Journal of Environmental Management 80 (2006) 156–166
Journal of Environmental Management
www.elsevier.com/locate/jenvman

Factors influencing farmers' concerns regarding bovine tuberculosis in wildlife and livestock around Riding Mountain National Park

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Received 27 October 2004; received in revised form 2 July 2005; accepted 29 August 2005
Available online 13 December 2005

Abstract

Despite intensive efforts over the last century to eradicate bovine tuberculosis (TB) in North America, several hotspots of infected wildlife and livestock remain, raising concerns that the disease will never be eradicated. The stress and frustration for a farmer caused by having a herd test positive for TB or living in an infected region can be substantial. The goal of this study was to investigate the concerns of farmers around Riding Mountain National Park (RMNP) regarding the presence of TB in wildlife and livestock and conduct an exploratory analysis of causal factors. Data were collected from 786 farmers within 50 km of RMNP using a mail-back questionnaire. Overall, farmers indicated a high level of concern toward diseases in both wildlife and cattle relative to other concerns. The spatial variables that had the greatest influence on TB concern were both the distance of farms to the RMNP boundary and distance of farms to previous cases of TB. The most important aspatial factor associated with high TB concern was the frequency with which farmers observed elk on their land. These results underscore the important differences between 'objective' measures of risk, such as epidemiological estimates of disease prevalence, and subjective measures of disease concern, such as risk perception and acceptability of management actions. Written responses suggest that concerns regarding disease may affect how farmers view wildlife on their land and their relationship with neighbouring protected areas. Management activities that reduce the frequency of elk interactions with farms, but also recognize the complex relationship that farmers have with wildlife and protected areas, will be most effective in mitigating farmer concern regarding this important problem.

Keywords: Farmer attitudes; Bovine tuberculosis; Protected areas; Logistic regression

> 'Farming near these tuberculosis positive farms is like having a sniper in the hills, it's like farming with a gun to your head—you never know when it's going to get you' (cattle producer, R074, May, 2002).

1. Introduction

Protected areas have been conventionally managed as 'islands' of natural habitat in isolation from the surrounding landscape (Shafer, 1999). Although they play a critical role in maintaining biodiversity (Janzen, 1983), few are large enough to be self-contained (Newmark, 1985; Herrero, 1994). Wildlife movements out of parks often generate management challenges as they tend to be cross-jurisdictional (Forbes and Theberge, 1996). Wildlife can adversely affect people living near these protected areas by causing economic impacts and creating risks to human health and safety (Hill, 1998; Newmark et al., 1993; Sekhar, 2003). Cross-boundary issues will only become more pronounced as landscapes continue to be altered, as protected areas become more fragmented, and as the scale of environmental pressures continues to increase (Schonewald-Cox et al., 1992). These issues have been particularly important in rural areas where wildlife associated with protected areas cause significant agricultural damage (Dudley et al., 1992; Sukumar, 1995; Naughton-Treves, 1998) and where they have been implicated in the spread of diseases that directly affect livestock (Yuill, 1987; Aguirre et al., 1995; Simonetti, 1995).

Bovine tuberculosis (TB) is a bacterial disease (*Mycobacterium bovis*) found in wildlife and livestock throughout much of the world, particularly in regions dominated by agriculture (Barlow, 1993; Schmitt et al., 1997). Impacts of TB on human health and agriculture have been devastating worldwide for

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doi:10.1016/j.jenvman.2005.08.022

centuries. More than 3.5 million people die annually from TB, with *M. bovis* responsible for approximately 3% of these cases (Cosivi et al., 1998). Bovine tuberculosis is now quite rare in humans living in industrialized countries, as a result of TB control in cattle (Ayele et al., 2004), increased hygiene, pasteurization of milk, and improved husbandry practices. TB creates significant challenges for agriculture because apparently healthy animals can be both infected and infectious, making the disease difficult to detect and remove (Radostits et al., 2000). In countries where eradication of tuberculosis is the national policy such as the US and Canada, the entire herd of cattle is destroyed when individual animals test positive. Whole herd eradication is necessary due to the difficulties in correctly identifying infected individuals using existing live animal tests and there is currently no economical or efficacious treatment for individual infected cattle. While some compensation is provided, there remains considerable stress and indirect economic impacts on farm communities (Griffore and Phenice, 2001). TB presents major challenges for the protection of human and animal health, economic sustainability of agriculture, and, indeed, the conservation of wildlife.

Historically, TB was much more widespread in North American cattle (*Bos taurus*), declining in prevalence from 2.3 to 0.003% in United States cattle in the period from 1916 to 1984 (Black, 2004) and following a similar decline in Canada. However, TB continues to be a serious problem in a few isolated areas. The disease was confirmed in nineteen cattle herds in Michigan since 1994 (Hickling, 2002), eight cattle herds in Texas (Pillai et al., 2000) since 1997, and eleven cattle herds in Manitoba since 1991 (Lees et al., 2003), as well as numerous herds in other states and provinces. TB has also been recognized as a significant problem in ranched elk (*Cervus elaphus*) and other captive wildlife (Stumpff, 1982; Whiting and Tessaro, 1994). While cases of TB in free-ranging wildlife in North America are generally rare, TB has recently been found in isolated groups of wild bison (*Bison bison*), elk, deer (*Odocoileus virginianus*), and a variety of carnivore species including wolves (*Canis lupus*) and coyotes (*C. latrans*) (Clifton-Hadley and Wilesmith, 1991; Joly et al., 1998; O'Brien et al., 2002). It can be spread by direct contact among infected animals, airborne exposure, or through shared foods, milk, urine and feces (Clifton-Hadley and Wilesmith, 1991; Radostits et al., 2000).

Risks associated with and responses to TB in North America have largely been science-based and identified using epidemiological models (e.g. McCarty and Miller, 1998; Pillai et al., 2000; Smith, 2001) and managed by government-initiated efforts focused on wildlife and agriculture (e.g. Frye, 1995; Lees, 2004). However, studies increasingly suggest that the mitigation of wildlife-agriculture conflict improves when the perspectives of local communities and other stakeholders are included in meaningful ways (Selin et al., 2000), especially since the majority of wildlife habitat outside of protected areas in human dominated landscapes is often privately owned (Horvath, 1976). Landowner concerns about wildlife impacts thus have broad, long-term repercussions for government programs designed to mitigate wildlife interactions on private property (Conover, 1994). Indeed, excessive impacts may discourage some private landowners and other stakeholders from managing in ways that benefit wildlife (Conover, 1994). There is currently a need for more comprehensive approaches for managing diseases such as TB that include models incorporating stakeholder concerns and experiences, especially those of farmers.

The overall objective of this study was to assess the concerns of farmers regarding the presence of TB in wildlife and livestock. More specifically, we examined TB-associated concerns relative to other issues confronting rural communities and conducted an exploratory assessment of the degree to which underlying socio-demographic and environmental variables affected TB-associated concerns. These analyses are part of a comprehensive study examining wildlife-agriculture interactions around Riding Mountain National Park.

2. Materials and methods

2.1. The study area

The study area is located in southern Manitoba, Canada and includes the agriculture-dominated area within 50 km of Riding Mountain National Park (RMNP) (Fig. 1). It represents a broad transition zone between the prairies and the more northern Boreal Plains (Bailey, 1968). Much of the region is dominated by glacial topography and is poorly drained. RMNP is 2,974 km^2 (297,746 ha) in size, extending 110 km from east to west and 60 km from north to south. It is dominated by the Manitoba Escarpment, which rises to 475 m above the surrounding, largely flat landscape. The park represents a core area of relatively undisturbed wilderness and is surrounded by land used for agriculture, which is dominated by oilseed and cereal crop, pasture and hay production, interspersed with patches of deciduous and mixed forest. Over 50,000 beef cattle are currently being raised in the region (Statistics Canada, 2002). Wildlife is abundant, including a regional population of approximately 2700 elk (*Cervus elaphus*), 2500 moose (*Alces alces*), and more than 5000 deer (Riding Mountain National Park 2004, unpublished data). Large predators include grey wolves (*Canis lupus*), black bears (*Ursus americanus*), lynx (*Lynx canadensis*), and coyotes (*Canis latrans*).

Conflicts among agricultural producers and government agencies in the Greater Riding Mountain Ecosystem are particularly common on matters such as water quality, flooding, wildlife depredation and damage (Dodds and Fenton, 1999), hunting seasons, resource extraction (Schroeder, 1981), and disease (Brook and McLachlan, 2003). Local residents often express dissatisfaction and discontent at how they have to bear costs associated with the movement of wildlife out of protected areas (Schroeder, 1981; Brook and McLachlan, 2003). Elk-agriculture interactions, particularly related to TB, have recently been associated with some of the most intense conflicts in the region (e.g. Seraphim, 2003; Nicoll, 2004). As a result of the number of recent TB positive cattle herds, the Riding Mountain Eradication Area (RMEA) was created in

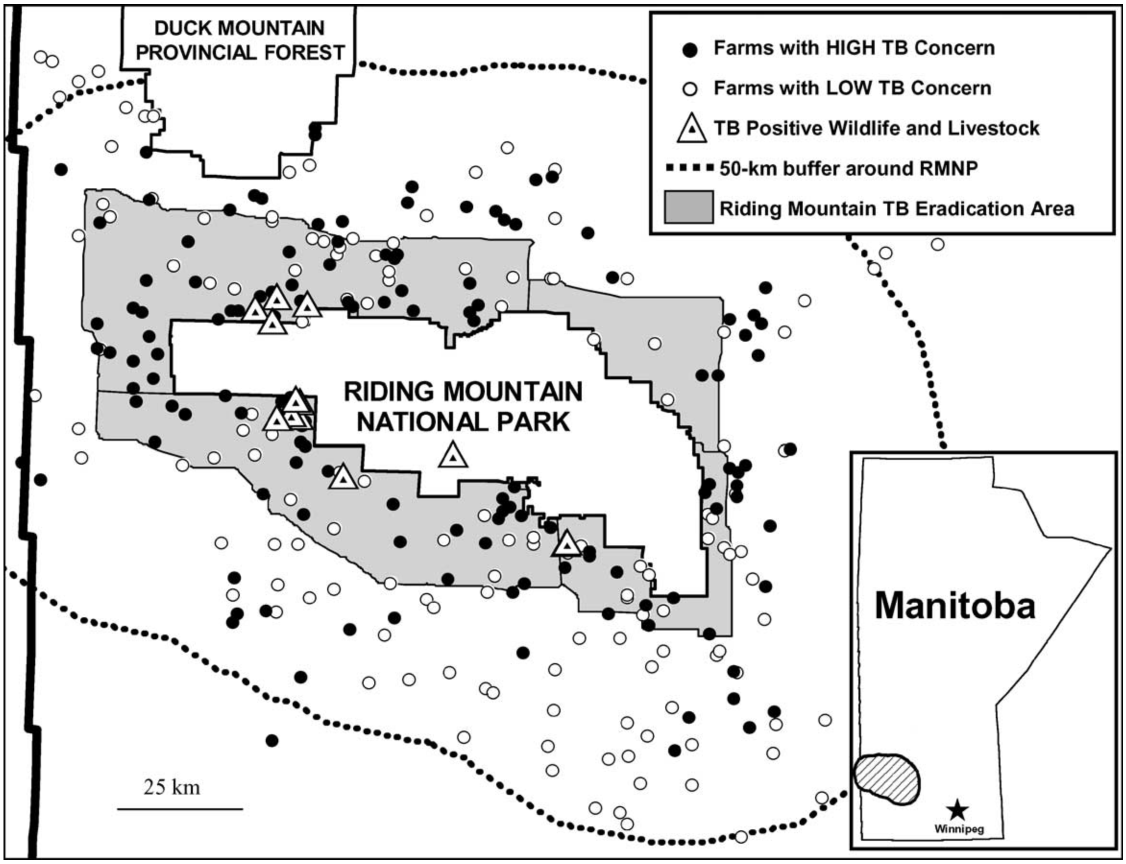

Fig. 1. The study area including distribution of farm respondents and TB positive wildlife and livestock relative to Riding Mountain National Park, Manitoba, Canada.

2003 by the Canadian Food Inspection Agency around RMNP to try to eradicate the disease through intensive livestock testing and controls on cattle movement (Fig. 1). Manitoba's TB-free status continues to be threatened by the presence of the disease around RMNP.

2.2. Data collection and field techniques

Canada Post mailing lists were used to identify all 4220 rural households within 50 km of RMNP. All households listed by Canada Post as operating a farm were mailed a questionnaire on 18 April 2002. A self-addressed, stamped envelope was enclosed with the survey to facilitate its return. A follow-up letter was sent 18 May 2002. All surveys returned prior to 31 August 2002 were included in subsequent analyses. Overall response rate was calculated by dividing the number of completed questionnaires from farm operators ($n=788$) by the number of surveys sent out to verified farm operators ($n=3148$). Study design was approved under the authorization of the Joint-Faculty Human Subject Research Ethics Board Protocol at the University of Manitoba. Seventy-five survey recipients that had not responded to the survey were telephoned and asked five questions subset from the original questionnaire to assess whether a non-response bias existed.

The questionnaire was, in part, designed to determine farmer concerns regarding TB in wildlife and livestock and to identify the influence of socio-demographic and farm management variables on these concerns. Important themes were initially identified by attending seven town hall meetings throughout the study area between January and April 2002, where comments of over 500 local agricultural producers were documented. Insights were also gained from discussions with staff from federal and provincial agencies as well as agricultural and wildlife stakeholder groups. The questionnaire was pre-tested on 15 highly knowledgeable farmers, as well as researchers and government staff. The final version was nine pages long, contained 257 data variables, and took about 30–50 min to complete. Respondents rated statements on a 7-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. Farmers were also asked to provide written comments on all aspects of this survey and list any other concerns that they had. One question asked respondents to indicate the location of their farm.

2.3. Data analysis

2.3.1. Farmer socio-demographic composition

Socio-demographic variables describing respondents in the region were summarized to characterize farmers and compare cattle producers with non-cattle producers. Data from the 2001 Agriculture Census of Canada for this region (Region 3, Division 15) (Statistics Canada, 2002) were compared with survey results in order to assess the representative nature of the questionnaire data from this study using *t*-tests.

2.3.2. Regional context of disease concern

In order to consider farmers' concerns regarding disease within the context of other regional concerns, factor analysis was used (unweighted least squares method, varimax rotation) to reduce the fifteen questions regarding concerns into conceptually similar groups (SAS Version 8.3, SAS Institute Inc., USA). Items were assigned to factors if the loading on the factor was at least 0.400. Scale reliability was assessed by calculating coefficient alpha (Cronbach, 1951). Differences in group means of the factor scores between cattle producers and non-cattle producers were analyzed using *t*-tests.

2.3.3. Factors underlying farmers' level of concern regarding disease

In order to examine socio-demographic and environmental variables associated with the factor 'disease concern' that was identified in factor analysis, a total of 546 surveys from farm operators with no missing responses were sorted into high, medium or low disease concern based on 33rd percentiles of factor scores. Factor scores for 182 respondents in each of the high and low categories were then used as a binary response variable in logistic regression to model the probability that concern would be high. Instead of using a null hypothesis and a single alternative hypothesis, a small meaningful set of multiple competing hypotheses were identified and compared using Akaike's information criterion (AIC) (Anderson and Burnham, 2002). Formal statistical inference was based on all of the models in the set (multi-model inference) rather than on the single best model (Anderson et al., 2002).

Ten socio-demographic, farm, and wildlife interaction explanatory variables were selected to create a set of candidate models of disease concern. Each of these variables was hypothesized to meaningfully influence farmers' concerns regarding disease according to the literature. These independent variables were first screened for excessive collinearity using a Spearman rank correlation matrix for all possible pairs of independent variables. If any two variables had $r>0.7$, the less important variable was removed. Following Burnham and Anderson (2002), we then developed a global model that included all variables and a set of alternate models that included linear and squared terms as interaction terms between elk use, elk contact, farm size and income that we hypothesized might influence overall disease concern. In order to estimate and graph the relative probability of high disease concern, scaled values from the logistic model were used. Predicted values were standardized to a scale of 0–1 following Johnson et al. (2004). Many farmers provided the location of their farm in the survey (71%), so spatial aspects of disease concern were analyzed separately from the other independent variables. The minimum distance of each farm to the RMNP boundary and to previous TB outbreaks in wildlife and cattle was measured using Arcview GIS 3.2 (ESRI Inc., USA).

Akaike's information criterion difference with small sample bias adjustment (ΔAIC_c) and Akaike weights (w) were used to evaluate and select the model that includes the fewest number of independent variables to explain the greatest amount of variation (Burnham and Anderson, 2002). The model with the lowest ΔAIC_c is selected as the best from the set. Akaike weights provide a normalized comparative score for all models and are interpreted as the probability that each model is the best model of the set of proposed models (Anderson et al. 2000). Substantial support for a model occurs when $\Delta AIC_c < 2$. Cumulative AICc weights were then calculated for each independent variable thought to influence TB concern by summing the AICc model weights of every model containing that variable (Burnham and Anderson, 2002). Variables with the highest cumulative AICc weights have the greatest influence on TB concern.

2.3.4. Qualitative responses

Farmers were also invited to write their comments on the questionnaire, which were recorded verbatim. Responses were systematically assessed and identified with underlying themes. Comments were incorporated with the quantitative results as complementary information, in that they provide a rich description of the concerns held by farmers and the factors that influence them.

3. Results

3.1. Questionnaire response

A total of 1338 surveys were returned by mail and the overall adjusted response rate was 25%. Questionnaires were received from 27 rural municipalities in Manitoba and one response was received from Saskatchewan. Reasons for refusing to complete the questionnaire, listed in decreasing order of importance, included: respondents did not operate a farm, frustration with government over wildlife management issues, respondents lived outside of study area, and frustration over study design. No differences in concern were identified between respondents and non-respondents.

3.2. Farmer socio-demographic composition

Nine socio-demographic variables were used to describe farmers in the region (Table 1). Slightly more than half (55%) of survey respondents had at least some cattle and 45% had more than 20 head. Respondents averaged 52 years of age (range 18–85). The 2001 Agriculture Census of Canada for this region (Region 3, Division 15) determined average age of operators to be 50 (Statistics Canada, 2002). On average, cattle producers were 3.5 years younger than non-cattle producers ($t=3.7$; $df=629$; $p=0.002$). Overall, there were many more male respondents (91%) than female (9%). While 78% of farmers in the region are male (Statistics Canada, 2002), farms are generally operated by both women and men working together. The large majority of respondents (92%) lived at the current location for 5 or more years and most (81%) were

Table 1
Comparison of socio-demographic characteristics of cattle producers and non-cattle producers on farms area (% of each category for each variable)

Variable	Cattle producers ($n=444$)	Non-cattle producers ($n=340$)	All farmers combined ($n=784$)
Gender			
Males (%)	91	90	91
Females (%)	9	10	9
Mean age			
>55 years	41	51	40
40–55 years	44	37	45
<40 years	15	12	15
Income from farming			
>60% of total	69	49	60
30–60% of total	22	20	21
<30% of total	9	31	19
Education			
College/university	40	45	43
High school	41	33	38
Grade school	18	21	20
Farm size (ha)			
>500 ha	36	23	31
100–500 ha	54	47	51
<100 ha	10	30	18
Cattle herd size			
>100 cattle	28	n.a.[a]	28
40–100 cattle	36	n.a.	36
<40 cattle	35	n.a.	35
Distance to RMNP			
>20 km	38	35	40
10–20 km	21	25	23
<10 km	41	40	40
Location raised			
Farm	92	87	86
Non-farm	8	13	14
Hunting days on farm			
>50 days	11	12	12
1–50 days	58	46	53
0 days	30	42	35

[a] Not applicable.

raised on a farm. The highest level of educational achievement varied, with very few having no formal education (<1%), 35% having high school education, and 40% having college, university, or technical training. The mean respondents farm size was 467 ha (range 16–5666 ha), whereas the overall average farm size is 419 ha for this region (Statistics Canada, 2002).

3.3. Regional context of disease concern

Three separate factors were identified in the factor analysis that summarized the concerns of farm operators (Table 2). Factor 1 represents the level of concern regarding disease in wildlife and livestock, specifically TB in cattle, deer, elk, and moose, but also including concern regarding chronic wasting disease (CWD). Factor 2 represents concern regarding wildlife issues, particularly those associated with elk hunting, as well as elk ranching. Factor 3 represents broader societal issues, including cuts to agricultural subsidies, grain elevator closures, and rural crime. Values of Cronbach alpha for the disease concern, wildlife issues, and societal issues factors were 0.92, 0.80, and 0.66, respectively (Table 2). All alpha values are > 0.60, which is adequate for variable reduction (Nunnally and Bernstein, 1994).

A wide range of disease concern was expressed in the factor scores (range $= -3.79$ to $+1.53$). At one extreme, one cattle producer indicated 'The reason I have no concern for TB in cattle is because the cattle industry has a program to deal with TB' (cattle producer, R311, May, 2002). In contrast, many farmers expressed extreme levels of concern regarding TB and its impacts. Another cattle producer indicated its economic ramifications:

> 'I am very concerned about the threat of TB in our area and the economic impact on the beef industry in Manitoba if a widespread outbreak happens. I have lived my entire life on my farm and my family has raised cattle here for nearly 50 years and I do feel threatened by this TB problem north of us. We have bills to pay and debt to service, if cattle prices drop or we can't sell them because of TB in our area we will be forced out of business. I like seeing wildlife on my land, but not if they are threatening our livelihood' (cattle producer, R346, May, 2002, emphasis in original response).

Indeed, many of the written comments indicated a strong feeling that TB could irreparably damage their farm and that

Table 2
Variable reduction of farmer's concerns toward a range of regional issues using factor analysis

Factor	Variable	Mean scores[a] cattle producers (SD) ($n=444$)	Mean scores[a] non-cattle producers (SD) ($n=340$)
Disease concern	TB in cattle	5.9 (1.7)	5.5 (1.8)
	TB in WILD ELK	5.7 (1.8)	5.5 (1.8)
	TB in DEER	5.7 (1.8)	5.5 (1.8)
	Chronic wasting disease	5.6 (1.8)	5.6 (1.8)
	TB in CAPTIVE ELK	5.5 (1.9)	5.5 (1.8)
	TB in MOOSE	5.2 (2.0)	5.3 (1.8)
Wildlife issues	ELK baiting by hunters	5.0 (2.2)	4.9 (2.1)
	ELK ranching	4.7 (2.3)	4.5 (2.2)
	Feeding ELK	4.5 (2.1)	4.2 (1.9)
	Length of ELK hunt season	4.2 (2.0)	4.3 (1.9)
	Number of ELK hunters	4.1 (2.0)	4.1 (2.0)
Societal issues	Rural crime	5.8 (1.6)	5.9 (1.6)
	Cuts in Ag subsidies	5.7 (1.9)	5.9 (1.8)
	Grain elevator closures	5.6 (1.9)	5.9 (1.7)

[a] Scores were derived from a 7-point scale, with 1 indicating 'no concern' and 7 indicating 'extremely high concern'.

Table 3
Spatial and aspatial explanatory variables used in developing the set of models to examine TB concern

Abbreviation	Variable
GENDER	Gender of respondent (male, female)
ELKCON	Elk have come into direct physical contact with cattle on the farm (yes, no)
ELKIND	Elk have come into indirect contact with cattle on the farm through shared feed (yes, no)
DEERCON	Deer have come into direct physical contact with cattle on the farm (yes, no)
DEERIND	Deer have come into indirect contact with cattle on the farm through shared feed (yes, no)
AGE	Age of respondent (years)
EDUCAT	Highest level of educational achievement of respondent (grade school, high school, college/university)
BEEFCATL	Size of cattle herd (0, 1–20, 21–40, 41–60, 61–80… >160)
ELKUSE	Frequency of elk observations on farm over last 5 years (never, rarely, regularly all years)
DEERUSE	Frequency of deer observations on farm over last 5 years (never, rarely, regularly all years)
DISRMNP[a]	Minimum distance from farm to RMNP (km)
DISTB[a]	Minimum distance from farm to a TB positive wildlife or livestock case (km)

[a] Spatial variables.

disease represents a new type of risk. Some farmers felt it was unlikely that TB would ever be eradicated from the region.

Overall, farmers indicated a high level of concern toward diseases in both wildlife and cattle relative to all concerns listed in the questionnaire (Table 2). Predictably, the mean factor score regarding level of concern associated with disease was significantly higher for cattle producers (mean $=0.07$, SD $=1.01$) than for non-cattle producers (mean $=-0.08$, SD $=0.98$) ($t=3.7$; df $=629$; $p=0.035$). For cattle producers, concern regarding TB in cattle was highest relative to all other questions retained in the factor analysis (Table 2). For non-cattle producers, the three social issues, rural crime, cuts in agriculture subsidies, and grain elevator closures were of greatest concern relative to the other variables, followed by all of the disease issues. All of the issues related to hunting including baiting, feeding, and the length of the hunting season scored relatively low for both cattle producers and non-producers.

The questionnaire was primarily focused on disease issues but the open-ended responses included a broad range of other concerns. One producer felt that

> ‘There should be better cooperation between the park and its neighbours. It is all right for the elk to come out and eat our hay and crops but we cannot take a stick of dry wood or pick a pail of cranberries’ (farm operator, R093, May, 2002).

Farmers also frequently expressed concern regarding beavers (*Castor canadensis*) and their impacts. Indeed, the word ‘beaver’ was included 141 times in the written responses, even though there were no questions about or references to beavers in the questionnaire. However, many farmers made the link between beavers and disease, suggesting that habitat inside RMNP has been significantly degraded by beavers and many felt that this is an important cause of elk movements out of the park. Other concerns included wildlife impacts from bears, wolves, geese and coyotes. Anxiety related to all levels of government and their management actions was also readily apparent.

3.4. Factors underlying farmers’ level of concern toward disease

We used ten independent variables (Table 3) from 364 responding farms to construct nine plausible models to represent aspatial factors influencing disease concern of farmers (Table 4). The maximum Spearman rank correlation among the ten variables used was $r=0.619$ and the minimum was only $r=-0.219$, and so all were included in the analyses. The best model included only the frequency of elk observed on the farm (ELKUSE) as a single variable, resulting in a ΔAIC_c value of 0 (Table 4). Three models that included the frequency of elk observed on the farm (ELKUSE) along with perceived direct contact between elk and cattle (ELKCON) and perceived indirect contact between elk and cattle (ELKIND), as well as number of beef cattle (BEEFCATL) had moderate support relative to the top-ranked model (i.e. $\Delta AIC_c < 4$).

Table 4
Number of model parameters, differences in Akaike information criterion ($\Delta-AIC_c$), and AIC_c weights (w) for candidate aspatial models developed for farmer concern regarding disease around Riding Mountain National Park

Model structure	-2Log(L)	k	$\Delta-AIC_c$	AIC_cw
ElkUse	489.593	2	0.0	0.586
ElkCon + ElkInd + ElkUse + BeefCattle	486.409	5	2.8	0.143
$ElkUse^2$ + ElkInd + ElkUse* ElkCon	484.512	6	2.9	0.136
$ElkCon^2$ + ElkInd + ElkUse	486.59	5	3.0	0.131
ElkCon + ElkInd + DeerCon + DeerInd + ElkUse + DeerUse + Age + Gender + Education + BeefCattle	482.437	11	10.8	0.003
ElkInd	502.718	2	13.1	0.001
ElkCon	504.611	2	15.0	<0.001
Age + Gender + Education + BeefCattle	502.947	5	19.4	<0.001
DeerCon + DeerInd + DeerUse + Age + Gender + Education + BeefCattle	498.914	8	21.3	<0.001

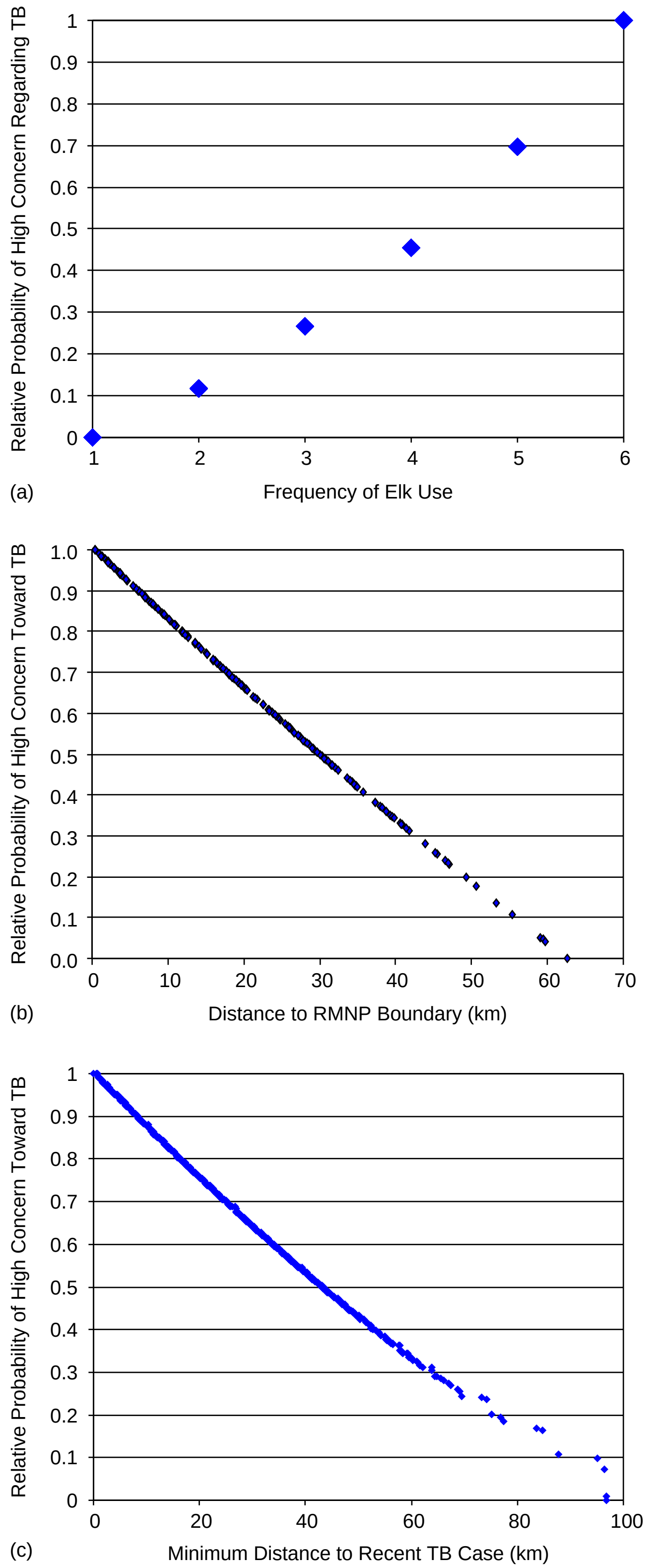

Fig. 2. Relationship between relative probability of high level of concern regarding TB and (a) frequency of elk use of respondent's farm; (b) distance of the respondent's farm to the RMNP park boundary; and (c) distance of the respondent's farm to the nearest case of TB in livestock or wildlife in the last 15 years. Each figure represents the modeled results using the coefficients that were obtained from the best logistic regression model describing factors influencing farmers' concern regarding TB (Tables 3, 4 and 6).

The positive coefficient for ELKUSE indicated that farmers observing elk more frequently on their land were more likely to have higher levels of disease concern (Fig. 2). Written responses frequently indicated that elk were considered to be reservoirs of disease that come out of the park and infect cattle herds. Perceiving that elk are central to the TB issue, one cattle producer indicated:

> 'The Big ANIMAL in question is elk. What are we going to do with this ANIMAL? How are we going to stop the spread of this disease within this animal? We have to have a control of some type, monitoring, eradicating some of the animals that carry the disease or are ill. Letting the animals run free and wild is not too acceptable at this moment if they are the ones spreading this disease. Keeping them in the park is a very important factor in controlling this disease outside the park' (farm operator, R427, May, 2002, emphasis in original response).

This comment reflects the frustration and fear that farmers have about disease and suggests that wildlife may not be as welcome on some farms as they once were. It also emphasizes the attitude of many farmers that elk belong inside the park and should not be moving outside of the boundary.

Summation of the Akaike weights (Burnham and Anderson, 2002, p.168) for the independent variables results in a value of 0.99 for the frequency of elk observed on the farm (ELKUSE), thus the weight of evidence strongly supports this variable as the most important (Table 5). The other nine variables (direct contact between elk and cattle, indirect contact between elk and cattle, gender, direct contact between deer and cattle, indirect contact between deer and cattle, age, education, size of cattle herd, and frequency of deer observed on the farm) were of minimal importance relative to the frequency of elk observations.

In response to the questions regarding the area from which farmers perceived that elk using their land came from, mean response was highest for RMNP (mean = 6.0, SE = 0.13) on a scale ranging from 'strongly disagree (1)' to 'strongly agree (7)'. In contrast, few believed these elk originated from private land on or near their farm (mean response = 3.7, SE = 0.12) or from the Duck Mountains, a provincial forest and park 20 km to the north (mean response = 2.9, SE = 0.12). In their comments, many respondents indicated that they tolerated or even enjoyed seeing wildlife on their land, but also suggested that this could change because of TB:

> 'I don't push bush or drain water on my land and if ducks, geese, deer, coyotes and many other animals survive there that's great, but I think it would be silly and stupid to protect any species of wildlife that threatens to ruin the beef industry in Manitoba' (cattle producer, R483, April, 2002).

The feeling that wildlife were directly threatening the survival of farms was common among respondents and many felt that level of concern warranted significant action to reduce or eliminate the disease. One farmer noted that:

Table 5
Cumulative AICc weights (*w*) for all ten independent variables hypothesized to influence farmer concern regarding TB around Riding Mountain National Park

Variable[a]	Cumulative AICc weight[b]
ELKUSE	0.99
ELKIND	0.07
ELKCON	0.07
DEERCON	0.07
DEERUSE	0.06
EDUCAT	0.06
DEERIND	0.06
GENDER	0.06
AGE	0.06
BEEFCATL	0.06

AICc, Akaike's Information Criterion with small-sample bias adjustment (Burnham and Anderson 2002).
[a] Variables are described in Table 3.
[b] 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.

> 'I grow and sell hay and oats for sale to the horse and cattle trade. My concern is I've had some hay sales rejected because elk and deer were in the bales. The concern was of TB risk' (farmer, R347, May, 2002).

However, the written comments also reflected a broader context to the concerns, in that they viewed disease risk within the scope of impacts on the community as a whole and on future generations. One farmer expressed great concern regarding TB, but felt that:

> 'Depleting the elk population is not an option. They must be managed accordingly, so that our children's grandchildren may enjoy the presence of these wonderful creatures in a wild state' (cattle producer, R079, May, 2002).

The two spatial variables, distance to RMNP (DISRMNP) and distance to TB cases (DISTB) (Table 3) were used to develop five plausible spatial models using responses from the 381 farmers that included location of their farms in their responses. All of the resulting models were well supported, i.e. $AIC_c < 2$ (Table 6). Two models had $AIC_c = 0$; distance to RMNP alone (DISRMNP) and distance to TB cases (DISTB) alone, indicating that both variables influence disease concern

Table 6
Number of model parameters, differences in Akaike information criterion ($AIC_c\Delta$), and AIC_c weights (*w*) for candidate spatial models developed for farmer concern regarding disease around Riding Mountain National Park

Model structure	−2Log(L)	K	$AIC_c\Delta$	AIC_cw
DISRMNP	351.90	2	0.0	0.437
DISTB	351.86	2	0.0	0.445
DISRMNP + DISTB	350.46	3	0.6	0.330
DISRMNP*DISTB	352.11	3	2.3	0.145
$DISRMNP^2$*DISTB	351.31	4	3.4	0.080

(Fig. 2). Many cattle producers emphasized the relationship between disease risk and proximity to RMNP:

> 'Farmers with livestock who live along the park are constantly worried about their animals as elk and deer eat their bales along with their cattle. There is always the risk that the elk and deer may be disease carriers' (cattle producer, R493, May, 2002).

Many respondents indicated that the threat is so serious that their perceptions regarding disease and wildlife are unlikely to change in the future.

4. Discussion

The results of this study suggest that both cattle producers and non-producers are greatly concerned about disease in livestock (66% of respondents) and wildlife (64% of respondents). Cattle producers were more concerned, in large part because they are more directly threatened by TB, since any infected livestock herd must be destroyed in its entirety. Understanding the subjective nature of perceptions of disease, and the risk that diseases represent, is particularly important in the Riding Mountain region because of the low level of disease and high level of concern. The likelihood of any single cattle farm becoming infected is < 1% per year (Lees et al., 2003), yet the impact on any farm testing positive is severe. Farmers are compensated by the federal government with the market value of the cattle if they are destroyed, but the financial and emotional impacts of testing positive remain extremely high. There is typically a significant delay of several months between testing positive for TB and receiving compensation. There are also important indirect impacts related to financial costs of lost sales of forage crops and other livestock from this region due to fear that these products may also carry disease. Of particular concern is the impact of TB positive livestock on Manitoba's TB-free status, which has important implications for national and international beef sales (Lees, 2004). Similarly, in Michigan, 58% of livestock producers agreed or strongly agreed that TB in deer is a serious threat to the health of Michigan cattle herds (Dorn and Mertig, 2002). Predictably, livestock producers are the most concerned about TB in cattle and hunters are the most concerned about TB in deer (Dorn and Mertig, 2002).

The occurrence of positive test results for TB in elk, deer and cattle near each other and close to the RMNP boundary has intensified concerns that TB is spreading between wildlife and domestic animals and that RMNP is acting as a disease reservoir (e.g. Sopuck, 2002). Farmers that see elk more frequently on their farms, those that feel that the elk are coming into direct and indirect contact with cattle, and those that are located close to RMNP and to previously identified TB cases in wildlife and livestock have the highest concern regarding disease. However, it is also important to note that farmer concerns vary widely regarding these impacts and regarding the role of governmental agencies in managing this problem. These results emphasize that farmers cannot be assumed to have a common set of concerns. It is also critical to recognize that these concerns exist within the social and cultural context (Douglas, 1985). That context includes a long history with decades of conflict with Parks Canada, and the provincial government regarding natural resource and wildlife issues related to ungulate crop damage, beaver flooding, bear baiting, and hunting regulation (Schroeder, 1981; Dodds and Fenton, 1999; Brook and McLachlan, 2003). Concerns were often associated with anxiety about centralized federal and provincial government decision making, lack of trust, difficulty in accessing relevant information, and a general sense that decisions were made with little or no farmer input.

National park managers are beginning to realize the strategic value of having good relationships with the people living along their borders (Hough, 1988; Schonewald-Cox et al., 1992; Parks Canada Agency, 2000). However, TB in and around RMNP has emerged in the last decade as an issue that has had serious and adverse impacts on relationships between farmers and the park. Many of the respondents considered the park to be the source of the elk coming onto their farms and believed these elk to be the primary reservoir and vector of TB. This may have long-term ramifications for conservation practices and how wildlife is valued in this region. If these concerns are not adequately addressed, farmers may ultimately conclude that elk and other wildlife are incompatible with farming priorities (Simonetti, 1995). Indeed, some farmers around RMNP have called for fencing of the park boundary to keep the wildlife in, and/or the total eradication of elk in order to reduce the risk of TB transmission to cattle (Brook and McLachlan, 2003). It has been a point of considerable frustration for many farmers around RMNP that their cattle herds are destroyed if they test positive for TB, yet Parks Canada refuses to eliminate the elk population within RMNP even though it is known to be infected. Conservation attitudes of local people living near protected areas are strongly influenced by their experiences with wildlife (Newmark et al., 1993; Conover, 2001) and their long-term experiences with management actions that influence wildlife. Since agricultural producers control the majority of wildlife habitat in rural landscapes outside of protected areas, their attitudes toward wildlife can substantially influence the quality and quantity of existing habitat (Horvath, 1976) and ultimately the regional viability of these wildlife populations.

Research on risk perception emphasizes that concerns may not be about the objective nature of the risk itself (Douglas, 1985; Short, 1984; Tesh, 2000) and thus, reducing the probability of impact may not diminish concern. Any attempts to characterize, compare and regulate risks should recognize the broader issues that collectively influence farmer concerns. Indeed, concern regarding TB may actually be a surrogate for other social or ideological concerns (Slovic, 2001). Many farmers feel that TB infected elk emanate from RMNP and are the source of the problem. At the same time, many feel that the park is a direct source of other wildlife species such as beaver, black bear, and wolves that have significant impacts on their farm operations and in many cases create fears for personal health and safety (Schroeder, 1981; Menzies, 1998; Dodds and Fenton, 1999). Relationships between farmers and the park are also influenced by park-directed changes in management practices that have adversely affected producers, these including the banning of haying, cattle grazing, and logging inside the park, and the re-introduction of beavers (Schroeder, 1981). Concerns regarding TB cannot be reduced without understanding and managing these broader issues.

5. Conclusions and management implications

Diseases like bovine TB have important implications for protected areas because they carry significant impacts, particularly for those people living nearby. Some diseases such as brucellosis continue to be a dominant issue after many decades, and affect elk and bison in Yellowstone (Meagher and Meyer, 1994) and bison in Wood Buffalo National Parks (Joly et al., 1998). Chronic Wasting Disease (CWD) has emerged as an important wildlife disease across North America (Miller, 2003) and farmers and rural communities in Canada are currently being devastated by a single occurrence of Bovine Spongiform Encephalopathy (BSE) (Leiss, 2004). These disease issues are further negatively influenced by the globalization of the rural economy, increasing farm sizes, climate change, and rural depopulation (e.g. Hinrichs and Welsh, 2003). In these rural landscapes, the level of support for protected areas will ultimately be determined by their combined economic and social benefits and costs (Wells et al., 1992; Simonetti, 1995) as well as the overall social and economic conditions of farmers and their communities. The long-term viability of protected areas and the wildlife species that use them are dependent on the attitudes and actions of local residents. If TB persists in wildlife and livestock, support for wildlife and protected areas will likely decrease, as will attitudes toward conservation programs aimed at enhancing wildlife habitat and establishing corridors. More intensive pressure to eliminate the Riding Mountain elk population is also an immediate concern. The severe reduction or extirpation of the elk would have broad impacts on local economies as well as ecosystem processes, including reducing grazing and browsing pressure, and eliminating the primary food supply of the wolf population (Estes, 1996).

In order to effectively manage TB and reduce farmer concerns, effective partnerships are needed among producers, federal and provincial wildlife and agriculture government agencies, universities, and other stakeholders. These can develop research priorities, risk management strategies, and best practices that meaningfully reduce the likelihood of and stress associated with disease transmission. This approach would facilitate the exchange of skills and knowledge between producers and other stakeholders, while ensuring that these best practices reflect local concerns. In Riding Mountain, the establishment of the TB Stakeholders Advisory Committee (TBSAC) in 2003 represents an important step toward increased communication and cooperation. However, even more encompassing discussions with producers and federal and provincial government funding support will ultimately be required to effect meaningful change because most farmers still feel marginalized from the TB management process and many demand a greater role in decision-making. Modelling efforts to assess the distribution of disease and risks of future transmission should explicitly incorporate the knowledge base and concerns of farmers, acknowledging that there is a strong distinction between 'objective' measures of risk (such as epidemiological estimates of disease prevalence) and subjective measures of disease concern (such as risk perception and acceptability of management actions) (Brook and McLachlan, 2003).

Better access to information about TB will help farmers reduce their vulnerability to disease. Of particular importance is communicating the ways that TB can be transmitted between elk and cattle. A better understanding of the environmental and farm management variables that influence elk use of the landscape would also help farmers understand the risks involved and help identify best practices appropriate for their operation. For example, farmers indicated a high level of concern regarding baiting and feeding of wildlife. Despite these concerns, a few landowners, some of which are cattle producers, continue to bait and feed elk and deer to increase hunting opportunities. These practices increase elk use of their farms and may inadvertently increase elk concentrations on neighbouring farms and facilitate contact between wildlife and cattle (Brook and McLachlan, 2003). Farmers can reduce their vulnerability to TB by eliminating baiting and feeding, which would be facilitated by better communication, as well as more intensive enforcement of the regulations on the part of government. Communication efforts should first be focused in areas directly adjacent to RMNP where concern is generally higher. Greater cooperation and multi-way communication among farmers, government agencies, and other stakeholder will help identify and implement strategies to reduce the risk of TB transmission. In particular, this will help improve the overall relationship between farmers and RMNP, this being an identified priority for national parks in Canada (Parks Canada Agency, 2000). As farmers become more aware of TB and its modes of transmission and adapt their farming practices to minimize their vulnerability, their level of concern toward TB may decrease. Ultimately, though, farmers and other stakeholders have to be actively involved in decision-making regarding the disease if it is to be effectively managed in the future.

Acknowledgements

We would like to thank the residents of the Riding Mountain region for sharing their time and expertise with us. Funding for this project was provided by Manitoba Agriculture, Food, and Rural Initiatives and the Social Science and Humanities Research Council (SSHRC). Additional support for our research is provided by Riding Mountain National Park, Manitoba Conservation, Riding Mountain Biosphere Reserve, Manitoba Wildlife Federation, Eastlands Wildlife Association, Westlake Wildlife Association, Louisiana Pacific, Nature Conservancy of Canada, Prendiville Industries Ltd, Shur-Gro Farm Services Ltd, Earth Rhythms Inc., Seven Oaks Game and Fish, and Friends of Riding Mountain National Park. Special thanks to Nicole Lavalee for helping to get the surveys delivered, to Andrea Thorgilsson, Amber Jays, Rob Watson, and Julie Preston for assisting with data entry. David Anderson provided the training that made application of the Information-Theoretic approach possible and Ian Mauro provided assistance with data analysis. We greatly appreciate the input of two anonymous reviewers. Thanks also to Ken Kingdon, Paul Paquet, Rob Watson, John Whitaker, Ray Armbruster, Bonnie Hallman, the Task Group for Bovine Tuberculosis, and the Environmental Conservation Lab at the University of Manitoba who are constant sources of encouragement and insight.

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