Prevalence of antibodies to *Brucella* spp. and individual risk factors of infection in traditional cattle, goats and sheep reared in livestock–wildlife interface areas of Zambia

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Abstract

A cross-sectional study was performed in the livestock–wildlife interface areas of Lochinvar and Blue Lagoon National Parks and the non-interface area of Kazungula to determine the prevalence of antibodies to *Brucella* spp. in domestic ruminants and identify individual animal risk factors of infection. Atotal of 1245 cattle from 124 herds and 280 goats and sheep from 29 flocks were tested sequentially for *Brucella* antibodies using the Rose Bengal test (RBT) and competitive ELISA. In cattle, individual seroprevalence ranged from 14.1% to 28.1%, while herd sero–prevalence ranged from 46.2% to 74.0% in the three study areas. No goat or sheep tested positive for *Brucella* antibodies. Three types of cattle grazing strategies were encountered: locally grazed herds (LGH), transhumantly grazed herds (TGH) and river flood plain grazed herds (FGH). *Brucella* seroprevalence was seen to vary according to area and grazing strategy: Lochinvar and transhumant grazed herds recorded the highest figures, respectively. Age, sex and history of abortion were found to have independent effects on individual seroprevalence. This study establishes that brucellosis is endemic in domestic animals in the livestock–wildlife interface areas of Blue Lagoon and Lochinvar national parks and the disease is also present in Kazungula. We observed that type of grazing strategy had significant impact on cattle *Brucella* seroprevalence and that transhumant herds were at high risk of being infected.

Keywords *Brucella* . Seroprevalence, Livestock–wildlife interface, Zambia

Abbreviations

CBPP	contagious bovine pleuropneumonia
(c-)ELISA	(competiitve) enzyme-linked immunosorbent assay
FGH	flood plain grazed herds
FMD	foot and mouth disease
LGH	locally grazed herds
OR	odds ratio

Introduction

Brucellosis, a bacterial disease caused by various types of *Brucella* spp., is a disease of economic and public health importance and has a worldwide distribution. While *Brucella abortus* is known as an important cause of abortion in cattle, *Brucella melitensis* also causes cattle abortions but is more known for infections in sheep, goats and wildlife. The zoonotic capacity is most strongly expressed for *B. melitensis*, but *B. abortus* also causes disease in humans. It is generally difficult to differentiate between *Brucella* spp. infections on the basis of serology, and only culturing of the agent can differentiate between types of infection (Alton *et al*., 1975; OIE, 2004).

In 2000, the total livestock population in Zambia was estimated to be 2 904 880 cattle, 82 281 sheep, and 953 757 goats (Anon, 2000). Farming in Zambia is divided into the traditional and commercial sectors. About 84%, 96% and 64% of the national cattle, goats and sheep, respectively, are found in the traditional sector, in which about 90% of cattle are found in the Southern, Western, Eastern and Central provinces (Perry *et al.*, 1984). Cattle distribution is principally affected by the availability of grazing land and the distribution of tsetse flies (*Glossina morsitans*) (Perry *et al.*, 1984). The vast flood plains along the Zambezi and Kafue rivers (Figure 1) provide suitable land for communal cattle grazing and the absence of tsetse flies (vectors of trypanosomosis) make the plains ideal for increased cattle productivity (Robinson, 1998; Robinson *et al.*, 2002). The flood plains also provide suitable habitats for wildlife in the Liuwa plain, Kafue, Blue Lagoon, Lochinvar and Sioma Ngwezi national parks. Interaction between cattle and wildlife on these plains is common and wildlife have been suspected to be reservoirs of livestock diseases (Rottcher, 1978; Ghirotti *et al.*, 1991). At present, Zambia has 19 national parks covering a total of 63 585 km2, representing about 8.0% of the country's total area (Saiwana, 1995). Most of these national parks are surrounded by local communities and cattle raised in these areas share grazing land and water with wildlife for a large part of the year.

Most Zambian rural populations in cattle-rearing areas depend on livestock for their livelihood (Perry *et al.*, 1984). However, it has been observed that the traditional livestock sector is characterized by low productivity with limited commercial offtake. Animal health is characterized by high mortality rates and low reproductive efficiency, manifested by low conception rates, low parturition rates and long inter-calving intervals (Perry *et al.*, 1984; Anon, 2000). The annual calving rates are estimated at 40–55%, compared to 55–75% in the commercial sector, while annual milk production stands at 42 million litres against 80 million litres produced by the commercial sector (Perry *et al.*, 1984; Anon, 2000). Despite these apparent restrictions, cattle continue to form an integral part of rural life and a sustainable means of livelihood, and cattle are required for draught power, payment of dowry, use during traditional ceremonies, manure and meeting other socio-economic obligations (Perry *et al.*, 1984; Anon, 2000).

Brucellosis and other infectious diseases such as anthrax, contagious bovine pleuropneumonia (CBPP) and foot and mouth disease (FMD) are prevalent in the traditional sector owing to poor husbandry practices, low standards of hygiene and inadequate resources to control diseases (Ghirotti *et al.*, 1991; Mainar-Jaime and Vazquez-Boland, 1999). The interaction between traditional livestock and wildlife facilitates bimodal transmission of diseases, with both domestic animals and wildlife being important reservoirs (Godfroid *et al.*, 1994; Jiwa *et al.*, 1996). In many places in Zambia, traditional animal husbandry depends on seasonal grazing in game parks or other areas where interaction with wildlife is common.

The role of brucellosis as a constraint to livestock production in the traditional sector in Zambia is not well documented. Some studies have been conducted on brucellosis in Zambia (Bell *et al.*, 1976; Ghirotti *et al.*, 1991; Pandey *et al.*, 1999), but these previous studies were mainly concentrated in commercial herds in peri-urban areas. However, circumstantial evidence suggests

that the disease could be one of the major constraints to livestock production under this farming system, and both brucellosis and abortions in Lochinvar area have been documented in previous studies (Perry *et al.*, 1984; Ghirotti *et al.*, 1991; Suzuki *et al.*, 1996). In general however, there is no updated information on *Brucella* infections in the traditional animal sector. Moreover, the public health impact of *Brucella* spp. infections is likely to be high in the communal sector on account of people's lifestyles, which may readily facilitate transmission from animals. Human brucellosis in Zambia is estimated at about 1% in occupationally exposed people such as abattoir workers, butchers and herdsmen (Orino *et al.*, 1994). However, this may not represent the true figure since the sample size involved in the study was small.

It is estimated that about 40% of milk produced in the traditional sector is marketed locally and consumed either as raw milk or as soured (cultured) milk. In addition, about 34% of milk from commercial farmers is sold as raw milk to the general public. Since consumption of raw, unpasteurized milk has been identified as one of the major risk factors in human brucellosis (Al-Shamahy *et al.*, 2000; Omer *et al.*, 2000a), many people in Zambia are likely to be at risk of *Brucella* infections.

Apart from individual efforts, there has been no *Brucella* control programme in place at the national level in Zambia, and vaccination is done mainly in the commercial sector. However, some traditional farmers, especially those who are members of cooperatives and supply milk to processing factories, are also obliged to vaccinate their animals as a requirement of selling their milk.

The aim of this study was to determine the individual and herd-level seroprevalence of *Brucella* infections in cattle, sheep and goats reared in livestock–wildlife interface areas of Blue Lagoon and Lochinvar (Kafue flats) in Zambia and to identify individual risk factors of infection in the cattle population. The study was a starting point for further studies to improve the understanding of the complex epidemiological patterns of *Brucella* infection in these areas.

Materials and methods

Study areas

The research was conducted in the livestock–wildlife interface areas on the Kafue flats, comprising Blue Lagoon and Lochinvar national parks and the Kafue Game Management Areas (Fig. 1). In these areas, domestic animals and wildlife share grazing land and water for large parts of the year. The selection of study areas was based on the following criteria: (1) presence of susceptible domestic and wildlife animal hosts; (2) previous evidence of *Brucella* in the population; (3) documented interaction between livestock and wildlife.

To obtain a proper estimate of the prevalence of antibodies to *Brucella*, a cross-sectional seroprevelence survey was planned. Each of the selected national parks with its immediate surrounding villages formed a study area. Kazungula, a place that is outside the interface area, was included in order to gain insight into the *Brucella* situation outside the interface area and also to compare the study areas with an area with different animal-to-animal and animal-to-human interaction patterns (Figure 1).

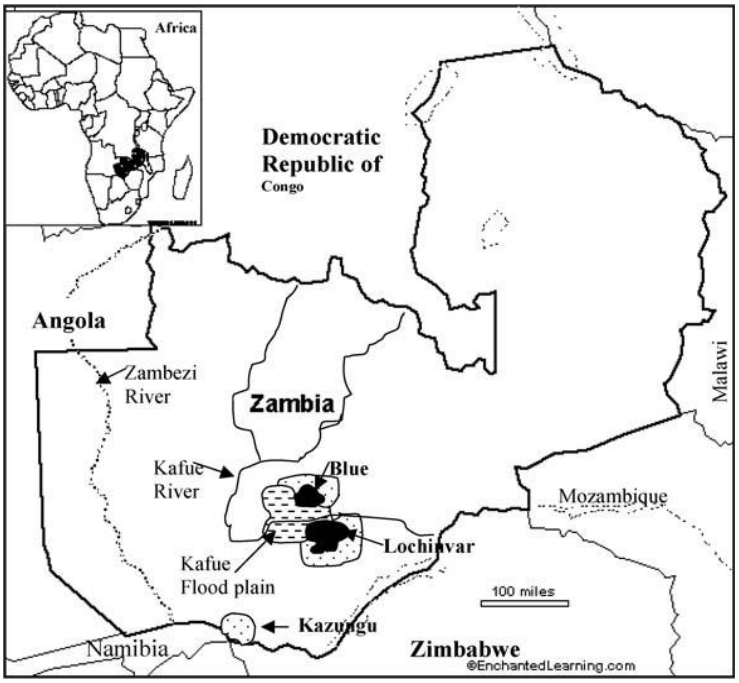

Fig. 1 Map of Zambia showing geographical locations of Blue Lagoon and Lochinvar national parks with surrounding sampling areas. Kazungula is in the south along the Zambezi River

Study design

The study population included non-vaccinated cattle, sheep and goats that was reared in the interface areas and had the opportunity to interact with wildlife. Cattle were the main domestic animals in the population, and the statistical design was targeted at this species.

Cattle

The cattle study populationwas divided into three strata based on the study areas (Blue Lagoon, Lochinvar and Kazungula). Since there was little or no veterinary supervision and input, no comprehensive lists of farmers on which to base a truly random sample were available. In addition, the nomadic type of grazing system practised by most farmers made them inaccessible. Sampling was therefore based on lists of farmers generated with the help of local veterinary/agricultural officers (where available) and of some farmers. Herds reared in close proximity were considered as one herd, and only herds with 10 or more animals were included in the study. A total of approximately 110 and 100 reasonably independent herds (a clear separation of herds was not always easy) were identified from Blue Lagoon and Lochinvar, respectively. The number of herds in Kazungula could not be fully ascertained before the study started.

There were three types of cattle grazing strategies in the study areas: locally grazed herds (LGH), transhumantly grazed herds (TGH), and flood plain grazed herds (FGH). LGH were defined as those animals that grazed within the village boundaries and had not been to the interface grazing area/flood plains for the previous two years. TGH were defined as those animals that practised seasonal grazing between villages and the interface area/flood plains. These cattle are typically moved to the flood plains immediately after the harvest season (March to May) and returned to the upland with the onset of rains (November to December). FGH cattle were those that grazed permanently in the interface areas/flood plains and did not migrate back to the village (except for oxen that brought in supplies and returned for duty).

Calculation of sample sizes was based upon a mean herd size in the study area of 100 (Perry *et al.*, 1984). Further, *Brucella* was supposed to exist at 16% within herd and 60% between-herd prevalence (Ghirotti *et al.*, 1991; Pandey *et al.*, 1999). The diagnostic sensitivity and specificity for the Rose Bengal test (RBT) were assumed to be 90% and 75%, and for competitive ELISA (c-ELISA) 98% and 99%, based on previous validation studies (Nielsen *et al.*, 1995, 1996; McGiven *et al.*, 2003). Therefore, at individual animal level, the combined sensitivity and specificity for RBT and c-ELISA in serial (sequential) intepretation were calculated at 88.2% and 99.8%, respectively.

To balance the number of herds and animals to be sampled within the resources available for the project, we decided to sample a minimum of 10 animals and a 10% fraction from herds with >100 animals. This gave a herd sensitivity of 79.5% and a herd specificity of 100% in a 100-animal herd, calculated with Herdaac (Jordan, 1995).

The number of herds to be sampled was calculated for each strata using the formula for simple random sampling with correction for a finite population (Dohoo *et al.*, 2003). We desired a precision of 10% of the true prevalence with 95% certainty. Given that there were 110 and 100 herds in Blue Lagoon and Lochinvar, respectively, and assuming that sampling would be done randomly, the number of herds to be sampled from each stratum was 50 and 48, respectively.

Table I shows the details of the sampling plan, including animals sampled as compared to the original plan. Two herds from Lochinvar were dropped because of S19 vaccination history. Real random sampling for individual animals inside herds was not achievable because of lack of animal restraining facilities and the semi-wild nature of most free-range animals. Only animals of age 2 years and above with no *Brucella* vaccination history were included. Owing to the practical situation, it was not possible to stratify sampling on age and sex. In situations where selected herds were inaccessible, a replacement herd was conveniently chosen within the village. Each animal was restrained and cast before 10 ml of blood was collected in evacuated plain tubes by jugular venepuncture.

Goats and sheep

A parallel blood sampling of goats and sheep owned by the farmers included in the study was done alongside that of cattle, without any statistical planning. Five ml of blood was collected from breeding animals through jugular venepuncture.

Epidemiological information

For each individual animal, information on sex, age, parity, and history of abortion in case of cows, was recorded on sample data sheets during serum collection. Herd/flock level and area level information on husbandry practices, grazing and watering patterns, herd structure, animal additions, offtakes, and other potential herd-level risk factors was collected using an interviewer-administered pre-tested questionnaire. Some of the information collected was envisaged for future use in understanding factors influencing *Brucella* spread and maintenance in the study populations.

Laboratory Analysis

Blood samples were kept shaded for about 10 min to allow clotting and then maintained at approximately +4◦C in a cool-box until they were processed. In the laboratory, sera were separated by centrifugation at 2500 rpm (503 g) for 15 min and stored in 2ml cryo vials at −20◦C until laboratory tests were performed.

Antibodies to *Brucella* spp. were detected by sequential testing of samples using the Rose Bengal test (RBT) for screening and competitive ELISA (c- ELISA) for confirmation. RBT was done as described by Alton and colleagues (1975). Standardized *Brucella abortus* and *B. melitensis* antigens (VLA, UK) were used to screen sera for the presence of antibodies to *B. abortus* and *B. melitensis*, respectively. Svanovir Brucella-Ab c-ELISA kits (Svanova Biotech ABUppsala, Sweden) were used to determine *Brucella* antibody titres. The assay was conducted according to the manufacturer's instructions. Sera and controls were run in duplicates. The optical densities (OD) were measured at 450 nm in a microplate photometer (Humareader, Model 18500/1, Awareness Technology, Inc., Germany), and antibody titres were recorded as percentage inhibition (PI) defined by the ELISA kit supplier as:

$$PI = 100 - \frac{\text{(Mean OD value of sample or control}}{\text{(Mean OD value of conjugate control)}} \times 100$$

The threshold for determining seropositivity was according to the manufacturer's recommendations (≥30%). An animal was considered to be positive if it tested positive on both RBT and c-ELISA.

Data analysis

The databasewas established in Excel, and data manipulation was done using the same program before transferring to Stata SE 8 forWindows (Stata Corp. College Station, TX, USA). The database included information about each animal as well as some herd-specific information.

Individual prevalence estimates with confidence intervals were computed using the survey command estimates in Stata, with adjustments for the three strata (study area), primary sampling unit (herd/flock) and weighting according to sampling fraction in each primary sampling unit (herd/flock), as described by Dohoo and colleagues (2003). Separate estimates were obtained for each study area, age group and sex.

The influence of age on seropositivitywas first tested using Lowess smoothing graphs in Stata, giving an illustration of the trend in the relationship. Animals were then assigned into age groups based upon quartiles of the number of animals sampled at various ages. With individual *Brucella* test result as the outcome, the possible independent effect of sex and age group was assessed using the commands for logistic regression for survey data with the above-mentioned settings. Another modelwas restricted to females, where the history of abortion was included as an additional predictor of seropositivity. Model assumptions were tested using standard procedures including diagnostic plots and the Hosmer–Lemeshow test.

The proportion of infected cattle herds and proportion of herds with abortions in each area were determined using the proportion command in Stata.

Table 1 Cattle sample distribution by study area, including planned and obtained number of samples

Study area	Target herds	Herds sampled	Target number of animals	Animals sampled (tested)[missing][a]	Age distribution of animals sampled[b]	
					Age (years)	No. of animals
Blue Lagoon	50	52	500	575 (564) [11][a]	2-3	120
					3.5-5	196
					5.5-7	120
					>7	139
					Bulls	39
					Oxen	147
					Females	389
Lochinvar	48	50	480	528 (515) [13][a]	2-3	175
					3.5-5	153
					5.5-7	91
					>7	109
					Bulls	20
					Oxen	127
					Females	381
Kazungula	-	22	-	174 (166) [8][a]	2-3	20
					3.5-5	65
					5.5-7	35
					>7	28
					Males	30
					Females	144

[a]Missing includes haemolysed samples and mislabelled and broken sample tubes
[b]Animals with missing age entry not included

Results

Cattle

Table 1 shows the planned and final sampling, including information on age groups and sex of sampled animals. As can be seen, the intended numbers of herds sampled was practically obtained in Blue Lagoon and Lochinvar. In Kazungula we eventually sampled 22 herds. A total of 1277 serum samples were collected, out of which 32 samples could not be analysed owing to haemolysis, mislabelling or damage to the sample tube, leaving 1245 samples for testing.

Table 2 shows the individual *Brucella* seroprevalence in cattle by age groups and sex in the three study areas. Results varied from 14.1% in Blue Lagoon to 28% in Lochinvar, with expressed variability across sex and age groups. Weighting of prevalence estimates was perceived to be necessary to obtain proper population based prevalence estimates.

Figure 2 shows the Lowess-smoothed curves for antibody prevalence for various age groups across study areas and grazing strategies. Survey logistic regression results showed an independent effect

of sex (higher prevalence in females), and in case of females also history of abortion and study area (Table 3). The model showed an increasing prevalence with increasing age, but this effect was less evident statistically. A total of 119 animals with abortion history of unspecified aetiology were recorded in the study. The results showed a strong association between antibodies against *Brucella* spp. and a history of abortion among female animals (OR = 3.61) (Table 3).

Herd-level seroprevalence by study area is shown in Table 4. Again, the highest prevalence was found in Lochinvar (74.0%), followed by Kazungula (54.5%) and Blue Lagoon (46.2%). Herd sizewas also observed to differ within areas and between grazing strategies, and herd seroprevalence also differed between grazing strategies, with TGH showing the highest levels (Table 4).

Table 2 *Brucella* seroprevalence in cattle by age and sex in the three study areas, calculated using the survey estimators in Stata. Results are given as prevalence with 95% confidence intervals (CI)

Study area	Category	Percentage seroprevalence (95% CI)
Blue Lagoon	All animals	14.1 (7.5–20.6)
	2–3 years	9.0 (2.4–16.1)
	3.5–5 years	13.5 (5.1–21.9)
	5.5–7 years	13.2 (0.3–26.1)
	>7 years	18.6 (3.3–34.0)
	Bulls	0.0 (–)
	Oxen	7.9 (1.6–14.1)
	Females	17.6 (9.1–26.3)
Lochinvar	All animals	28.1 (17.1–39.2)
	2–3 years	17.9 (5.7–30.2)
	3.5–5 years	26.9 (13.2–40.7)
	5.5–7 years	34.0 (26.8–41.2)
	>7 years	41.8 (20.0–63.6)
	Bulls	2.7 (0.1–8.2)
	Oxen	20.0 (6.3–33.7)
	Females	31.6 (20.4–42.9)
Kazungula	All animals	17.9 (6.1–29.7)
	2–3 years	15.8 (0–38.3)
	3.5–5 years	22.4 (6.8–37.8)
	5.5–7 years	24.4 (0.4–48.4)
	>7 years	19.4 (7.1–31.7)
	Males	0.0 (–)
	Females	22.1 (8.2–36.0)

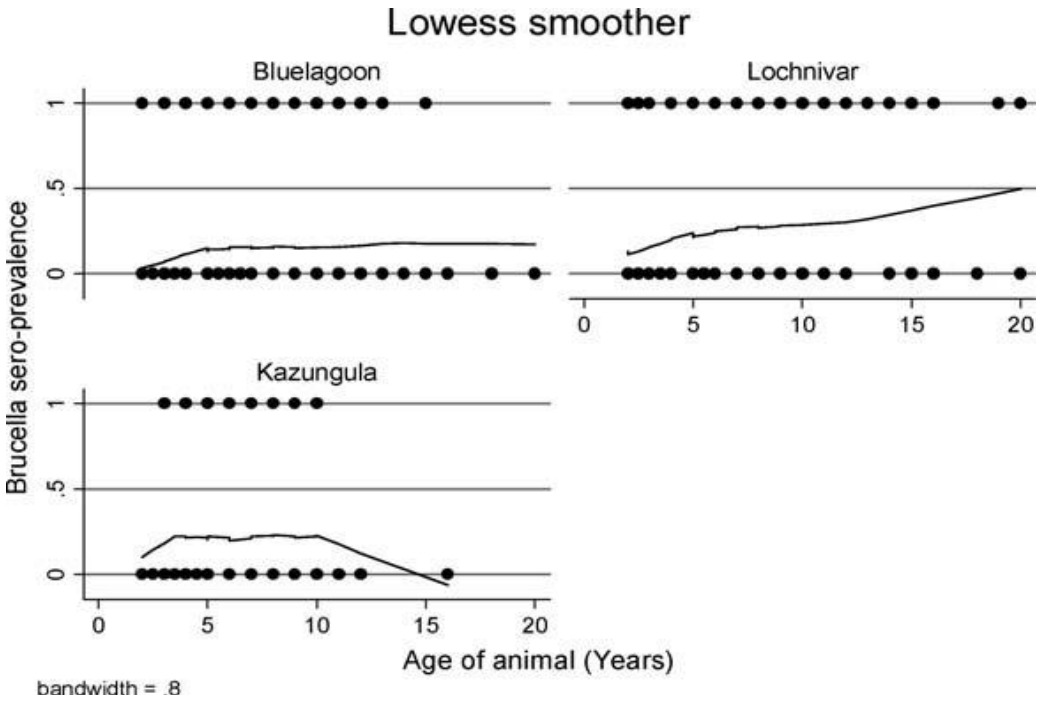

Fig. 2 Lowess-smoother graphs and scatter plots showing an increase in *Brucella* prevalence with increasing age in cattle in Blue Lagoon and Lochinvar. Kazungula had few data points and outliers in the older animal category distort that relationship.

Goats and sheep

Few farmers kept goats and sheep. Of the 280 goats and sheep tested from Blue Lagoon (208) and Lochinvar (72), none tested positive for antibodies to *Brucella* spp. An interesting finding was that most goats had a history of abortion that was characterized by arthritis in the final trimester.

Discussion

In many African countries, brucellosis has been shown to be prevalent in areas of livestock–wildlife interaction (Sachs *et al.*, 1968; Nicoletti, 1980; Jiwa *et al.*, 1996). This is the first systematic study on cattle brucellosis in the Zambian livestock–wildlife interface areas of the Kafue flats. Distinct area differences in seroprevalence were found, with Lochinvar recording both high individual and herd seroprevalences (28.1% and 74.0%) compared to Kazungula (17.9% and 54.5%) and Blue Lagoon (14.1% and 46.2%). The high seroprevalence indicates that brucellosis might be a public health problem in all the three areas. Our results for Lochinvar corroborate those of Ghirotti and colleagues (1991), who observed a 28% individual seroprevalence in cattle grazing along the Kafue flats, although the sample size (5 herds) was small. Abattoir seroprevalence estimates of 10.2% and 16.2% for Southern province by Ahmadu and colleagues (1999) are also indicative of the level of brucellosis in this region, though the estimate was based on a biased sample. We did not find any documented reports of brucellosis specific for Blue Lagoon and Kazungula.

Table 3 Survey logistic regression analysis of overall and female cattle *Brucella* seropositivity in traditional cattle living in livestock–wildlife interface areas. Results given as odds ratio with 95% confidence intervals (CI).

Predictor variable	Odds ratio	95% CI
Overall analysis		
Lochinvar vs Blue Lagoon	2.54	1.17–5.48
Kazungula vs Blue Lagoon	1.41	0.55–3.65
Male vs female	0.44	0.26–0.72
3.5–5.0 years vs 2.0–3.0 years	1.41	0.84–2.36
5.5–7.0 years vs 2.0–3.0 years	1.58	0.82–3.04
>7.0 years vs 2.0–3.0 years	2.09	0.91–4.80
Analysis restricted to female animals		
Lochinvar vs Blue Lagoon	2.70	1.12–6.51
Kazungula vs Blue Lagoon	1.50	0.62–3.62
3.5–5.0 years vs 2.0–3.0 years	1.39	0.61–3.14
5.5–7.0 years vs 2.0–3.0 years	1.74	0.73–4.18
>7.0 years vs 2.0–3.0 years	2.30	0.80–6.66
History of abortion vs no history of abortion	3.61	1.65–7.91

Table 4 Herd structure information and herd-level *Brucella* seroprevalence and abortion proportions by study area. Prevalences estimated using the proportion command in Stata.

Study area	Median herds size (range)	Herd seroprevalence (95% CI)	Herds with abortion history (95% CI)
Blue Lagoon	47 (16–750)	46.2% (32.3–60.0%)	61.5% (48.0–75.0%)
Lochinvar	35 (10–500)	74.0% (61.6–86.4%)	46.0% (31.9–60.0%)
Kazungula	58 (19–175)	54.5% (33.0–76.1%)	31.8% (11.6–52.0%)
LGH[b](n = 52)[a]	36 (16–200)	46.1% (32.3–60.0)	38.4% (24.9–60.0%)
TGH[b] (n = 60)	40 (10–270)	68.3% (56.3–80.3%)	55.0% (42.2–67.8%)
FGHb (n = 12)	207 (57–750)	66.7% (38.5–94.8%)	75.0% (49.2–100%)

[a]Herds with ≥1 animal positive on both RBT and ELISA
[b]LGH = locally grazed herd; TGH = transhumantly grazed herd; FGH = flood plain grazed herd

It was evident that females had increased chances of testing *Brucella* positive, as did older animals. The observed relationships between *Brucella* status and sex and age is consistent with what is generally known about the biology of the infection (Kadohira *et al.*, 1997; Kubuafor *et al.*, 2000; Omer *et al.*, 2000b). However, the relationship between *Brucella* status and sex has been observed to vary with different subpopulations (Kadohira *et al.*, 1997; Turkson and Boadu, 1992; Kubuafor *et al.*, 2000; Omer *et al.*, 2000a). Similarly, the observed relationship between *Brucella* seropositivity and history of abortion is consistent with what has generally been observed (Kubuafor *et al.*, 2000; England *et al.*, 2004).

The possibly high number of *Brucella*-related abortions in Kazungula was associated with high median antibody titre (results not shown). This might suggest a recent introduction of *Brucella*. On the other hand, the assumed low number of *Brucella*-related abortions and a lower median titre in Lochinvar might suggest *Brucella* endemicity. More research has to be done to clarify this finding.

Blue Lagoon had a large mean herd size compared to other areas. Large herd size could have resulted from better disease prevention and high rate of cattle additions. The close proximity of Blue Lagoon to Lusaka also enables farmers in this area to have access to veterinary drugs and a relatively high income because of a ready market for their produce in Lusaka. Despite the large herd sizes in Blue Lagoon, seroprevalences were lower than in Lochinvar, with relatively smaller herd sizes. This appeared to be contrary to the suggestion that if *Brucella* spp. are introduced in a large herd, a high proportion of animals will become infected and the disease will persist for a long time (Kadohira *et al.*, 1997; Omer *et al.*, 2000b; Salman and Meyer, 1984). The explanation for this may be that grazing strategy could have a stronger effect on seroprevalence levels compared to herd size.

Area variation was observed to be strongly linked to the predominant type of grazing strategy, with TGH being the most risky group. Hence, Lochinvar had high seroprevalence compared to Blue Lagoon, despite the fact that Blue Lagoon had older animals and larger herds than Lochinvar. This is probably because individual seroprevalences were greatly influenced by types of herd grazing strategy, which were predominantly TGH and LGH in Lochinvar and Blue Lagoon, respectively.
It has generally been observed that transhumance grazing is associated with high *Brucella* seroprevalence because of the increased opportunity for animals to come in contact with potentially infected herds during their movements and co-mingling (MacPherson, 1995; Omer *et al.*, 2000b). Additionally, animal housing in transhumant herds tended to be poor and small temporary pens were constructed that resulted in overcrowding of animals and increased the chance of within-herd transmission. Transhumant grazing allows interaction of livestock and wildlife and may facilitate transmission of diseases (Nicoletti, 1980; Godfroid *et al.*, 1994). In Lochinvar, and partly in Blue Lagoon, cattle interact with wildlife on the grazing pasture and at drinking water points for the larger part of the year, and a number of diseases affecting both livestock and wildlife, including brucellosis, have been reported (Ghirotti *et al.*, 1991; Suzuki *et al.*, 1996). Cattle in TGH and FGH shared grazing land with *Brucella*-susceptible wild ruminants like the Kafue lechwe (*Kobus lech kafuensis*), Cape buffalo (*Syncerus caffer*), wildebeest (*Connchaetes taurinus*), hippopotamus (*Hippopotamus amphibius*) and impala (*Aepyceros melampus*). The Kafue lechwe is of particular interest because of its large population of about 40 000–45 000 (Kamweneshe *et al.*, 2002), close contact with cattle on the flood plains and past history of *Brucella* cases (Rottcher, 1978; Ghirotti *et al.*, 1991; Suzuki *et al.*, 1996). In terms of public health importance, the Kafue lechwe is also the most highly hunted species for game meat (Siamudaala *et al.* in press). Considering that *Brucella* is highly contagious, infections in cattle may suggest similar trends in wildlife sharing the grazing land (Jiwa *et al.*, 1996; Reviriego *et al.*, 2000) and also pose a threat to public health. Similar studies done in interface areas have shown that sharing of infections between livestock and wildlife occurs in areas of interaction, such as Lochinvar and Blue Lagoon (Nicoletti, 1980; Godfroid *et al.*, 1994; Jiwa *et al.*, 1996).

Our tests could not discriminate between *Brucella abortus* and *Brucella melitensis*. The absence of *Brucella* antibodies in goats suggests that *Brucella melitensis* may not be a problem in this region. However, since only few sheep and goats were sampled, no conclusive inference can be made about the *Brucella* status in goats and sheep. The causes of goat abortions could not be ascertained, although they are unlikely to be due to *Brucella* spp. infection.

Serological cross-reactions due to *Yersinia enterocolitica* were unlikely to influence these results because that pathogen is assumed to be rare or absent in the tropical region (Murry *et al.*, 1999) and partly because there was no evidence of contact between cattle and either domestic or wild pigs (Godfroid *et al.*, 2002). In addition, the use of specific tests such as c-ELISA results in a substantial decrease in the number of such cross-reactors (Nielsen *et al.*, 2004).

This study has established that brucellosis is endemic in the livestock–wildlife interface areas of Blue Lagoon and Lochinvar national parks and has indicated that the disease is also present in

Kazungula. There was a clear indication that type of grazing strategy had a significant impact on cattle *Brucella* seroprevalence and that transhumant herds were at high risk of being infected. However, epidemiological evaluation of other possible risk factors is required. The high number of potentially *Brucella*-related abortions observed in this study indicates the potential economic significance of *Brucella* in livestock and possibly on wildlife productivity. The zoonotic risk to traditional farmers, slaughterhouse workers and other people involved in livestock production should be a cause of concern, but no information on brucellosis in humans in the study areas was available when this study was undertaken.

The results of the study provide baseline data for further studies of *Brucella* infections in the area, and a starting point for control measures in the cattle population in the area.

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