The Existing and Potential Importance of Brucellosis and Tuberculosis in Canadian Wildlife: A Review

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ABSTRACT

As the campaign to eradicate bovine brucellosis (*Brucella abortus*) and tuberculosis (*Mycobacterium bovis*) in Canadian livestock nears completion, the importance of extraneous sources of these diseases increases. This review summarizes the literature on brucellosis and tuberculosis in Canadian wildlife species to determine existing and potential hosts. Canadian caribou (*Rangifer tarandus*) are reservoirs of *Brucella suis* biotype 4 which is pathogenic in caribou, humans and muskoxen but reportedly nonpathogenic in livestock. Bison (*Bison bison*) and elk (*Cervus canadensis*) are significant reservoirs of *B abortus* and *M. bovis*. The bison in and around Wood Buffalo National Park have both diseases and are the only wildlife reservoir in Canada. Free-ranging elk are important reservoirs of brucellosis in Wyoming, and captive elk initiated the recent outbreak of bovine tuberculosis in 20 American states which has also involved bison and cattle herds. If bison and elk ranching continues to develop in Canada, the industry will have to be monitored to prevent the introduction and spread of infectious diseases like brucellosis and tuberculosis. This requires the evaluation and/or development of effective diagnostic methods for use in these animals.

Key words: Wildlife, brucellosis, tuberculosis, Canada, disease control.

RÉSUMÉ

Revue de l'importance actuelle et éventuelle de la brucellose et de la tuberculose, au sein de la faune du Canada

Alors que la campagne d'éradication de la brucellose (*Brucella abortus*) et de la tuberculose (*Mycobacterium bovis*) bovines tire à sa fin, l'importance des sources étrangères de ces maladies augmente. La présente revue résume la littérature sur la brucellose et la tuberculose, dans la faune canadienne, afin d'en déterminer les hôtes actuels et éventuels. La caribou canadien (*Rangifer tarandus*) constitue un réservoir de *Brucella suis* biotype 4, bactérie pathogène pour lui-même, les hommes et les boeufs musqués, mais apparemment non pathogène pour le cheptel bovin et ovin. Le bison (*Bison bison*) et l'élan (*Cervus canadensis*) représentent des réservoirs significatifs de *B. abortus* et *M. bovis*. Les bisons du Parc national "Wood Buffalo" et de ses environs souffrent des deux maladies précitées et en constituent le seul réservoir, au sein de la faune du pays. Les élans qui vivent à l'état sauvage constituent un réservoir important de la brucellose, au Wyoming, tandis que leurs congénères gardés en captivité sont à l'origine de l'éruption récente de tuberculose bovine, dans 20 états américains; la maladie impliquait aussi des bisons et des troupeaux de bovins. Si le nombre de ranchs de bisons et d'élans continue d'augmenter, au Canada, il faudra exercer une surveillance étroite pour prévenir l'introduction et la propagation des maladies infectieuses telles que la brucellose et la tuberculose. Cette éventualité exigera l'évaluation et/ou le développement de moyens de diagnostic efficaces et utilisables chez ces animaux.

Mots clés : faune, brucellose, tuberculose, Canada, éradication des maladies.

INTRODUCTION

Brucellosis and tuberculosis are diseases of great veterinary, public health, economic and historical significance throughout the world. In Canada, bovine brucellosis (*Brucella abortus*) and bovine tuberculosis (*Mycobacterium bovis*) have nearly been eliminated from livestock through the cooperative efforts of veterinarians and members of the cattle industry, with Agriculture Canada directing the eradication programs. The veterinary and public health benefits and the resulting economic gains have increasingly offset the cost of this lengthy process. As the last few infected cattle are eliminated, the importance of extraneous sources of these diseases increases. Surveillance must be maintained to prevent the importation and spread of brucellosis and tuberculosis, and to manage other reservoirs that exist in Canada. The purpose of this review is to examine the real and potential significance of wildlife reservoirs of these diseases in this country.

Bovine Brucellosis

Review articles on brucellosis in world wildlife indicate that a wide range of species can produce *Brucella* antibodies and some can harbor the pathogen (1,2,3). Serological surveys provide most of the published information on brucellosis in wildlife but these studies should be interpreted cautiously when assessing the significance of a species as a reservoir of bovine brucellosis. In many instances, sample sizes have been too small to permit generalization. Furthermore, the sensitivity and specificity of serological tests are frequently not known when applied to wildlife species. Some titers may result from nonspecific agglutinins or from cross-reactions with antigens other than those of Brucellae. Serological reactions may indicate exposure but not necessarily current or active infection, and not the species of *Brucella* involved. Isolation of the pathogen, in conjunction with serology, provides better information but few studies have done this. Experimental studies should follow field surveys when a wildlife species is implicated in the epidemiology of brucellosis. This would provide data on host susceptibility, duration of infection and modes of transmission. It would also indicate the pathogenicity of *Brucella* in that host and could evaluate the effectiveness of serological tests. Lastly, the presence of a reservoir, such as infected cattle, may exaggerate the prevalence and significance of antibody titers or infections in closely associated wildlife species that otherwise might not maintain the disease or have a role in the transmission of brucellosis. Some wildlife species therefore are more important as disease sentinels than as reservoirs and thus, whenever brucellosis occurs in wildlife, follow-up studies are warranted.

There are only a few published reports of bovine brucellosis in Canadian wildlife. In 1946-47, sera from 37 bison (*Bison bison*) from Elk Island National Park in Alberta included six positive and five suspicious reactors, while sera from 187 elk (*Cervus canadensis*) from a different (not named) national park were all negative on tube agglutination tests (4). A later survey at Elk Island National Park found 111 (32.4%) positive and 34 (11.3%) suspicious reactors on tube and plate agglutination tests of sera from 343 bison (5). The same study found 25 (11.3%) positive and four (1.8%) suspicious titers in 221 elk, but no reactors in 124 moose (*Alces alces*) from that park. There were two positive and one suspicious reactors among 20 bison from Riding Mountain National Park in Manitoba in 1956-57, and one positive reactor out of 17 elk collected in 1957 from Waterton Lakes National Park in Alberta. There was limited evidence that moose may be a dead-end host for bovine brucellosis based on necropsy findings in two bulls. The report concluded that the park-confined bison were not a health threat to cattle but that free-ranging bison, such as those in Wood Buffalo National Park, could be a hazard. It was also concluded that brucellosis in elk represented a significant problem for disease eradication programs and circumstantial evidence of transmission of brucellosis from elk to cattle was given. Test and slaughter programs have since eliminated brucellosis from wildlife at Elk Island National Park and there are no known infected elk herds in Canada.

Brucellosis was detected in bison at Wood Buffalo National Park in 1955 when three of 11 sera were found positive on agglutination tests (5). Choquette *et al* (6) have reviewed the results of serological surveys in the park bison. In eleven annual collections between 1959 and 1974, tube agglutination tests detected 625 (30.3%) positive and 141 (6.8%) suspicious reactors out of 2,066 sera. Sera from bison collected at Hook Lake, Northwest Territories (outside the park) in 1970 and 1974 contained 114 (38.1%) positive and 16 (5.4%) suspicious reactors out of 299 samples. Cases of orchitis and arthritis were observed in park bison and *B. abortus* was cultured from some of these lesions. The authors suggested that brucellosis could well be a factor in the poor reproductive rate of the park herd.

Current studies on diseases in Wood Buffalo National Park (Tessaro and L.B. Forbes, unpublished) have found *B. abortus* biotype 1, biotype 2, and a new urease-negative strain of biotype 1 in the bison. Biotype 1 has also been isolated from a wolf (*Canis lupus*) and a red fox (*Vulpes fulva*), and the new strain of biotype 1 has been found in a second wolf. There has not been any serological or bacteriological evidence of infection in black bears (*Ursus americanus*), fishers (*Martes pennanti*), martens (*Martes americana*), lynx (*Lynx canadensis*), mink (*Mustela vison*) or in a variety of rodents sampled to date.

A serological survey for diseases in Alberta wildlife did not find *Brucella* antibodies in three wolves, nine bighorn sheep (*Ovis canadensis*), 11 snowshoe hares (*Lepus americanus*), or 22 woodland caribou (*Rangifer tarandus caribou*) (7). Complement fixation tests revealed minimal titers in three of 283 sera from black bears. One hundred forty-six sera from moose in British Columbia (8,9) and 208 sera from moose in Quebec (10) were all negative on Brewer's card test and slide agglutination tests, respectively. Many of the British Columbia samples were collected from moose in the vicinity of infected range cattle. A 1948-49 survey of 58 deer (species not given) from southeastern Saskatchewan did not find any reactors on tube agglutination tests despite the high prevalence of brucellosis in cattle in that area at that time (11).

Numerous studies on brucellosis have been done in the United States on a wide range of wildlife species, many of which are also indigenous to Canada. Serological surveys on large numbers of free-ranging white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*) have indicated overall reactor rates of less than one percent (1,12). In a recent survey of 713 white-tailed deer in Missouri, only one reactor was found and it came from a sub-sample of 49 deer deliberately selected from quarantined farms (13). *Brucella abortus* was isolated from one of 70 white-tailed deer (14) but there are no reports of isolates from mule deer. As in Canada, reports of brucellosis in moose are rare and it has been suspected of being a fatal disease in moose (15,16). Significant *Brucella* titers have not been found in pronghorn antelope (*Antilocapra americana*) even though thousands of sera have been tested (17). *Brucella* antibodies were detected in three of 73 Dall sheep (*Ovis dalli dalli*) from Alaska (18).

Bovine brucellosis is a significant problem in Wyoming elk herds (12,19,20,21). Approximately 20,000 elk utilize 22 feeding grounds in the western part of the state. *Brucella abortus* biotype 1 has been isolated from aborted elk fetuses and nonviable calves, and from 17 of 45 adult elk at necropsy. Approximately 50% of mature cow elk in the National Elk Refuge and Grays River herds have had serological evidence of infection. Experimentally infected elk had serological responses similar to those of infected cattle and they could maintain active infections for up to 56 months. Horizontal transmission was demonstrated between infected elk and noninfected elk and cattle in the same enclosure. Fourteen of 29 infected cow elk either aborted or delivered premature or nonviable calves and several of the infected elk lost their antibody titers despite maintaining the pathogen. Serological studies indicated the use of multiple test methods rather than any single test for diagnosis of the disease in elk, and indicated the need for more stringent diagnostic criteria than those applied to cattle. There has been circumstantial evidence of natural transmission of *B. abortus* between elk herds and two cattle herds in Wyoming, and a reduced-dosage Strain 19 vaccination trial is being conducted on free-ranging elk (E.S. Williams, personal communication).

Bovine brucellosis is an important problem in publicly and privately owned bison herds in the United States but little scientific information has been published. Disease management in Yellowstone National Park bison has been debated for years; the United States Department of Agriculture has favored brucellosis eradication but the National Parks Service wants minimal disease control (22,23,24). At present, the park boundary is under surveillance and stray bison are shot. There are an estimated 500 to 1000 privately owned bison herds in the United States and brucellosis transmission between these herds is becoming a significant problem according to the Animal and Plant Health Inspection Service (25).

The role of wild carnivores in the epizootiology of bovine brucellosis is poorly understood. In the United States, antibody titers have been found in wild red foxes, coyotes (*Canis latrans*), black bears, bobcats (*Lynx rufus*), skunks (*Mephitis mephitis*) and (*Spilogale gracilis*), badgers (*Taxidea taxus*), opossums (*Didelphis virginiana*) and raccoons (*Procyon lotor*), and *B. abortus* has been isolated from foxes, coyotes, opossums and a raccoon (1). However, in most of these cases the sample size of the host species or the prevalence of infection have been too low to evaluate the significance, if any, in these carnivores. These species are likely exposed to brucellosis by preying or scavenging on primary reservoir species such as cattle, elk or bison. Cattle confined to a pasture with experimentally-infected coyotes did seroconvert and one cow aborted. *Brucella abortus* was cultured from the aborted fetus and from coyote feces (D.S. Davis, personal communication). Wild carnivores may also act as mechanical vectors by transporting aborted fetuses, placentas or other infected material. The persistence and pathogenicity of *B. abortus* in wild carnivores is not known, but infected dogs (26) and ranched mink (27) have aborted and large numbers of *Brucella* were cultured from fetuses and uterine exudate. Vertical transmission has been reported in coyotes (28).

Rodents have received much attention in regard to the epizootiology of brucellosis, but numerous serological surveys on large numbers of species have generally found a very low prevalence of reactors and the few *B. abortus* isolates from rodents have come from rats on farms where the cattle were infected (1). Meyer (29) concluded that rodents do not represent a significant reservoir of brucellosis. Surveys of lagomorphs, squirrels and beaver (*Castor canadensis*) in the United States have not revealed any foci of the disease (1).

The potential role of birds (30) and insects (31) in the transmission of brucellosis has been examined by some researchers. Although experimental infection and transmission was achieved in some instances and a few cases of natural infections found, birds and insects are probably of minor importance in the natural transmission of the disease.

Rangiferine Brucellosis

Several authors reported sporadic cases of brucellosis in Native people in the Northwest Territories (32,33,34,35) and Alaska (36,37) and some suggested that there was a link between these cases and the utilization of reindeer and caribou. The agent was characterized and identified as *Brucella suis* biotype 4 (38). Broughton *et al* (39) found *Brucella* agglutinating antibody titers of 1:25 or greater in 14 (4.37%) of 320 sera from Kaminuriak caribou and in 148 (8.74%) of 1,692 sera from reindeer in the Mackenzie Delta. These authors did not find any cases of orchitis, epididymitis, bursitis, metritis, abortion or retained placenta as have been observed in Russian and Alaskan reindeer and caribou, and no attempt was made to isolate the agent. *Brucella suis* biotype 4 has been isolated from carpal hygromata from Canadian caribou and from a case of granulomatous nephritis in one caribou (Tessaro and L.B. Forbes, unpublished). It has also been isolated from a carpal hygroma from a single muskox (40). In a 1982 serological survey of 99 muskoxen on Banks Island, Northwest Territories, all sera were negative on tube and plate agglutination tests (41). Recent surveys have detected the disease in Baffin Island caribou herds (Broughton, personal communication). Further studies are needed to determine if rangiferine brucellosis is endemic in the remaining Canadian barren-ground caribou (*Rangifer tarandus groenlandicus*) herds, Peary caribou (*Rangifer tarandus pearyi*), and woodland caribou populations.

In Alaska, *Brucella* agglutinating titers have been found in caribou, arctic ground squirrels (*Citellus undulatus*), a moose, grizzly bears (*Ursus arctos*), red fox, arctic fox (*Alopex lagopus*), sled dogs and wolves (42,43,44,45). Experimental *B. suis* biotype 4 infections have been produced in dogs, wolves, a black bear, a variety of rodents, and a moose (44,46,47).

There is limited information on experimental *B. suis* biotype 4 infections in livestock. Cattle developed agglutination titers of 1:80 to 1:320 but no lesions occurred and the bacteria could not be recovered from tissues at necropsy (48,49). Sheep also did not develop lesions and the agent was not isolated from necropsy tissues.

In conclusion, rangiferine brucellosis does not appear to pose a health threat to Canadian livestock. However, it is of public health significance and may become a more important herd health problem for reindeer and caribou if intensive husbandry of this species continues to develop in Canada as it has in Alaska.

Bovine Tuberculosis

Numerous wildlife species can contract tuberculosis. This alone does not determine their relative importance in the epizootiology of the disease. Given the transmissibility and importance of tuberculosis, all wildlife cases merit close scrutiny because they might represent a reservoir or sentinel of the disease. One problem in the detection of tuberculosis in wildlife is the lack of proven test methods; there is no reliable blood test, intradermal tuberculin tests have not been properly evaluated in many wildlife species, and lymphocyte activation tests are not yet perfected. Furthermore, the immune spectrum of mycobacterial infections in different host species and the resulting variation in the appearance of lesions can complicate the diagnosis (50). When tubercular lesions are found in wildlife, attempts should be made to determine whether *M. bovis, M. avium, M. tuberculosis* or "atypical mycobacteria" are involved because all of these agents have been reported in wild animals and the difference is critical for analysis of the problem and prediction of the outcome.

Mycobacterial infections are more often a problem in zoo collections and nonhuman primate colonies than in free ranging wildlife. Primate colonies have received a great deal of attention because of the relative frequency of outbreaks and the related veterinary and public health implications (51). One study of 166 mycobacterial isolates from captive wild mammals found that 44.6% were *M. bovis,* 32.5% were *M. avium,* and 16.9% were *M. tuberculosis* (52). The prevalence of tuberculosis in Canadian zoos, game parks and primate colonies is very low, but national and international trade in wildlife species always presents the potential for disease introduction and spread.

The largest free roaming wildlife reservoir of bovine tuberculosis in North America is the hybrid bison population in and around Wood Buffalo National Park at the border between Alberta and the Northwest Territories. The disease was introduced into the park between 1925 and 1928 when 6,673 plains bison were moved there from the infected herd at Buffalo Park near Wainwright, Alberta. The herd near Wainwright was eventually destroyed and the park disbanded in 1940. Between 1923 and 1937, 6,450 (53.7%) of the 12,005 bison slaughtered near Wainwright had tubercular lesions (53). From 1929 to 1974, bison were periodically slaughtered in Wood Buffalo National Park for meat production purposes. Tubercular lesions were first noted in the 1930's and between 1952 and 1956, 39% of 1,508 slaughtered bison had lesions (54). Intradermal skin tests (caudal fold) were used at five slaughters between 1955 and 1962 but the reactor rates were notably lower than the prevalence of lesions in the bison. In the 1959-60 slaughter, Choquette *et al* (55) found 151 (13.5%) reactors among 1,116 bison tested. Reexamination of their data indicates that the intradermal skin test only had a sensitivity of 66.6% but a specificity of 89.6%. Necropsy examinations indicated that 31 (14.2%) of 219 bison with tubercular lesions had the generalized form of the disease and the remaining animals had caseous and/or calcified lesions in one or more lymph nodes, especially those of the head and chest. Orchitis, metritis and fetal deaths were attributed to tuberculosis. Current studies on diseases in Wood Buffalo National Park have thus far only found tuberculosis in bison and not in any other species of wildlife. The park bison population has declined from an estimated high of 12-15 thousand in the late 1940's to approxiamtely 5,000 animals at the present time.

Mycobacterial infections have been observed in members of the deer family. In Canada, lesions due to *M. bovis* were found in 73 (5.5%) of 1,329 elk, six (5.6%) of 107 moose and two (0.8%) of 242 mule deer that ranged with the infected bison at Buffalo Park near Wainwright (53). The disease has more recently been found in one white-tailed deer (56). In the United States, *M. bovis* was also found in a white-tailed deer (57), but otherwise reports of tuberculosis in free ranging deer are scarce (58). On the world scale, mycobacteriosis has been more frequently reported in confined deer herds, and *M. bovis, M. avium* and atypical mycobacteria have been isolated (59).

Taxonomists now consider North American elk (*Cervus canadensis*) and European red deer (*Cervus elaphus*) to be conspecific. This is likely the cervid of greatest concern in the epizootiology of bovine tuberculosis on this continent. A recent outbreak of *M. bovis* infection occurred in the United States which required the investigation of nine elk herds in seven states and the testing of associated bison and cattle herds (60). Three persons in contact with the infected elk converted from negative to positive status on tuberculin tests. The investigation, clean up and legal repercussions are ongoing because the disease spread to bison in contact with the elk. Due to shipments of approximately 370 potentially infected bison, 87 bison herds in 20 States have been investigated and 18 of these herds are considered infected. The sale and distribution of infected elk and bison exposed over 2,450 bison and approximately 4,190 cattle to the disease (61). In New Zealand, bovine tuberculosis is a significant problem in red deer on game ranches and there is concern that the disease could spread to cattle (62). The intradermal skin test has not been completely evaluated in cervids and this has caused problems in diagnosis and eradication of tuberculosis in New Zealand deer farms and zoo and game park collections (59,62).

Bovine tuberculosis has rarely been reported in free ranging, wild carnivores. The only report of the disease in wild wolves was based on culture-positive lesions in two animals from Riding Mountain National Park in Manitoba (63). Follow-up studies were not done to determine the source of infection. Occasional cases of the disease might be expected in wild carnivores closely associated with infected hooved stock, since tuberculosis has been reported in farmed mink and foxes fed contaminated meat (64,65) and in domestic cats and dogs exposed to infected cattle (66).

Myobacterium bovis has not been reported in wild mice, has only rarely been reported in wild rats, and has been identified only once in a wild rabbit (50).

Important wildlife reservoirs have been found in other countries. The low level persistence of bovine tuberculosis in English cattle led to the discovery of European badgers (*Meles meles*) as a reservoir (67). In New Zealand, bovine tuberculosis is widely distributed in brush-tailed possums (*Trichosuris vulpecula*) (68). Asian buffalo (*Bubalis bubalis*) are reservoirs throughout their range including Australia (69) and free-ranging Cape buffalo (*Syncerus caffer*) are maintenance hosts in Africa (70).

CONCLUSIONS

Brucellosis and tuberculosis share a wide range of potential wildlife hosts. However, field surveys on free ranging populations have only rarely found infected individuals and most of those cases had been in contact with infected cattle. There are a few important exceptions to this generalization. In North America, bison and elk have been, and are, important reservoirs of bovine brucellosis and tuberculosis. In the presence of primary reservoirs, other wildlife species can contract the diseases and may secondarily be important mechanical or biological vectors. As with other contagious diseases, close confinement is conducive to the transmission of tuberculosis and brucellosis. Hence, zoos, wildlife parks, laboratory animal colonies and fur farms can become nidi of infection.

The hybrid bison in and around Wood Buffalo National Park are the largest reservoir, and the only existing wildlife reservoir, of *B. abortus* and *M. bovis* in Canada. The introduction of these diseases into the park should stand as a classic example of the problems that can occur when wildlife are transplanted without due attention to disease status. These bison have been geographically isolated from livestock and people. However, northern agricultural expansion, regional development, Native land claim negotiations and the establishment of other publicly and privately owned bison populations in the area have all increased the potential for spread of the diseases. Infected bison do stray out of the park but these have been under intense hunting pressure from local Native communities. This reduces the opportunity for geographical spread of the diseases but increases the possibility of human infection. There is no attempt at disease control or eradication being made at the present time by any of the involved government agencies.

There is increasing interest in game ranching in Canada (71,72). The Government of Alberta has recently distributed a discussion paper, which indicates their support for this developing industry (73). Bison and elk are advocated as the species of choice for game ranches in western Canada (74). Because these species are also potentially significant reservoirs of brucellosis and tuberculosis, game ranches will have to be monitored and the transport of live animals regulated. In the United States, there have been conflicts between agricultural agencies and game ranchers because regulations were often created after problems arose. There have been arguments over brucellosis testing and eradication in commercial bison herds and over indemnity for bison destroyed because of brucellosis and tuberculosis. It is still too early to say if game ranching will develop into a viable industry in Canada. However, the potential importance of this industry in the epizootiology of infectious diseases like brucellosis and tuberculosis must not be overlooked.

The immediate need is to evaluate, improve and develop testing methods for the reliable diagnosis of brucellosis and tuberculosis in bison and elk, and to consider ways of minimizing the risk of disease transmission among susceptible animal populations.

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