fence around their particular operation and needs. All respondents except 1 indicated that they believed the fences were well constructed and would function for more than 10 years. However, it was generally recognized that the fences would require on-going maintenance to keep them functioning. Indeed, 7 of the fences that were 2-3 years old were already showing some signs of wear, including leaning fence posts, crooked gates, and sagging wire. In some cases, bales have fallen over and stretched the wire, which may sag over time and create a spot where wildlife can jump over the fence. Currently, the policy of the barrier-fencing program is that fence owners are responsible for any maintenance or repairs required but little follow-up or monitoring is conducted by government agencies. Six respondents noted that it was critical to have several gates at different parts of the fence and make the fence large enough to allow the tractor to move hay in and out quickly and easily so that it did not interfere with the need to access hay bales daily.

Analysis of the 12 variables predicted to determine fence owner satisfaction did not identify any specific variable that had a strong effect on overall satisfaction, as cumulative AIC weights were all <0.36.

The most significant concern that emerged from the interviews was that 5 fence owners felt that they were forced into having a fence even though they did not want or need it:

"*I felt that I was 'strong armed' into taking the fence with the fact that if we didn't take the fence that we would not be covered by insurance for damaged hay bales from wildlife*" (Cattle Farmer 2006).

This was viewed by several respondents as a critical concern because if they did accept the fence then they also would not be able to make claims for hay bale damage. However, most farmers were ultimately pleased with the fence. In addition, support for the barrier-fencing program has increased substantially from the early days of 2001 when there was considerable scepticism and most farmers did not fully understand the nature and intent of the program. One farmer that received a fence indicated a high level of support:

"*I was satisfied all the way through, I just went in and made an application for it and they come out and put it up, no problem. They made a good job putting it up and it's a nice fence; it is in very good shape*" (Cattle Farmer 2006).

Satisfaction with fence allocation (interviews with barrier fence owners)

Of the fence owners interviewed, 69% agreed that the process of deciding who receives a fence is fair to everyone. Eleven participants identified 3 areas of concern regarding farms that they felt were in serious need of a fence but did not currently qualify under the existing program: 1) farms with hay damage from elk and white-tailed deer but that were far away from RMNP; 2) farms that produced large numbers of hay bales for sale, but that did not own cattle; and 3) captive elk and bison farms. In response to preliminary results from this research, the hay yard barrier fence program was broadened in 2007 to include some of these farmers. At the same time, 14% of respondents expressed concern that fences were allocated to farms that rarely or never saw elk or white-tailed deer.

Perceptions of agency participation (interviews with barrier fence owner)

Fence owners that were interviewed generally correctly knew that Manitoba Conservation and Parks Canada signed individuals up for the fence and that Parks Canada and to a lesser degree, Manitoba Conservation paid for the program. Although Manitoba Agriculture, Food, and Rural Initiatives contributed financially to the barrier-fencing program, few fence owners were aware of their involvement during the time of the interviews. Generally, the preference was that the agencies offering fences, Manitoba Conservation and Parks Canada, continue to do so. A small number of individuals had previous negative experiences with either Parks Canada or Manitoba Conservation regarding unrelated charges being laid or concerns regarding beaver (*Castor canadensis*) and other wildlife management issues and wished to have the option to choose whom they dealt with. Many respondents also felt that other groups had a responsibility to actively participate in the program, including the Manitoba Cattle Producers Association, CFIA, MAFRI, the University of Manitoba, and the Manitoba Wildlife Federation.

Barrier fence refusals

Of the 10 farmers that refused a fence and were willing to be interviewed, the reasons for refusal included: previous negative experiences with government agencies regarding charges laid in previous years for various wildlife related offences, and other wildlife management conflicts (especially related to beavers, and to a lesser degree, gray wolves (*Canis lupus*), black bears (*Ursus americanus*), elk, and white-tailed deer) were important in their decision. Six respondents that refused a fence also felt that one was not actually needed since they had little or no elk or deer use of their farm and no damage to hay bales. Five respondents felt that the TB issue was entirely the responsibility of government and it was not the responsibility of the individual farmer. Three farmers that refused a fence felt the fences would be too much trouble for them to set up in their yard appropriately and maintain, or would be difficult to work around. Fire risk that occurs when the entire feed supply is in 1 small area was a serious concern for 3 farmers. Two respondents expressed concerns regarding bales in the fenced area rotting during wet years. One farmer noted that the process of building the fence by the contractor was unacceptable:

"*I was disappointed with the service. I took a couple of days off work to help the contractors put up the fence but the contractors didn't show up to put up the fence on those days. The contractors didn't give a [expletive] and they stalled me a few times. The contractors had already dropped off the fence posts but I got really frustrated and asked them to just pick up the posts and they eventually did. I've now sold my cattle but still supply feed to other cattle producers. I wasn't big into cattle production and felt that the inconveniences of TB made them not worth keeping*" (Cattle farmer that refused a barrier fence 2005).

DISCUSSION

My findings strongly support the contention that engaging local people in assessing interventions to address natural resource-related conflicts is a critical step and that the subjective aspects of a program require detailed attention. Before the initiation of the barrier-fencing program, I identified good regional support for the concept of the program, with over half of all farmers in the region indicating support. The primary factors that determined support for the concept of fencing were the frequency of observing deer on farms and the overall level of TB concern. I have identified areas of very high success and high satisfaction among barrier fence owners after the fences were built, including strong evidence that fence owners believe that the fences are working well at protecting hay bales. However, I also identified several key areas of concern regarding the fences, which suggests important opportunities for implementing an active adaptive resource management approach that recognizes both the subjective and objective aspects of risk.

Active adaptive management represents a systematic approach to advancing the management process and responding to change by learning from the results of the implemented interventions and policies that drive them through intensive monitoring of the outcomes (Holling 1978; Walters and Holling 1990). This adaptive approach is intended to assist resource managers in responding to the surprises that inevitably occur during a management program (Clark 1980). In contrast, passive adaptive management occurs when learning occurs by chance or through cursory examination of the outcomes (Shea *et al.* 2002). When uncertainty is especially high, an active adaptive response is essential since the uncertainty limits the ability of science to predict the future (Robertson and Hull 2001). Disease problems are particularly fraught with high levels of uncertainty when multiple species of wildlife are involved and the disease itself is poorly understood (Wobeser 1996). Active adaptive management presents challenges in designing monitoring approaches for disease management strategies that allow managers to learn efficiently and incorporate information on an on-going basis.

Key aspects of active adaptive management include implementing management actions as scientific experiments with detailed monitoring of the results in order to learn and modify as required (Walters and Holling 1990). Before this study, no formal assessment had been done of the barrier-fencing program and changes have been made on an informal, ad-hoc basis by the TB Task Group, with occasional informal input from fence owners. Furthermore, The Riding Mountain barrier fencing program was not implemented as an experiment and did not have stated hypotheses or predictions of potential alternative outcomes. There has been no formal monitoring process in place before or after this study to regularly assess fence owner perceptions of fence effectiveness, nor was there any evidence of preparation for unexpected effects of the fencing program. As such, these shortcomings should be viewed as important learning opportunities.

MANAGEMENT CONSIDERATIONS

The stated goal of the Riding Mountain federal-provincial hay yard barrier fencing program was to "*reduce contact between domestic cattle and wild cervids by constructing barriers that exclude cervids from either stored hay yards or cattle feeding sites*" (Task Group for Bovine Tuberculosis 2002, 2007). Given the design and implementation of the program, it appears that there have also been 2 important unstated objectives as well: 1) to generate good will with local producers in the face of considerable conflict regarding TB management in wildlife and livestock; and 2) to obtain TB-free status recognition for the RMEA region from the United States Department of Agriculture to facilitate cattle sales into the United States. All of these have been positively addressed by the barrier fencing program. Engaging all farmers collaboratively in the process of evaluating their hay yard barrier fences has generated important results that can contribute to immediate improvements in the fencing program. This approach can serve as a model for assessing the other aspects of the bovine TB management program and indeed provides a useful approach for evaluating other resource management issues, especially those that are highly controversial in nature. The study findings underscore the need to effectively engage communities in implementing and evaluating mitigating options on an on-going basis.

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ABOUT THE AUTHOR

Ryan Brook is an Assistant Professor in the Indigenous Land Management Institute, Department of Animal and Poultry Science, and the School of Environment and Sustainability at the University of Saskatchewan. His focus is on wildlife ecology and community sustainability issues that intersect with indigenous and rural communities in Canada including caribou (*Rangifer tarandus*) health, deer, elk, moose, and feral wild boar (*Sus scrofa*). His research uses local and traditional knowledge with ecological and social research to answer theoretical and applied questions about wildlife movements, disease, and evaluating management options based on a collaborative stakeholder approach. This transdisciplinary work utilizes both ecological and social research.

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