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Wildlife reservoirs for bovine tuberculosis (*Mycobacterium bovis*) in Canada: Strategies for management and research

John S. Nishi [a,*], Todd Shury [b], Brett T. Elkin [c]

[a] *Department of Environment and Natural Resources, Box 900, Government of the Northwest Territories, Fort Smith, NT X0E 0P0, Canada*
[b] *Parks Canada Agency, Room 1669B, Department of Veterinary Pathology, Western College of Veterinary Medicine, 52 Campus Drive, Saskatoon, SK S7N 5B4, Canada*
[c] *Department of Environment and Natural Resources, 600, 5102-50th Ave., Government of the Northwest Territories, Yellowknife, NT X1A 3S8, Canada*

Abstract

In Canada, there are two known regional foci where wildlife populations are infected with bovine tuberculosis (*Mycobacterium bovis*) and considered to be disease reservoirs. Free-ranging populations of wood bison (*Bison bison athabascae*) in and around Wood Buffalo National Park (WBNP) and wapiti (*Cervus elaphus manitobensis*) in and around Riding Mountain National Park (RMNP) are infected with bovine tuberculosis. In this paper, we provide an overview of these diseased wild ungulate populations and the complexities of attempting to manage issues relating to bovine tuberculosis in and around protected areas. We do not describe the quantitative science and epidemiological data in detail from these case histories, but instead compare and contrast these two cases from a broader perspective. This is achieved by reviewing the context and process by which a diverse group of stakeholders engage and develop strategies to address the controversial problems that diseased wildlife populations often present. We suggest that understanding the factors that drive the strategic-level management processes is equally important for addressing a wildlife disease problem as the tactical-level issues, such as design and implementation of technically sound field research and management programs. Understanding the experiences within the WBNP and RMNP areas, particularly the strategies that have failed or succeeded, may prove useful to understanding and improving management approaches when wildlife are infected with *M. bovis*. Applying this understanding is consistent with the principles of adaptive management in which we learn from previous experiences to develop better strategies for the future.

Keywords: Bovine tuberculosis; *Mycobacterium bovis*; Adaptive co-management; Wood Buffalo National Park; Riding Mountain National Park; Bison; Wapiti; Elk

* Corresponding author. Tel.: +1 867 872 6400; fax: +1 867 872 4250.
E-mail address: john_nishi@gov.nt.ca (J.S. Nishi).

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1. Introduction

In Canada there are two known regional foci where wildlife populations are infected with bovine tuberculosis (*Mycobacterium bovis*) and considered to be disease reservoirs (sensu Haydon et al., 2002). In northern Alberta and the adjacent Northwest Territories, wood bison (*Bison bison athabascae*) in and around Wood Buffalo National Park (WBNP) are infected with bovine tuberculosis and brucellosis (*Brucella abortus*) (Connelly et al., 1990; Joly and Messier, 2004a) (Table 1, Fig. 1). In southwestern Manitoba, North American wapiti, or elk (*Cervus elaphus manitobensis*), are the primary reservoir hosts for bovine tuberculosis in and around Riding Mountain National Park (RMNP) (Lees et al., 2003) (Table 1, Fig. 1).

Although these two foci are geographically separate and occur within different wildlife species, there is a common underlying management theme. Bovine tuberculosis (and brucellosis) is a zoonotic pathogen that exists within a host–parasite continuum (Daszak et al., 2000) that includes wildlife, livestock, and humans. Consequently, the maintenance of bovine tuberculosis in these wild ungulates is not only an important issue for national park and wildlife management agencies; the occurrence of these disease reservoirs is also a real concern to the commercial livestock industry, as well as to those people who may hunt animals from those infected populations. Correspondingly, management and research has been conducted primarily to control or contain the disease in and around WBNP and RMNP since it was discovered.

Table 1
Geographic, ecological, socio-economic and political characteristics of Wood Buffalo and Riding Mountain National Parks

Factors	Wood Buffalo National Park	Riding Mountain National Park
Geographical		
Size of park	44,802 km^2	2969 km^2
Natural region	Northern boreal plains	Southern boreal plains
Provincial/territorial jurisdictions	Alberta and Northwest Territories	Manitoba
Ecological		
Reservoir species	Wood bison (*Bison bison athabascae*)	Wapiti (*Cervus elaphus manitobensis*)
COSEWIC[a] conservation status	Threatened	Not listed
Population size in 2004 (trend)	4727 (increasing)	1980 (declining)
Major predators	Wolves (*Canis lupus*)	Wolves (*C. lupus*)
	Black bears (*Ursus americanus*)	Black bears (*U. americanus*)
Spillover of bovine tuberculosis	No—but wild bison herds	Yes—white-tailed deer
to other wildlife	(Hay Zama and Mackenzie)	(*Odocoileus virginianus*) &
	at greatest risk	wolves (*C. lupus*)
Socio-economic		
Spillover of bovine tuberculosis to commercial livestock	No	Yes
Proximity to commercial livestock	100–200 km	Surrounds park boundary on all sides
Annual value of livestock production in province[b]	CAN$ 5.1 billion (2002)	CAN$ 1.7 billion (2002)
Average annual number of park visitors[c]	1305	411,267
International designations	UNESCO World Heritage Site	UNESCO Biosphere Reserve
Political		
First Nations involvement in park management	High	Low
Hunting by Aboriginals within park	Yes[d]	No

[a] Committee on the Status of Endangered Wildlife in Canada.
[b] Source: Agriculture Canada Statistics Canada, Agriculture Economic Statistics, Catalogue No. 21-603.
[c] Source: Data are for 2001–2002. Internal Parks Canada reports, Ecological Integrity Branch 2005.
[d] Hunting for bison in Wood Buffalo National Park is not permitted, but Aboriginals with General Hunting Permit are eligible to hunt game and trap in the park. Source: Wood Buffalo National Park Game Regulations (update to August 31, 2004) [online]. URL: http://laws.justice.gc.ca/en/N-14.01/SOR-78-830/38709.html#rid-38874.

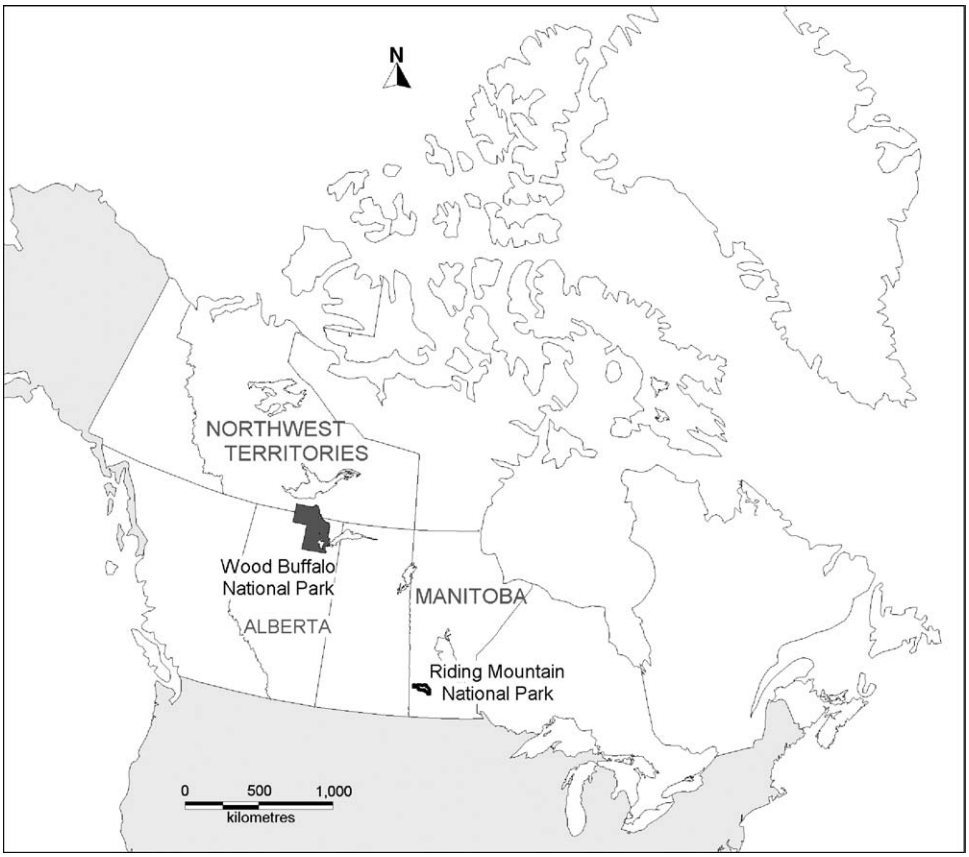

Fig. 1. Locations of Wood Buffalo and Riding Mountain National Parks in Canada.

The problem of bovine tuberculosis in wildlife is not unique to Canada. The complexity and controversy in addressing the management of bovine tuberculosis in wildlife and the interface of this disease with livestock and humans is global in scope, and occurs in many other parts of the world (Tweddle and Livingstone, 1994; de Lisle et al., 2001, 2002; Michel, 2002; Delahay et al., 2002; O'Brien et al., 2002; Schmitt et al., 2002; Caron et al., 2003; Phillips et al., 2003; Aranaz et al., 2004). The issue of bovine tuberculosis in wildlife cuts across a variety of stakeholder interests, and arises from a mix of ecological, socio-economic, and political issues and associated values. Within an atmosphere of conflict and uncertainty, wildlife disease reservoirs for bovine tuberculosis often pose a ''wicked problem'' (sensu Rittel and Weber, 1973; and see Gates, 1993; Ludwig, 2001) that is tricky, complex, and thorny (Rausher, 1999).

In this paper, we provide an overview of the Canadian experience in addressing the disease reservoirs of bovine tuberculosis in wildlife within the Greater WBNP and RMNP ecosystems. Our intent is to dissect this collective experience within a context that illustrates the complexity of the problem and yet distills it into a form that is understandable, so that we may become better informed by lessons learned from past experiences. We do not describe the available quantitative science and epidemiological data in detail from these case histories—because it has either been published (Fuller, 1962; Broughton, 1987; Tessaro et al., 1990; Joly and Messier, 2004a,b, 2005; Lees et al., 2003; Lees, 2004) or is in the process of being collected (Bergeson et al., 2003; Brook and McLachlan, 2004; Task Group for Bovine Tuberculosis, 2002; Shury et al., 2004; Lutze-Wallace et al., 2005). Instead, we compare and contrast these two

case histories from a higher-level, strategic perspective; we review the context and process by which a diverse group of stakeholders engage and develop ways of addressing the controversial problems that diseased wildlife populations often present.

2. Dissecting the disease management issue

Management issues that revolve around wildlife disease reservoirs are often a result of a combination of conflict and uncertainty at both strategic and tactical levels. The distinction between strategic- and tactical-level issues is important. Strategic issues are future-oriented and strategic plans provide a general course of intention based on a long-term vision. Tactical issues are present-oriented and tactical planning turns strategy into reality, providing a specific course of action and implementation over a shorter term.

Multiple stakeholders (Table 2) often incur strategic-level conflicts that arise from competing interests and values, mandates, jurisdictional authorities and varying levels of risk tolerance. This is apparent when stakeholders are tasked with developing a long-term vision for management and research. Uncertainty at a tactical-level is represented by an incomplete understanding in the collective science-based knowledge of the ecology of a disease, epidemiology and population biology of the pathogen–host interaction, risk of spillover into specific target populations, and feasibility of management options.

Management of wildlife diseases can be classified into four basic categories: prevention, control,

Table 2
Stakeholder groups that have been recently or currently engaged in management and research on bovine tuberculosis in the Wood Buffalo National Park and Riding Mountain National Park areas

	Federal government agencies	Provincial/territorial government agencies	Other
Greater Wood Buffalo National Park Ecosystem			
Wildlife management & conservation	Parks Canada Agency (Wood Buffalo National Park) Canadian Wildlife Service	Alberta Sustainable Resource Development Government of the Northwest Territories (Environment and Natural Resources)	First Nations (Treaty 8) and Metis Councils Canadian Parks and Wilderness Society National Wood Bison Recovery Team
Agriculture	Canadian Food Inspection Agency	Alberta Agriculture, Food and Rural Development Alberta Aboriginal Affairs and Northern Development	Industry (Canadian Cattle Producers, Canadian Bison Association)
Human health	Health Canada		First Nations (Treaty 8) and Metis Councils
Greater Riding Mountain National Park Ecosystem			
Wildlife management & conservation	Parks Canada Agency (Riding Mountain National Park)	Manitoba Conservation	Manitoba Wildlife Federation Canadian Parks and Wilderness Society Riding Mountain Biosphere Reserve Committee
Agriculture	Canadian Food Inspection Agency Prairie Farm Rehabilitation Administration	Manitoba Agriculture and Food	Industry (Manitoba Cattle Producers Association, Manitoba Lodge & Outfitters Association)
Human health			Local communities

eradication and doing nothing (laissez faire) (Wobeser, 2002). As Wobeser (2002, pp. 160–161) outlines, the choice from among these categories depends upon several considerations including: (a) the need for management; (b) the presence or absence of the disease; (c) availability of techniques for detecting, diagnosing, and managing the disease; (d) availability of funding; (e) the likelihood of success. For bovine tuberculosis in wildlife, the question of ''why management is required'' is the first and most important strategic question. If there is disagreement among stakeholders on the need for management, then the entire management (and applied research) process will likely fail. In addition, agreement on the need for management implicitly requires that the disease reservoir be recognized, and that the stakeholder group identify and prioritize the target population(s) (sensu Haydon et al., 2002) that are of the greatest management need and concern. Only then can tactical questions on how to control the infection, i.e., (a) target control, (b) blocking transmission, or (c) reservoir control (Haydon et al., 2002, p. 1470), be effectively determined.

Although initial assessment on the need for management often depends on the specific jurisdiction in which the disease is first diagnosed (i.e., national parks), the larger issue of disease spillover requires a regional perspective that is not bound by jurisdictional boundaries or mandates of government agencies. An epidemiological approach identifies links to potential target populations that may be at risk of exposure and infection due to direct or indirect contact with the disease reservoir, but the management importance of a target population is largely based on anthropocentric values. For example, when bovine tuberculosis occurs in a wildlife reservoir, management concern and effort is most often directed at protecting commercial livestock from infection because of the economic interests of industry (Michel, 2002; Schmitt et al., 2002; Phillips et al., 2003; Lees, 2004). Other considerations are apparent when the infected wildlife population is considered threatened or endangered (Gates et al., 2001a,b), whether it has a high intrinsic value due to commercial outfitting or wildlife watching (Table 2).

Because the strategic aspect of wildlife disease management issues are so often embroiled in stakeholder values, the dynamics of power, conceptualized as social relations, built on the asymmetrical distribution of resources and risk (Paulson et al., 2003), are often played out in a political environment. This power play influences stakeholder interactions and ultimately directs the management process. Consequently, the political ecology (Paulson et al., 2003; Walker, 2005) of a wildlife disease issue often directly affects strategic-level management processes, or lack thereof, and influences the tactical aspects of management and research activities in the field.

3. Case histories

3.1. Wood Buffalo National Park

Wood Buffalo National Park occurs within the boreal forest of northern Alberta and the adjacent Northwest Territories (Fig. 1). It is Canada's largest national park (44,802 km^2) and was designated as a UNESCO (United Nations Educational, Scientific and Cultural Organization) World Heritage Site in 1983 (Table 1). The park was created in 1922 in order to protect a remnant population of wood bison from further decline and possible extinction (Ogilvie, 1979). However, between 1925 and 1928, the Government of Canada translocated 6673 plains bison (*B. b. bison*) from Wainwright Buffalo Park in east-central Alberta, to the southern part of WBNP because of an overabundance of plains bison at Wainwright Buffalo Park (Ogilvie, 1979; Carbyn et al., 1993; MacEwan, 1995; Sandlos, 2002; Fuller, 2002). Unfortunately, this action resulted in the introgression of plains bison genes into the indigenous wood bison (see Wilson and Strobeck, 1999), and also resulted in the introduction of bovine tuberculosis and brucellosis to the bison population (Fuller, 1962; Carbyn et al., 1993; Fuller, 2002). These diseases had likely 'spilled over' (sensu Daszak et al., 2000) from infected cattle to the Wainwright plains bison herd (Fuller, 2002).

Despite detection of bovine tuberculosis and brucellosis in WBNP bison in 1937 (Connelly et al., 1990) and 1956 (Fuller, 1962), respectively, the first strong impetus to seriously consider options for managing the diseased population did not occur until 1985, following the declaration that Canada's cattle industry was brucellosis-free (Carbyn et al., 1993). Freedom from this disease in cattle was the result of an intensive disease eradication effort

initiated by Agriculture Canada in 1928 (Connelly et al., 1990). In 1986, due largely to concerns over the risk of the diseases 'spilling back' (sensu Daszak et al., 2000) into domestic cattle herds in the area of the park, and to a lesser extent, into the non-diseased Mackenzie wood bison population in the Northwest Territories, an intergovernmental Steering Committee was formed to discuss the national implications of the diseased WBNP bison (Connelly et al., 1990). The Steering Committee, comprised of representatives from the governments of Canada, Alberta and Northwest Territories, established and directed a Task Force to evaluate potential management options (Bison Disease Task Force, 1988). In 1988, the Federal Minister of the Environment established an Environmental Assessment Panel to examine all feasible solutions, including those suggested by the Task Force, to protect the health of domestic livestock, Mackenzie wood bison, and humans through control or elimination of contact with diseased bison. In 1990, the Environmental Assessment Panel recommended that the best option was to remove all free-ranging bison in and around WBNP, and replace them with what were considered to be genetically pure wood bison from Elk Island National Park and the Mackenzie bison herd (Connelly et al., 1990). This option was met with widespread public opposition, largely from the local First Nations communities and non-governmental environmental organizations, based on concerns that the proposed option would result in a loss of genetic diversity and possible impairment of ecosystem integrity (see Gates et al., 1997; Peterson, 1991; McCormack, 1992).

Due to the resulting public opposition, a Northern Buffalo Management Board (NBMB) was established which was comprised of Aboriginal members (representing Treaty 8 Dene Bands in the Greater WBNP area), government agencies and private organizations. Although the NBMB was given the task of formulating a management plan, after 18 months of intense, fractious and often political deliberations (Gates et al., 1997), it concluded that significant information gaps existed in the epidemiology of bovine tuberculosis and brucellosis, the ecological impact of the diseases, and the possible effects of management action on the ecosystem. The board recommended that a 3-year, CAN $18 million research program be conducted before any management plan could be developed (Northern Buffalo Management Board, 1992). Due to the high cost and uncertainty regarding the feasibility of these recommendations, the Government of Canada did not renew funding for the NBMB after 2 years.

In 1995, the Parks Canada Agency, the federal department responsible for national park management, responded to recommendations of the Environmental Assessment Panel and the NBMB by announcing a CAN $2.5 million, 5-year Bison Research and Containment Program (BRCP). The BRCP's main goal was to facilitate research on bison and disease ecology in WBNP, and to continue to work with the Government of the Northwest Territories to prevent the spread of brucellosis and tuberculosis to the Mackenzie bison population (see Nishi, 2002). A multi-stakeholder Research Advisory Committee (RAC) was also created to advise the Parks Canada Agency on the planning, implementation, and evaluation of bison research with the objective that the research would form the basis for a realistic, ecologically sound and knowledge-based (including scientific and traditional ecological knowledge) management plan for WBNP bison (Chisholm et al., 1998; Research Advisory Committee, 2001). Through the work of the RAC, the Bison Research and Containment Program funded a major study on the population-level effects of tuberculosis and brucellosis on WBNP bison (Joly and Messier, 2004a,b, 2005), and also supported a research project to develop a landscape model of bison movements and distribution in defined risk areas around Wood Buffalo National Park (Gates et al., 2001a; Gates and Wierzchowski, 2003). However, once the official 5-year term of the BRCP was over in 2001, the program was ended and the Research Advisory Committee was dissolved. No additional funding was provided by the Parks Canada Agency despite the committee's request to complete its research objectives (Research Advisory Committee, 2001).

In the absence of the BRCP and a structured process for addressing the continued concerns regarding the diseased bison, the Canadian Bison Association – on behalf of the commercial livestock industry – requested that the Federal Government initiate a management process to re-engage the various stakeholders (see Table 2). Despite subsequent efforts in 2001 and 2002 by a federal Interdepartmental Steering Committee to develop a common federal

position and prepare a strategy for implementing a consultation and management process, there was no progress made on engaging stakeholders. Shifts in emphasis for developing a National Disease Strategy (Environment Canada, 2004), and the diagnosis of bovine spongiform encephalopathy in the Canadian cattle herd in May of 2003, were also factors that contributed to the demise of the Committee and lack of progress on engaging stakeholders on the diseased bison issue.

In 2003, at the request of the Chief Executive Officer of the Parks Canada Agency and Deputy Ministers of three separate Alberta Government departments, an intergovernmental committee was created to develop risk mitigation options to reduce the risk of transmission of tuberculosis and brucellosis from diseased bison in and around Wood Buffalo National Park to livestock and free-ranging bison that are free of these diseases in northern Alberta. This intergovernmental committee, with the inclusion of representatives from the Canadian Food Inspection Agency and the Government of the Northwest Territories, completed a technical report outlining a plan of interim measures (Interim Measures Technical Committee, 2004). These measures comprised a three-pronged approach to containing the two diseases in the southwest region of WBNP. This approach included (a) establishment of a bison-free control area in northern Alberta and the southwest part of WBNP, (b) an extensive education and communication program, and (c) enhanced surveillance of domestic bison and cattle in the adjacent agricultural area in northern Alberta. The interim measures are currently under review and will not be implemented until final approval and funding is secured from the responsible parties and extensive public consultation is undertaken.

3.2. Riding Mountain National Park

Riding Mountain National Park was created in 1930 (Parks Canada, 2002), and is a comparatively small national park (2969 km^2) (Table 1). It is located in a forest-agricultural transition zone in southwestern Manitoba and mostly within the southern boreal plains and plateau natural region of Canada (Fig. 1). Perhaps one of the most striking descriptions of RMNP is best illustrated through satellite imagery, where it is readily apparent that the national park is an 'ecological island situated amidst a sea of agricultural land' (Parks Canada, 2002).

Bovine tuberculosis was routinely found in cattle that were allowed to graze within RMNP in the 1950s and 1960s (Copeland, 2002). One of the later cases of bovine tuberculosis in livestock in the RMNP area was identified in 1981 and the disease did not re-emerge in cattle until 1991 when an outbreak was discovered in a cattle herd bordering the park (Copeland, 2002). There have been four other 'outbreaks' of bovine tuberculosis involving 11 cattle herds around RMNP, occurring in 1991, 1997, 2001 and 2003 (Lees, 2004). The organism was first confirmed in a hunter-killed free-ranging wapiti from RMNP in 1992 and subsequently, in a hunter-killed white-tailed deer (*Odocoileus virginianus*) in 2001 (Copeland, 2002; Lees, 2004).

In 1997, the United States Department of Agriculture (USDA) recognized all Canadian cattle herds (except those under quarantine) as being free of bovine tuberculosis. However, in response to additional findings of bovine tuberculosis in cattle within the RMNP area, the USDA implemented bovine tuberculosis testing requirements in 2002 for breeding cattle and commercial bison herds in Manitoba before livestock could be shipped into the United States (Koller, 2002). In order to maintain trade status with the United States and harmonize with USDA rules and regulations, the Canadian Food Inspection Agency (CFIA) amended the Health of Animals Regulations by zoning Manitoba and Canada to bovine tuberculosis (TB)-Free, TB-Accredited, and TB-Accredited Advanced areas (Canadian Food Inspection Agency, 2002). In 2003, the CFIA designated the Riding Mountain Eradication Area (RMEA) with TB-Accredited Advanced status and the rest of Manitoba as a TB-Free status, thus allowing cattle from the remainder of the province to be exported to the United States without additional testing (Canadian Food Inspection Agency, 2002). Movement and additional testing restrictions were placed on cattle herds within the RMEA.

Concern over wildlife being a reservoir of bovine tuberculosis lead to the formation of an Interagency Task Group for Bovine Tuberculosis in 2000, consisting of personnel from the CFIA, Parks Canada Agency, Manitoba Agriculture and Food, and Manitoba Conservation with input from local stakeholder

groups. A 5-year management strategy and implementation plan was developed to attempt to eradicate bovine tuberculosis from the greater Riding Mountain ecosystem. The long-term goals of the plan were to: (1) achieve and maintain TB-free status in domestic cattle; (2) eradicate bovine tuberculosis in wildlife that may pose a risk to agriculture; (3) minimize wildlife–livestock interactions in the Riding Mountain region; (4) minimize unnatural cervid herding behaviour, which occurs where cervids feed on agricultural produce, thereby minimizing the potential for disease transmission (Task Group for Bovine Tuberculosis, 2002).

Surveillance for bovine tuberculosis in wildlife has focused on both examination of samples from hunter-killed wapiti, deer and moose and live capture and testing of wapiti and deer using helicopter net-gunning (Shury et al., 2004). Between 1997 and 2005, 9 (0.4%) of 2245 wapiti and 4 (0.2%) of 2398 white-tailed deer have tested positive for bovine tuberculosis from samples submitted by hunters (primarily heads only) in the Greater RMNP ecosystem. This method underestimates true prevalence of disease because only animals that leave the park are hunted and only the heads of animals are generally examined for gross visible lesions of bovine tuberculosis (Shury et al., 2004). Live capture and testing of wapiti in and around RMNP since 2002 has detected 17 (3.6%) positive wapiti out of 467 tested to date. This testing revealed a significant focus of infection in wapiti in the northwest corner of RMNP, with 16 of the 17 positive live-captured wapiti coming from this vicinity, while the other case was from a single infected wapiti recently found in an adjacent protected area to the north of RMNP (i.e., Duck Mountain Provincial Forest). Strain typing of *M. bovis* isolates from both wildlife and cattle by spoligotyping indicate that it is a unique strain of *M. bovis* that is seemingly unrelated to other strains previously identified in Canada (Lutze-Wallace et al., 2005).

Management tactics that have been implemented to help reduce the transmission of *M. bovis* between wildlife and cattle have included: (1) barrier fencing to protect hay storage yards from wild wapiti and deer; (2) wapiti population reduction to historical low numbers through extended hunting seasons and predator (wolf) conservation; (3) legislation to prevent baiting and unnatural cervid herding behaviour; (4) the use of prescribed burning to improve wapiti habitat within RMNP. Current research is focused on determination of landowner attitudes to wildlife, study of wapiti behaviour and movements, wolf ecology and populations dynamics, coyotes (*Canis latrans*) as sentinels for bovine tuberculosis, and the history of bovine tuberculosis in and around RMNP (Brook and McLachlan, 2004).

4. Discussion

4.1. Greater Wood Buffalo National Park Ecosystem

Following the peak of controversy surrounding the northern diseased bison issue during the Federal Environmental Review Process in 1990, there has been some progress made in two areas. Firstly, the relationships among stakeholders (see Table 2) has evolved and developed through at least three separate research and management processes, i.e., the Northern Buffalo Management Board 1991–1992 (Northern Buffalo Management Board, 1992), the WBNP Bison Research and Containment Program 1996–2001 (Research Advisory Committee, 2001), and the Interim Measures Technical Committee (2003–2004) (Interim Measures Technical Committee, 2004). Secondly, there has been an improvement in our science-based understanding of: (a) the risks of disease transmission from infected bison in and around WBNP (Animal, Plant and Food Risk Analysis Network, 1999; Gates et al., 2001a; Gates and Wierzchowski, 2003); (b) the prevalence of bovine tuberculosis (and brucellosis) in WBNP (Joly and Messier, 2004a) and the effects of disease on population dynamics (Joly and Messier, 2004b, 2005); (c) genetic diversity that currently exists in northern wood bison (Wilson and Strobeck, 1999; Wilson, 2001), and the importance of genetic salvage (Gates et al., 1998; Nishi et al., 2001, 2002a,b) and management (Wilson et al., 2003; Wilson and Zittlau, 2004; Wilson et al., in press).

Although substantial, the progress outlined above has been piecemeal because the activities have not been coordinated and conducted within a larger strategic framework that combines and prioritizes research and management objectives at an appropriate

scale. Nor has the progress been a result of a long-term process based on a common vision developed through consistent engagement of stakeholders. Between the Northern Buffalo Management Board, the Bison Research and Containment Program, and the Interim Measures Technical Committee, the pendulum has swung between emphasizing research versus management, with varying involvement of stakeholders. This is contrary to an adaptive co-management approach that would integrate research and management into a dynamic learning process and would encourage sharing of management power and responsibility across different levels of organization from local communities to provincial/territorial and federal government agencies (Berkes, 2004).

Teamwork, collaboration across professional disciplines, and respect for scientific and traditional ecological knowledge among technical and non-technical stakeholders are basic prerequisites for effectively addressing complex management issues (Ewel, 2001; Ludwig, 2001; Berkes, 2004). However, lack of continuity in stakeholder engagement has undermined development of a common long-term vision for diseased bison in the Greater WBNP ecosystem. In the past, each time a new research or management process was initiated, there was a prolonged period of time required to build working relationships and trust within the respective working group or committee. This has been further compounded by a loss in continuity of work done by these groups because recommendations for additional research and management efforts were often disregarded once the tenure of a program was completed. Without leadership and commitment from federal and provincial/territorial government agencies to initiate and provide resources for a long-term adaptive process that effectively engages all stakeholders – primarily the northern aboriginal communities – (and see Table 2), it is likely that the northern diseased bison issue will continue to be mired within the inertia of inaction. Although we recognize the challenges and difficulties of implementing adaptive management (see Walters, 1997), we suggest that a pro-active, adaptive co-management approach (Berkes, 2004), with meaningful engagement of stakeholders (Shindler and Cheek, 1999; Ewel, 2001; Ludwig, 2001; Zio, 2003) is required to reach a common understanding and vision for addressing the bovine tuberculosis (and brucellosis) issue in and around WBNP. Only then is there a reasonable chance for developing a long-term management strategy at a regional scale, and addressing the difficult question of whether the benefits of disease eradication – in terms of eliminating the risk of spillover into livestock and wildlife, and wood bison recovery in and outside the park (Gates et al., 2001b) – are sufficient to justify an intrusive disease eradication program (Joly and Messier, 2004b).

Although concerns regarding technical feasibility of management options and/or potential negative ecological impacts of intrusive management action on ecological integrity within WBNP are valid, i.e., the removal and replacement option recommended by the Federal Environmental Assessment Panel (Connelly et al., 1990), complete inaction based on a precautionary approach is unacceptable. With an increase in number of diseased bison in WBNP (Table 1), the risk of spillover to target populations increases as well. As Rausher (1999, pp. 192) points out, ‘‘failure to make a decision is a decision and it is a different decision than to explicitly do nothing, knowing the consequences [the laissez faire approach (sensu Wobeser, 2002)]. Consequences will happen without opportunities to evaluate them or mitigate them if they are undesirable.’’ Although current available data suggest that spillover has not occurred, the implication of continued inaction is the failure of recognizing the management importance of disease spillover into target populations until it is too late. In other words, should government agencies wait until spillover occurs into either the healthy, free-ranging bison populations in northern Alberta and the Northwest Territories, or commercial cattle and bison herds in northern Alberta before they commit to a long-term management and research process?

Basili and Franzini (2004) argue that there are ex ante costs to a precautionary (laissez faire) approach, and these ex ante costs need to be understood and explicitly weighed against the probability and cost implication of ‘‘catastrophic events’’—in this case disease spillover. As bovine tuberculosis is a federally reportable disease in Canada under the Health of Animals Act, spillover from a sylvatic reservoir into commercial cattle or game farm herds would result in the depopulation of infected livestock herds and would have serious potential economic implications for

national and international trade (Essey and Koller, 1994). Spillover of bovine tuberculosis from diseased bison to non-diseased wild bison populations (Hay Zama herd in northern Alberta, Mackenzie and Nahanni bison herds in the Northwest Territories) would carry ecological and human health implications for sustainable harvesting by local communities, and prove disastrous for conservation and recovery efforts of wood bison in northern Canada (Gates et al., 2001b). But the economic and political implications of spillover in to non-diseased wild bison herds would pale in comparison to disease spillover in to commercial livestock herds in northern Alberta. On a provincial scale, the Alberta livestock industry is worth several billions of dollars a year (Table 2).

Another important yet immeasurable cost under a laissez faire approach to the diseased bison issue in the Greater WBNP ecosystem is the long-term cultural loss to First Nations and aboriginal communities who have been unable to fully and effectively participate in a traditional economy that would have included subsistence hunting of healthy wild bison. The impact of disease is expressed in two ways. Firstly, diseased bison populations are less able to sustain the combined demographic impact of both hunting and predation by wolves (see Joly and Messier, 2004b). Secondly, since bovine tuberculosis (and brucellosis) presents a zoonotic disease risk to hunters, the desirability of hunting bison from a diseased population is reduced. These impacts combined with a federal policy that has prohibited bison hunting within WBNP over the last 100 years, will effectively diminish the cultural link between hunters and wild bison. We suggest that restoring ecological integrity to this ecosystem likely involves a reconnection between First Nations and aboriginal hunters, and healthy bison populations.

4.2. *Greater Riding Mountain National Park Ecosystem*

With respect to management action, one of the main differences between the RMNP and WBNP case histories is that in the RMNP area there have been actual cases of spillover of bovine tuberculosis to commercial cattle herds. This is likely a function of the relative proximity between the commercial livestock herds and wildlife disease reservoirs (Fig. 2, Table 1). The occurrence of bovine tuberculosis in commercial cattle has been a powerful economic and political driver behind the current efforts for managing and eradicating bovine tuberculosis in RMNP.

In contrast to the diseased bison issue in and around WBNP, the strategic-level process involving stakeholders (Table 2) in the Greater RMNP ecosystem has been more engaging and has resulted in the creation of a multi-stakeholder Task Force to address the issue of bovine tuberculosis in wapiti in RMNP. The Task Force's management and research program is based upon a shared vision to eradicate bovine tuberculosis from the Riding Mountain ecosystem (Task Group for Bovine Tuberculosis, 2002). The efforts of the multi-stakeholder Task Group are commendable and consistent, but this could also be partially a result of the young nature of this process, i.e., it has only been running for 5 years, since 2000. Continued long-term support and resources are required in order for the Manitoba bovine tuberculosis management program to have any hope of reaching its strategic and tactical objectives. The proximity of the commercial cattle target population (Fig. 2, Table 1) to RMNP and the demonstrated spillover of disease into cattle herds will likely ensure that adequate support and resources are maintained.

As suggested by Lees (2004), there have been several valuable strategic lessons learned from the experience with bovine tuberculosis in RMNP. Forward-thinking industry leaders played a key role in allowing the public response to the bovine tuberculosis issue to proceed more rapidly and constructively through the initial stages of grief, anger and denial, to acceptance of the problem and working towards the solution. Similarly, an important factor in the success to date of the multi-stakeholder Task Group has been the extensive consultation and engagement of stakeholders in a decision-making process. Specifically, the early inclusion of key industry and interest group leaders in the process strengthened consultation and helped to develop a common vision and garner widespread support for the management program. Open public meetings held by Parks Canada prior to the Task Force being established in 1999, led to bitter, divisive, shouting matches between concerned local stakeholders and government officials with little or no dialogue or progress being conducted. A multi-agency cooperative framework was important because it facilitated collabora-

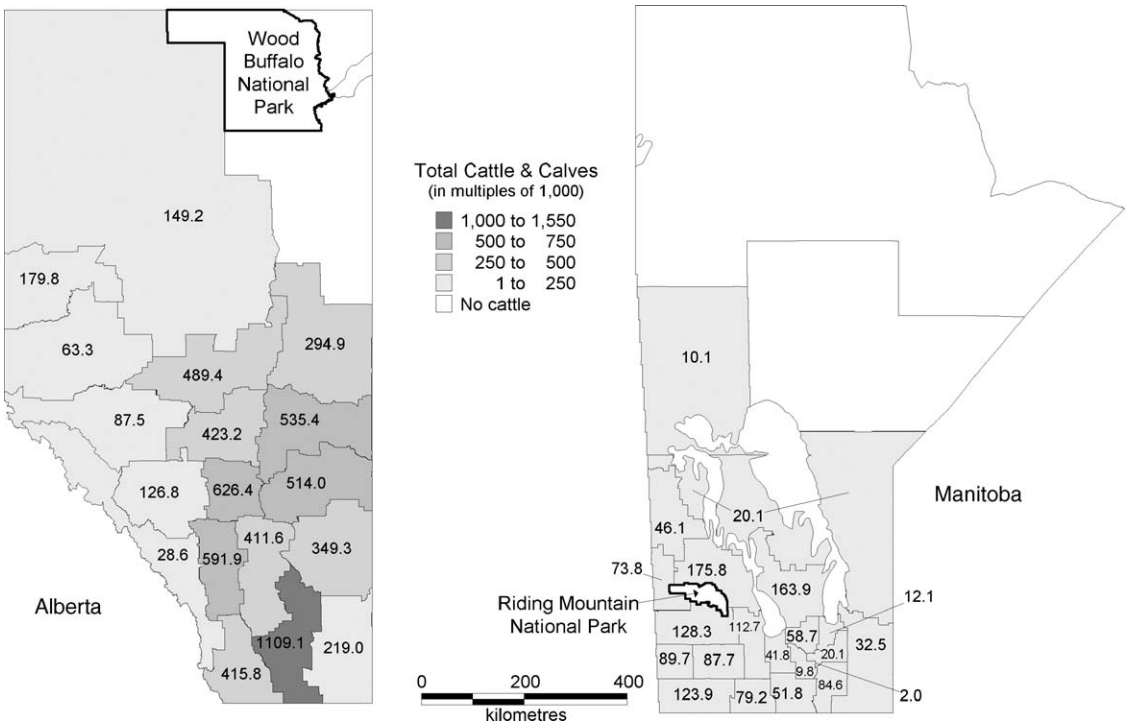

Fig. 2. Densities of commercial cattle and calves by census division relative to Wood Buffalo National Park in Alberta and Riding Mountain National Park in Manitoba, Canada (Data Source: Statistics Canada, Census of Agriculture 2001).

tion among representatives of provincial wildlife and agriculture departments, federal government agencies responsible for the management of RMNP and livestock disease control and eradication, and other key industry and conservation stakeholder groups (Table 2).

5. Conclusion

The occurrence of bovine tuberculosis in wildlife populations presents difficult and controversial problems at a regional scale because it typically affects many stakeholders from local communities and livestock producers, to provincial/territorial and federal government agencies. The impetus for managing bovine tuberculosis in wildlife is affected by the ecological, socio-economic and political implications of spillover into target populations, and this transcends political and jurisdictional boundaries of national parks.

In Riding Mountain National Park, an interagency Task Group has developed a long-term vision of eradicating bovine tuberculosis from the park and has initiated active management and research on the infected wapiti population. In WBNP, bovine tuberculosis (and brucellosis) is endemic in wood bison, but attempts to initiate and conduct research and management of the disease(s) in and around the park have been hampered by lack of a shared long-term vision, continuity, and strategic direction. It is likely that the spillover of bovine tuberculosis into cattle herds in the Greater RMNP ecosystem has been the driving economic and political force behind current management and research efforts by the Task Group. In the Greater WBNP ecosystem, bovine tuberculosis has not spilled over into either commercial livestock or free-ranging non-diseased bison herds. Compared to the bovine tuberculosis issue in RMNP, the risk of disease spillover to commercial cattle and bison in the Greater WBNP ecosystem is lower due to the larger geographic distance between infected bison in the

park and livestock (Fig. 1, and see Animal, Plant and Food Risk Analysis Network, 1999; Gates et al., 2001a). Considerable effort, coordination and political leadership by federal and provincial/territorial government agencies are required in order to initiate a strategic process in WBNP. This process should focus on an adaptive co-management approach to addressing the diseased bison issue at a regional scale and ensure that there is appropriate commitment of resources to suitably engage all stakeholders, especially the First Nations and aboriginal communities and livestock industry.

Understanding the ecological, socio-economic, and political factors that drive strategic-level management processes is equally important in addressing a wildlife disease problem as the tactical-level issues, such as designing and implementing technically sound field research and management programs. Wildlife disease managers tend to focus more on tactical-level concerns, but must understand and facilitate both strategic and tactical processes in order for management and research to proceed with any hope of success.

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