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RANGIFERINE BRUCELLOSIS ON BAFFIN ISLAND

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ABSTRACT: The standard tube agglutination test (STAT) and the complement fixation test (CFT) were used to assess the seroprevalence of antibodies to *Brucella* spp. in caribou (*Rangifer tarandus*) from three populations on Baffin Island, Canada. During late winter from 1983 to 1986, sera from 17 of 40 North Baffin (43%), 11 of 33 Northeast Baffin (33%) and 12 of 82 South Baffin (15%) adult caribou had antibodies in the STAT at 1:50 or the CFT at 1:5. Seroprevalence increased as caribou matured with one (4%) of 25 calves, four (13%) of 31 yearlings, and 40 (26%) of 155 adult caribou being positive. However, seroprevalence did not differ with sex in any age class. Positive antibody titers were higher in adult females sampled in May, 3 to 4 wk before parturition, than in adult females sampled in late March and April. The strength of positive titers did not differ with the time of sampling among adult males. Pathologic signs of brucellosis were found in three (13%) of 23 caribou that were assumed to have active infections (caribou with CFT titers > 1:160). *Brucella suis* biovar 4 was isolated from 24 (60%) of 40 caribou from which lesions were submitted. Between 1986 and 1990, the annual incidence of reported human (*Homo sapiens*) cases averaged 3.4 (34:100,000) on Baffin Island.

Key words: Brucellosis, *Brucella suis* biovar 4, caribou, tuktu, *Rangifer tarandus*, Inuit, *Homo sapiens*, zoonoses, epizootiology, epidemiology, Nunavut.

INTRODUCTION

Brucella suis biovar 4 causes disease primarily in caribou and reindeer (*Rangifer tarandus*) (Meyer, 1966), but also in humans (*Homo sapiens*) (Forbes, 1991), dogs (*Canis familiaris*) (Neiland, 1970; Neiland and Miller, 1981), wild predators (Zabrodin, 1984), and herbivores (Gates et al., 1984; Honour and Hickling, 1993) that cohabit with infected populations of *R. tarandus*. Rangiferine brucellosis is enzootic in Siberia (Zabrodin, 1984), Alaska (USA) (Neiland et al., 1968), and on the mainland (Broughton et al., 1970) and southern islands of the Northwest Territories (NWT), Canada. It has not been reported among woodland caribou (*R. tarandus caribou*) in North America or other subspecies from Scandinavia, Svalbard, Greenland or the Queen Elizabeth Islands of the NWT.

Brucellosis causes abortions (Rausch and Huntley, 1978) and lameness (Neiland et al., 1968) in some infected caribou and reindeer. Potential effects of brucellosis on the dynamics of infected populations are of concern, although impacts at the population level have not been documented. Lesions consistent with brucellosis in Baffin Island caribou were reported by hunters when I first asked in 1982.

Inuit of Baffin Island are concerned about health risks to subsistence hunters and their families. The first clinical case of brucellosis in the central NWT was confirmed through a marrow culture from an Inuit boy in 1953 (Matas and Corrigan, 1953). Subsequently, *Brucella* spp. antibodies were detected in two of 700 Inuit (one on Baffin Island and one in the central NWT) during a serologic survey in 16 NWT locations in 1955 (Greenberg and Blake, 1958).

My objectives were to assess the seroprevalence, distribution and sex-age differences in the serology of brucellosis among Baffin caribou populations during the 1980s, and to review the incidence and distribution of the disease among Inuit who use these caribou.

MATERIALS AND METHODS

Baffin Island (>500,000 km^2, 62° to 74°N, 62° to 90°W) forms the eastern margin of the Canadian Arctic archipelago, and is occupied by three caribou populations: North, South and Northeastern Baffin (Ferguson, 1989). Based on ear-tag returns and satellite telemetry studies, these populations appear to be distinct (M.A.D. Ferguson, unpubl.). From limited sur-

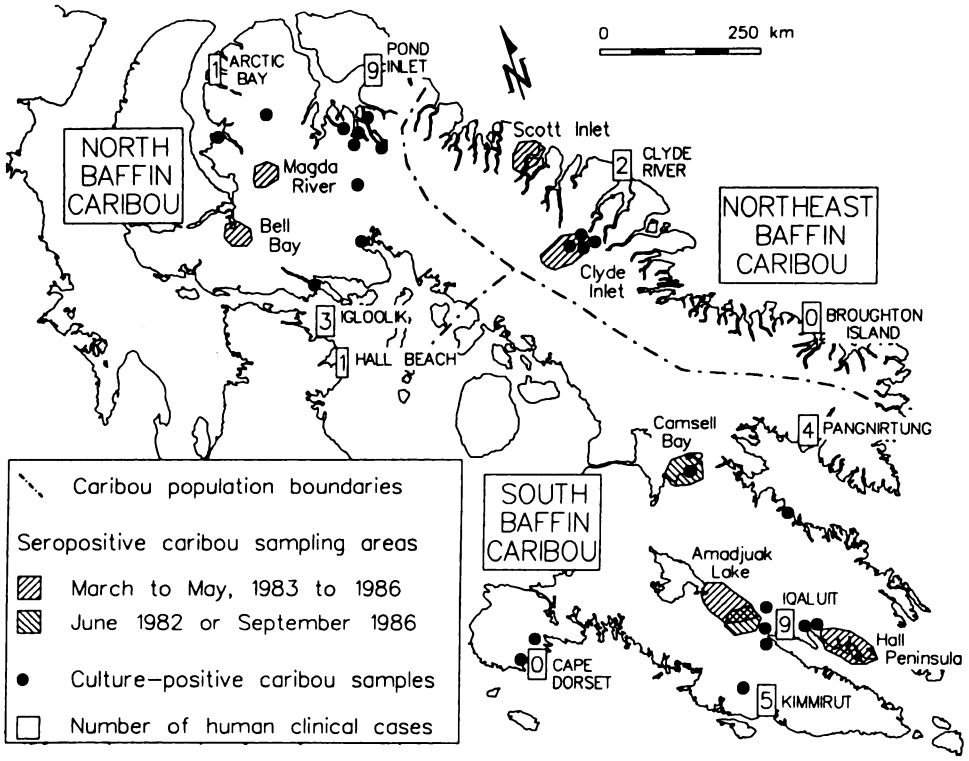

FIGURE 1. Distribution of rangiferine brucellosis on Baffin Island, Canada, from 1969 to 1990.

veys with extrapolations to unsurveyed areas, the South Baffin population was estimated at 60,000 to 180,000 in the late 1980s, while guesses placed the North Baffin population at 50,000 to 150,000 and the Northeast Baffin population at >10,000 (Ferguson and Gauthier, 1992).

In 1982, about 6,500 Inuit consumed more than 13,000 Baffin caribou (Donaldson, 1988), or about 2.2 caribou per person. Using the same consumption rate and 1991 census figures, about 17,000 caribou per year have been killed in recent years. In 1986, commercial quotas of 500 South Baffin and 100 North Baffin caribou were established for inter-settlement trade of meat within the NWT.

In late winter (March to May), blood and lower jaws were collected from 217 caribou during organized hunts from 1983 to 1986 (Fig. 1). The Inuit hunters were asked to select animals randomly, but the sampling may have been slightly biased because Inuit hunters tend to harvest animals that appear healthy. In addition, six blood samples were collected south of Amadjuak Lake (64°10′N, 69°10′W) in June 1982, and six more in Camsell Bay (66°15′N, 69°45′W) in September 1986. The June and September samples were included only to illustrate the distribution of the disease, and to evaluate agreement among serologic tests.

Usually within 10 min of death, 20 to 40 ml of blood were collected from the animal's thoracic cavity into glass vials. To prevent freezing, blood vials were kept in a special vest worn under a parka. Later, blood was allowed to clot and settle for 12–72 hr in styrofoam boxes warmed by freezer packs that had been in boiling water for 5 to 10 min. Based on readings from a minimum-maximum thermometer, blood was kept at 5 to 20 C while settling, after which serum was pipetted into a separate vial. Serum and blood were kept above freezing for up to 4 days, and centrifuged if possible. Centrifuged and uncentrifuged sera were frozen within 4 days of collection and kept at ≤−20 C until shipped for testing.

Brucella spp. antibody titers were determined at the Animal Diseases Research Institute (ADRI), Agriculture and Agri-Food Canada in Nepean, Ontario. Using *B. abortus* antigens, the standard tube agglutination test (STAT) (Malkin et al., 1968) and the complement fixation test (CFT) (Dohoo et al., 1986) were attempted on all samples. The STAT at 1:25 was conducted on only 103 samples in this study. The STAT results were provided for 225

of 229 samples at dilutions of 1:50, 1:100 and 1:200. For 218 of the samples, the CFT was reported for dilutions of 1:5, 1:10, 1:20, 1:40, 1:80, 1:160 and >1:160. Both STAT and CFT results were available for 214 samples. A sample was considered positive if either a 3+ reaction was obtained on the STAT at ≥1:50, equivalent to about 60 IU/ml (Stemshorn et al., 1980), or a positive reaction was obtained on the CFT at ≥1:5.

During the sampling, I examined all carcasses for lesions consistent with brucellosis. Tissue samples from suspected lesions in four carcasses were frozen at ≤−20 C and submitted for bacteriology at the Western College of Veterinary Medicine (WCVM) or the Health of Animals Laboratory (HAL), Agriculture and Agri-Food Canada in Saskatoon, Saskatchewan (Forbes et al., 1996). To augment these samples, frozen tissues from lesions in 36 additional caribou were submitted voluntarily by hunters between 1983 and 1990, and were sent for culturing at the WCVM or HAL. Biotyping of *Brucella* spp. was done at the HAL (Alton et al., 1988).

At the Baffin Renewable Resources Laboratory, Iqaluit, NWT, ages were determined for 211 of the 217 caribou sampled during late winter by examining tooth eruption in calves and yearlings and by counting cementum annuli in adult incisors (Miller, 1974). These 211 samples were used to assess differences based on sampling location and month, and age and sex of the animals.

Data were analysed using SPSS 6.1 for Windows (SPSS Inc., Chicago, Illinois, USA). I used the log-likelihood ratio test of independence (G test), unless >20% of the cells had expected values of less than five; in such cases, the Fisher exact test (Sokal and Rohlf, 1981) was used.

RESULTS

Two (2%) of 103 samples were positive for the STAT at 1:25, but negative at 1:50 and the CFT at 1:5. Although the STAT at 1:50 and CFT at 1:5 were in agreement for 208 (97%) of 214 samples for which both tests were conducted, the STAT was negative and the CFT was positive for all six cases in which the tests disagreed.

From March through May, prevalence of *Brucella* spp. antibodies was independent of sex among calves ($P = 0.36$, $n = 25$), yearlings ($P = 0.62$, $n = 31$), and adults ($P = 0.26$, $n = 155$). As well, seroprevalence did not vary ($P = 0.63$, $n = 155$) between year classes among caribou >2 yr old. However, seroprevalence increased ($P = 0.009$) as caribou matured during their first 3 yr of life; one calf (4%), four yearlings (13%), and 40 adults (26%) were seropositive. Therefore, only samples from adults were used to compare seroprevalence among populations and subpopulations, avoiding potential interactions between maturation and location effects.

Overall, *Brucella* spp. antibodies were found above threshold levels in 26% of adult caribou ($n = 155$) sampled on Baffin Island. North Baffin caribou had the highest seroprevalence (43%, $n = 40$), followed by Northeast Baffin caribou (33%, $n = 33$), and then South Baffin caribou (15%, $n = 82$) (Table 1). Serologic prevalence was not independent of population ($P = 0.002$). In pair-wise comparisons, seroprevalence in South Baffin adults was less than that in North ($P = 0.0009$) and Northeast ($P = 0.03$) Baffin caribou. However, seroprevalence in Northeast Baffin caribou did not differ ($P = 0.42$) from that in North Baffin caribou. Seroprevalence was independent of the sampling sites within each population ($P = 0.17$ for North Baffin, $P = 1.00$ for Northeast Baffin, $P = 0.75$ for South Baffin).

With parturition occurring in June, antibody titers increased among infected cows (adult females) during late pregnancy (May). Five of six seropositive North Baffin cows, sampled in May, had CFT titers over 1:160, compared with ($P = 0.0005$) none of 13 South and Northeast Baffin seropositive cows, sampled in late March and April. Among North Baffin cows sampled in May 1984 (when endpoint CFT titers were determined), four of five positive samples had titers of 1:640 ($n = 2$) or 1:1280 ($n = 2$). Only one seropositive cow was sampled on South or Northeast Baffin during May, and she also had a CFT titer over 1:160. In addition, seropositive males did not have ($P = 0.94$) higher titers in May (64% with CFT titers over 1:160, n

TABLE 1. Seroprevalence of brucellosis among adult caribou at six sampling sites on Baffin Island during late winter from 1983 to 1986.

Population Sampling site	Latitude (N), Longitude (W)	Sampling dates	Number of samples	Percent positive[a]
North Baffin			40	43%
Magda River	71°40′, 83°30′	May 1984	14	57%
Bell Bay	71°05′, 84°40′	May 1983	26	35%
Northeast Baffin			33	33%
Scott Inlet	71°10′, 72°10′	March and April, 1983 to 1985	14	36%
Clyde Inlet	69°40′, 71°30′	March and April, 1983 to 1985	19	32%
South Baffin			82	15%
Amadjuak Lake	64°20′, 69°45′	April and May, 1984 to 1986	52	14%
Hall Peninsula	63°20′, 66°30′	April and May, 1984 to 1986	30	17%

[a] A 3+ reaction on STAT with a titer ≥ 1:50 or a positive reaction on CFT with a titer ≥ 1:5.

= 11) compared with March and April (71% with CFT titers > 160, n = 7).

During the sampling, lesions consistent with brucellosis were seen in six caribou: three (5%) North Baffin, one (2%) Northeast Baffin and two (2%) South Baffin caribou. Five of these caribou were serologically positive, but *Brucella suis* biovar 4 was isolated from only one of four of these caribou (Table 2). In addition to this positive culture, *Brucella suis* biovar 4 was isolated from 23 of 36 other caribou on Baffin Island between 1983 and 1990 (Fig. 1).

DISCUSSION

Because *B. suis* biovar 4 has equal quantities of A and M antigens (Bevins, 1993), both *B. abortus* (used by ADRI) and *B. melitensis* antigens should react with *B. suis* biovar 4 antibodies. However, guidelines have not been established for the interpretation of STAT and CFT results with *R. tarandus*. Interpretation of serologic tests for brucellosis in Alaskan caribou has been based on the US Department of Agriculture's (USDA's) STAT at ≥1:20 (Neiland et al., 1968) and the USDA's standard plate test (SPT) at ≥1:25 (Zarnke, 1983). The USDA's STAT and SPT were standardized to be equivalent at 1:100 (Alton et al., 1988). A serologic survey of caribou on mainland NWT accepted ADRI's STAT at 1:25 as a positive reaction (Broughton et al., 1970). Based on the 103 samples tested with the STAT at 1:25, the estimated seroprevalence for Baffin caribou may have been about 2% less than by the methods of Neiland et al. (1968), Broughton et al. (1970) and Zarnke (1983), if dependent solely on the STAT at 1:50.

While the STAT detects immunoglobulin (Ig) M and IgG_2, it does not adequately detect IgG_1 and thus may yield more false-negatives than the CFT (Tizard, 1987). Use of the CFT in this study may have resulted in seroprevalence about 3% higher than the STAT at 1:50 alone. The net effect of using the STAT at ≥1:50 and the CFT at ≥1:5 probably yielded overall seroprevalence estimates similar to the meth-

TABLE 2. Serologic and bacteriologic results for Baffin Island caribou with physical signs of brucellosis during sampling in late winter from 1983 to 1986.

Lesions	Serologic results		*Brucella suis* biovar 4 isolated
	STAT	CFT	
Bursitis	Negative	Negative	NA[a]
Retained placenta	1:50	AC[b]	NA[a]
Orchitis	1:50	1:40	Yes
Bursitis	1:200	>1:160	No
Bursitis	1:200	>1:160	No
Bursitis, orchitis	1:200	>1:160	No

[a] NA = Not submitted for microbiology.
[b] AC = Anti-complementary reaction.

ods of Neiland et al. (1968), Broughton et al. (1970) and Zarnke (1983).

Zabrodin (1984) reported a seroprevalence of 33% (n = 157) among wild reindeer (*R. tarandus tarandus*) on Taimyr Peninsula, Russia, in September 1967; it is not clear how his test(s) compare to the STAT and CFT used in my study. In Alaska, seroprevalence of brucellosis in caribou varied between years, between seasons, and between populations. The highest documented seroprevalence for any Alaskan herd was reported from the Western Arctic herd, with a peak seroprevalence of 30% in autumn 1962, followed by 14% to 19% in spring from 1963 to 1965 (Neiland et al., 1968). Seroprevalence of brucellosis in the NWT has been reported for only two caribou populations. Seroprevalence was 4% (n = 320) between 1966 and 1968 in the Kaminuriak herd (Broughton et al., 1970). Although serologic tests and thresholds were not described, Gunn et al. (1991) reported that in April 1987, six of 17 samples from another population in the central NWT were seropositive. The seroprevalences of brucellosis among North (43%) and Northeast (33%) Baffin caribou are among the highest reported from any wild population of *R. tarandus* in the world. However, this assumes that workers in other studies used roughly equivalent serologic tests and thresholds, that their results were not influenced by seasonal infection, relapse or recrudescence of the disease, and that these workers sampled largely adult animals.

All *Brucella* sp. isolated from Baffin Island caribou were identified as *B. suis* biovar 4 (Forbes, 1991, 1992). Failure to culture *Brucella* sp. from 16 of the 40 submitted samples did not imply that these animals were not infected. Nevertheless, positive cultures confirmed that the disease occurred outside the serologic sampling sites (Fig. 1).

During this study in late winter, seroprevalence was lower among calves and yearlings than among older caribou. Seasonal sampling of young caribou, coupled with information about seasonal sex and age segregation, may help elucidate mechanisms of brucellosis transmission within caribou populations. The presence of *B. suis* biovar 4 in mildly infected testes and epididymides of Baffin caribou (M.A.D. Ferguson, unpubl.) is evidence that the disease may be transmitted venereally, as occurs in pigs (Blood and Radostits, 1989). However, caribou <2 yr old would have little opportunity for venereal transmission because they rarely participate in mating. Many female caribou calves may have latent infections but remain serologically negative until first parturition, usually at 3-yr-old, as may occur in cattle (Blood and Radostits, 1989). As well, some calves and yearlings in this study may have been infected recently, but had not yet seroconverted. Because of segregation from calving females, caribou calves and yearlings normally have less exposure than adults to fetal products (Pruitt, 1960; Miller and Parker, 1968) which are major sources of *B. abortus* infection among cattle (Blood and Radostits, 1989). However, based on such evidence as blood-stained hair around the vagina, abortions probably begin in late April on South Baffin wintering areas; thus, calves and yearlings may contact *Brucella* sp. infected fetal products before the calving season in June.

Neiland et al. (1968) suggested that in autumn seroprevalence was higher in males than in females, while the reverse was true in spring. In the March-to-May samples from Baffin, seroprevalence did not differ significantly between the sexes in any of the three populations. However, the relative strength of positive titers differed between the sexes depending the month of sampling. In May, the proportion (83%) of seropositive cows with CFT titers >160 was higher than that in March and April (0%). However, the proportions of seropositive bulls with CFT titers >160 were similar during May (64%), and March and April (71%). The strength of positive titers in this study generally followed Neiland et al.'s (1968) hypothesis

that brucellosis in males may be chronic in nature, while in females it may appear in a short-term, acute form. The increased serologic responses in females shortly before parturition may also represent recrudescence or relapse of chronic or latent infections.

Besides a dearth of standardized serologic tests for *R. tarandus*, the effects of sexual, age and seasonal differences have complicated comparisons between years and between populations. Both sampling and data analysis should be stratified based on these parameters. To maximize detection of *Brucella* antibodies in both sexes, serologic sampling of *R. tarandus* populations should be planned 3 to 4 wk before parturition. Although this timing may increase risks for sampling teams, it should increase detection in populations with low prevalences of brucellosis, as well as facilitate comparisons on a circumpolar basis.

Differences in seroprevalence between the three Baffin populations cannot be explained with certainty. Poor nutrition and severe weather may influence population effects of the disease (Neiland et al., 1968). There is circumstantial evidence that caribou density or nutritional status during late winter may influence seroprevalence (M.A.D. Ferguson, unpubl.). However, more research is required to assess the management implications of brucellosis in wild populations of *R. tarandus*.

Twenty (87%) of the 23 animals with CFT titers >160 (probable active infections) had no physical signs of disease. Therefore, hunters should be cautious when handling reproductive tracts and other internal organs of Baffin caribou, including those with no apparent signs of disease.

Human cases of rangiferine brucellosis in northern North America were first detected in Alaska where 49 clinical cases were reported during 1939 to 1953 (Huntley et al., 1963). Apparently many caribou-hunting peoples in Alaska were infected, but milder cases probably escaped diagnosis. Brody et al. (1966) also concluded that many cases may not be detected by medical personnel, especially chronic cases.

Since 1969, more brucellosis cases have been diagnosed in people subsisting on caribou from Baffin Island than elsewhere in the NWT (Department of Health, 1969 to 1990). The first human clinical case was detected on Baffin Island in 1969 and another case was diagnosed in 1972. Subsequently, six clinical cases were detected during 1976 to 1980; 14, during 1981 to 1985; and 17, during 1986 to 1990. In the latter period, the annual incidence of clinical cases of human brucellosis averaged 3.4, or about 34:100,000. This rate is more than three times that considered to be high (≥10:100,000) in a worldwide survey of human brucellosis (Thimm, 1982).

Based on the broad distribution of human clinical cases and caribou brucellosis, rangiferine brucellosis probably is present throughout Baffin Island (Fig. 1). From 1969 to 1990, human cases were detected in every community except Broughton Island and Cape Dorset (Department of Health, 1969 to 1990). The absence of human cases in Broughton Island was probably due to low caribou densities in that area. However, the absence of cases in Cape Dorset cannot be similarly explained given that the highest known wintering densities for Baffin caribou were near that community in the 1980s (3.5 caribou/km^2 in late 1984; M.A.D. Ferguson, unpubl.). The relatively low numbers of human cases in Arctic Bay and Clyde River seem incongruous given the high seroprevalence among caribou in those areas.

Age at diagnosis of brucellosis was available for 24 patients (Department of Health, 1969 to 1990). More clinical cases of brucellosis were diagnosed among persons aged 6 to 19 yr old (71%, n = 24) than among the age group of active hunters (30–59 yr, 25%). No cases were detected among Inuit >59 yr old, and only one case was aged 20 to 29 yr.

The primary route of *Brucella* spp. infection among abattoir workers was

through skin cuts and abrasions, followed by conjunctival contact with fluids while gutting animals, ingestion of uncooked meat and inhalation of aerosols (Buchanan et al., 1974). Inuit hunters probably are at risk to similar routes of infection. Baffin hunters aged 30 to 64 yr old were most active, killing over 18 caribou annually on average (Donaldson, 1988). Killing of caribou peaked among hunters aged 45 to 49 yr old, averaging about 27 caribou annually. Although human cases should be most common among the age group at greatest risk of exposure, most clinical cases were aged 6 to 19 yr old. Apparently, factors other than exposure risk determined development of detectable clinical symptoms.

Buchanan et al. (1974) found that among abattoir workers, clinical brucellosis occurred most often in young persons and older employees with little work experience; these are people who may have little acquired immunity to *Brucella* spp. infection. Similarly, young Inuit and others learning to hunt and process Baffin caribou may encounter *Brucella* spp.-infected tissues for the first time without having acquired immunity. Inexperienced hunters also may be at greater risk of exposure, being less knowledgeable about physical and behavioral signs of the disease. Nevertheless, most Baffin caribou hunters will be exposed to *Brucella* spp. since infected caribou rarely show signs of disease.

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