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THE ROLE OF WILD NORTH AMERICAN UNGULATES IN THE EPIDEMIOLOGY OF BOVINE BRUCELLOSIS: A REVIEW

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ABSTRACT: Published reports of *Brucella abortus* infections in wild North American ungulates and domestic cattle herds were reviewed to determine if infection in these species was related. Bison (*Bison bison*) were frequently found infected, but are probably a minor threat to livestock due to their current limited distribution. Most elk (*Cervus elaphus*) were free of infection except where their range was shared with infected bison or livestock. Deer (*Odocoileus* spp.), pronghorns (*Antilocapra americana*), moose (*Alces alces*), and bighorn sheep (*Ovis canadensis*) appeared to be insignificant hosts of *Brucella abortus*. The lack of significant wild ungulate hosts and the distribution of infected livestock herds in the United States suggests that wild ungulates are of little importance in the epidemiology of infections by *B. abortus* in cattle.

INTRODUCTION

Brucellosis is an infectious disease caused by six species of the bacterium *Brucella* (Thimm, 1982). The disease is important because of potential economic impacts on livestock industries, for which national eradication programs exist in Canada and the United States, and because it is transmissible to man. In most of North America, *B. abortus* is the most important species, causing abortions in cattle (Thimm, 1982). A relationship between brucellosis in cattle and wild animals, primarily wild ungulates, has often been suspected, since infection with *B. abortus* has been reported in several wild species (Katz, 1941; Shillinger, 1942; Moore and Schnurrenberger, 1981; Thimm, 1982). If wild ungulates are a significant reservoir of *B. abortus*, a brucellosis eradication program must consider their role in the epidemiology of the disease (Shillinger, 1942). The importance of wild ungulates as reservoirs of *B. abortus* has usually been inferred from detection of antibodies to *B. abortus* in serologic surveys or determination of susceptibility to experimental infections. Few studies have attempted to correlate brucellosis in wild species and domestic livestock (Hudson et al., 1980). This paper reviews evidence of the role of wild ungulates as reservoirs of *B. abortus* and correlates brucellosis in wild species with the occurrence of brucellosis in domestic livestock.

Serologic surveys have been used commonly to determine the distribution of *B. abortus* in populations of wild ungulates. The serologic procedures included tube or plate agglutination, card and complement fixation tests. However, results have been interpreted variously. Commonly, animals were considered seropositive only if the titers exceeded a threshold (e.g., >1:50), whereas animals with lower titers were classified as suspicious. In this review all animals with detectable titers were considered seropositive if animals with high titers were present in the same population. Considering all animals with a dectectable titer to be infected has been suggested previously for elk (Thorne et al., 1978b; Morton et al., 1981). We have extended this liberal interpretation of seropositivity to all wild ungulates to ensure a worst possible case assessment of the importance of wild ungulates as potential reservoirs of *B. abortus*.

BRUCELLA ABORTUS IN WILD UNGULATES

Brucella abortus was first reported in bison (*Bison bison*) of Yellowstone Na-

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TABLE 1. Serologic surveys for *Brucella abortus* in populations of elk in North America.

Location	Number tested	Number of reactors	Percent reactors	Reference
Wyoming	32	11	34.4	Rush, 1932; Tunnicliff and Marsh, 1935
Wyoming	1,165	370	31.8	Thorne et al., 1978b
Wyoming	119	16	13.4	Tunnicliff and Marsh, 1935
Alberta	221	29	13.1	Corner and Connell, 1958
Wyoming	36	2	5.5	Rush, 1932; Tunnicliff and Marsh, 1935
Wyoming	167	5	3.0	Hepworth, 1964
Colorado	3,844	11	0.3	Adrian and Keiss, 1977
Wyoming	497	1	0.2	Thorne et al., 1978b
Alberta	596	1	0.2	Choquette et al., 1966
Oklahoma	16	0	0.0	Wolfe et al., 1982
California	43	0	0.0	McCullough, 1971
Colorado	163	0	0.0	Denney, 1965
Idaho	54	0	0.0	Vaughan et al., 1973
Wyoming	42	0	0.0	Mills, 1936
Utah	88	0	0.0	Merrell and Wright, 1978
Alberta	186	0	0.0	Moore, 1947
Total	7,267	446	6.1	

tional Park in 1917 (Meagher, 1973). From 1930–1933, 305 of 484 (63%) bison slaughtered in herd reductions in the park were seropositive (Tunnicliff and Marsh, 1935). Sera obtained from live bison during the same period yielded 59 reactors from 82 (72%) animals (Tunnicliff and Marsh, 1935). During 1932–1933, 106 of 173 (61%) bison from the National Bison Range reacted positively (Tunnicliff and Marsh, 1935). Of 2,365 sera tested from bison in Wood Buffalo National Park and surrounding areas in northern Canada from 1959–1974, 739 (31%) were positive (Choquette et al., 1978). Similarly, 42% of 343 bison from Elk Island National Park in Canada were seropositive (Corner and Connell, 1958). The high prevalence of antibodies, particularly in free-roaming herds in northern Canada, suggests bison may be a natural reservoir of *B. abortus*. Bison seldom show clinical signs of infection, which has been interpreted as an evolutionary response to the presence of *B. abortus* (Meagher, 1973). The relatively high prevalence of infection recorded in bison is potentially significant in the epidemiology of brucellosis in domestic cattle.

Elk *(Cervus elaphus)* have been proposed as an important host for *B. abortus* (Shillinger, 1942; Moore and Schnurrenberger, 1981; Thimm, 1982). In 1931, 11 of 32 (34%) sera from elk ranging near infected bison in Yellowstone National Park were positive or suspicious. Only two of 36 (5%) sera from elk outside the range of infected bison were positive (Rush, 1932; Tunnicliff and Marsh, 1935). A serologic survey of 1,165 elk using two winter feedgrounds in Wyoming over a 5-yr period found that 370 (32%) were positive (Thorne et al., 1978b). While it might be inferred from these reports that elk are frequently infected with *B. abortus*, an examination of serologic surveys from several states and Canada indicated a low prevalence of infection in most elk populations (Table 1). All elk populations that showed a high prevalence of infection shared a common range with bison or cattle (Tunnicliff and Marsh, 1935; Corner and Connell, 1958; Thorne et al., 1979). It seems unlikely that elk have served as a natural reservoir of *B. abortus*, but rather have been infected by recent exposure to cattle or bison. Elk had a high susceptibility to infection, and exhibited clinical signs of disease in experimental studies (Thorne et al., 1978a), which is consistent with a lack of exposure to *B. abortus* during their evolutionary history. A low prevalence of infection in the conspecific red deer also supports this conclusion (Daniel, 1966; McDiarmid and Matthews, 1974). While it seems unlikely that elk have served as a reservoir of *B. abortus* historically, a reservoir may be developing in elk herds in northwestern Wyoming (Thorne et al., 1979).

Extensive serologic studies of deer of the genus *Odocoileus* have revealed few reactors. Sera from over 16,000 white-tailed deer (*O. virginianus*) and mule deer (*O. hemionus*), tested for *Brucella* antibodies in various parts of the United States, revealed only 20 seropositive animals using criteria applied to cattle (Fay, 1961). No reactors were found in 1,650 mule deer sampled in Colorado over a 10-yr period (Adrian and Keiss, 1977). Thirty-seven white-tailed deer from four ranches in Texas, where bovine brucellosis was endemic, were seronegative, and *B. abortus* was not isolated from tissues of 22 deer sampled (Boeer et al., 1980). Virtually all workers have concluded that deer are insignificant in the epidemiology of bovine brucellosis. Old World deer, such as fallow deer (*Dama dama*), axis deer (*Axis axis*), and roe deer (*Capreolus capreolus*) also have been shown to lack antibodies to *B. abortus* (McDiarmid, 1951; Daniel, 1967; Riemann et al., 1979). Pronghorns (*Antilocapra americana*) also appear to be insignificant hosts of *B. abortus*. No reactors were found when sera from 110 pronghorns in Alberta and Saskatchewan were tested (Barrett and Chalmers, 1975). Sera from 146 pronghorns in Idaho were negative for *B. abortus* (Stauber et al., 1980). One reactor was found in 5,272 sera from pronghorns in Colorado during a 10-yr survey (Adrian and Keiss, 1977).

Infection with *B. abortus* has been reported in moose (*Alces alces*) (Fenstermacher and Olsen, 1942; Jellison et al., 1953). Of eight moose, in poor condition, sampled in Minnesota, one was seropositive (Fenstermacher and Olsen, 1942). This animal had a high titer (1:50,000) to *B. abortus*. Serum from a moose that died in Montana after being ill for several days also had a high titer (1:20,000) in the tube agglutination test (Jellison et al., 1953). *Brucella abortus* was isolated from both animals. Similarly, two ill moose from Elk Island National Park were either seropositive (1:12,800) in the tube agglutination test or culture-positive (Corner and Connell, 1958). While brucellosis is usually nonfatal in adult animals, it could not be ruled out as the cause of death in these moose. These reports suggest that the clinical manifestations of *B. abortus* infection in moose are severe and that this species may be a dead-end host (Corner and Connell, 1958). Sera from nine of 35 (26%) moose from Montana, tested subsequent to the isolation of *B. abortus* in the dead animal, were reactive although the highest titer was 1:40 in the tube agglutination test (Jellison et al., 1953). Moose in British Columbia, where an outbreak of brucellosis in cattle had recently occurred, were tested for *B. abortus* during 1977–1978. Since no reactors were found in 104 sera, it was concluded that moose were epidemiologically insignificant in the spread of bovine brucellosis (Hudson et al., 1980). No positive reactors were found in sera from 44 moose in Alberta (Zarnke and Yuill, 1981).

Caribou (*Rangifer tarandus*) are not a reservoir of *B. abortus* but are infected by *Brucella suis*, type 4. This biotype has been recovered only from caribou, conspecific domestic reindeer, and predators of cari-

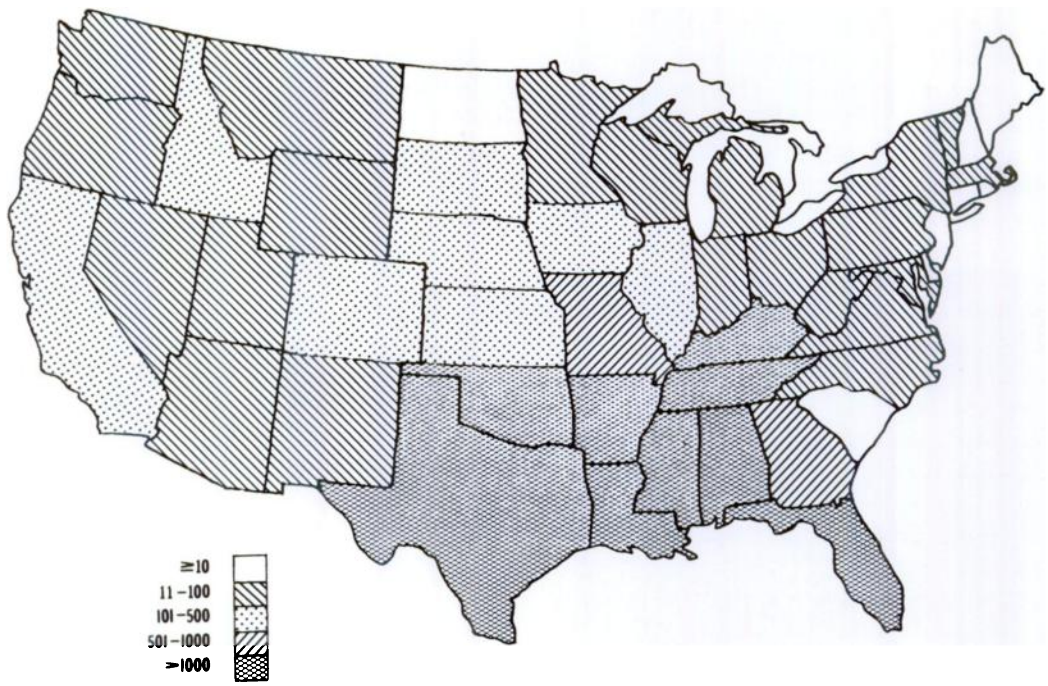

FIGURE 1. Yearly mean number of cattle herds with brucellosis in the United States, 1971–1980 (U.S.D.A., 1980).

bou (Huntley et al., 1963; Neiland, 1975). In Canada, 14 of 320 (4%) sera from wild caribou, and 148 of 1,692 (9%) sera from reindeer were positive (Broughton et al., 1970). The infection is widespread in caribou populations, and probably reflects a historical relationship between caribou and rangiferine brucellosis (Rausch and Huntley, 1978). The limited distribution of domestic livestock within the geographical range of caribou probably makes *B. suis*, type 4 of little importance to livestock, except for domestic reindeer herding.

Brucella abortus infections have not been found in the few studies of other wild ungulates. Sera from nine bighorn sheep (*Ovis canadensis*) in Alberta were negative (Zarnke and Yuill, 1981). In California, 10 sera from desert bighorns (*O. c. cremnobates*) were negative (Turner and Payson, 1982). There are no published reports of *B. abortus* infection in mountain goats (*Oreamnus americanus*). No reactors were found in 14 sera from the chamois (*Rupicapra rupicapra*) and 93 sera from the Himalayan tahr (*Hemitragus jemlahicus*) (Daniel, 1967), Old World relatives of the mountain goat. The only common nonruminant wild ungulates in North America are the collared peccary (*Tayassu tajacu*) and feral pig (*Sus scrofa*). *Brucella abortus* has not been reported in peccaries, and the *Brucella* organism found in feral swine is *B. suis* (Wood et al., 1976; Becker et al., 1978). Hence, these species appear to play no role in the epidemiology of bovine brucellosis.

BRUCELLOSIS IN CATTLE

Both the United States and Canada have made progress in the control of brucellosis (Thimm, 1982). As of October 1983, there were only six herds with confirmed infection in Canada (Smith and Mitchell, 1983). In the United States, the occurrence of brucellosis has varied regionally (U.S.D.A., 1980). Between 1971 and 1980 there were more infected herds in the southeastern U.S., from Florida to Texas, than in the midwest, and few infected herds in the west and northeast (Fig. 1).

While many authors infer the importance of wild ungulates in the epidemiology of bovine brucellosis simply from the number of reported cases in a particular wild species (Katz, 1941; Shillinger, 1942; Moore and Schnurrenberger, 1981), a better understanding may be gained by correlating infections of *B. abortus* in wild ungulates with brucellosis in livestock. *Brucella abortus* in wild ungulates is a threat to the eradication of bovine brucellosis if there is interspecific transmission (Thimm, 1982). While there is indirect evidence that domestic livestock may spread the infection to wild species (Thimm, 1982), there are no reports that wild species are a source of infection for domestic animals under natural conditions.

The high frequency of bovine brucellosis in the southeastern United States is most likely perpetuated by a closed cycle in domestic livestock. The only wild ungulate in this region capable of transmitting *B. abortus* is the white-tailed deer, and it has been excluded as an important host of this organism (Shotts et al., 1958; Hayes et al., 1960).

Bison are potentially important hosts of *B. abortus*, but their range is now so limited that they are probably of little importance in spreading brucellosis. Few free-roaming herds exist, and most do not share range with livestock. The bison of Yellowstone National Park have frequently been suspected as an important reservoir of *B. abortus* for surrounding cattle herds. It has been shown, however, that bison rarely leave the park, and those that do are usually bulls (Meagher, 1973). Since the usual mode of transmission is oral contact with aborted fetuses and placentas (Witter and O'Meara, 1970; Moore and Schnurrenberger, 1981), bulls would be unlikely disseminators of infection. Venereal transmission appears to be unlikely, since interspecific copulation under natural conditions probably does not occur.

Elk have been shown to be susceptible to infection and are regionally abundant. However, a comparison of the regional occurrence of bovine brucellosis with the distribution of elk does not implicate elk as a significant reservoir of *B. abortus*. Elk occur mainly in the western and Rocky Mountain states (Boyd, 1978). This region has relatively few infected herds of cattle. Eradication through measures limited to domestic animals has been relatively successful in these states. Infections of *Brucella abortus* in elk have been reported frequently from Wyoming, yet few infected cattle herds are reported annually (Fig. 1). The tendency for pregnant elk to seek seclusion prior to calving (Geist, 1982) reduces the risk of disseminating infection to cattle.

CONCLUSION

While the information presented is of a correlative nature, serologic studies and the geographic relationship between *B. abortus* infection in cattle and wild ungulates suggest that the latter do not play a significant role in the epidemiology of brucellosis in cattle in North America. Therefore, infection in wild ungulates should not preclude the eradication of brucellosis in cattle. There have been no published reports of wild ungulates hindering eradication of bovine brucellosis in any part of the world.

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