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Brucellosis in cattle and micro-scale spatial variability of pastoral household income from dairy production in south western Uganda

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Highlights:

- We investigated *brucellosis* prevalence in cattle and its association with a unit price of milk produced around Lake Mburo National Park (LMNP).
- Data on *brucellosis* in cattle revealed high prevalence of 43.8%, with spatial variations where cattle reared at park boundary had significantly higher prevalence of *brucellosis*.
- The variations of *brucellosis* prevalence in cattle had direct pattern with the incidences of abortion in cattle, but inverse association with the unit price of milk from LMNP boundary.
- Pastoralist communities associated low milk prices at park boundary with symptomatic abortions in cattle and buyers' perception that milk produced at park boundary was contaminated.

Abstract

Brucellosis in cattle and humans has received world-wide research attention as a neglected and re-emerging zoonotic disease with many routes of transmission. Studies of *brucellosis* in Uganda have emphasized occupational exposures and also revealed variations in prevalence levels by region and cattle production systems. To date, research linking pastoralist household income from dairy production to *brucellosis* and its transmission risk pathways do not exist in Uganda. We assessed whether spatial differences in unit milk prices can be explained by *brucellosis* prevalence in cattle along a distance gradient from Lake Mburo National Park in Uganda. Semi-structured interviews administered to 366 randomly selected household heads were supplemented with serological data on *brucellosis* in cattle. Statistical analysis included Pearson correlation test, multiple regression and analysis of variance (ANOVA) using SPSS version 17. Serological results showed that 44% of cattle blood samples were sero-positive for *brucellosis*. The results obtained from interviews put the statistical mean of household reported cattle abortions at 5.39 (5.08 – 5.70 at 95% CI, n=366). *Post-hoc* analysis of variance revealed that both sero-positive cattle and reported cattle abortions significantly were much lower when moving outwards from the park boundary ($p < 0.05$), while the price of milk increased significantly ($p < 0.05$) along the same distance gradient. Further studies should identify public and private partnerships needed to create and strengthen good zoonotic *brucellosis* management practices at the nexus of wildlife and livestock in Uganda.

Key Words: Brucellosis, spatial pattern, dairy production, household income, Uganda

1. INTRODUCTION

Bovine brucellosis has a global distribution and recognition as a disease of public health importance (WHO, 2006; Lopes *et al.*, 2010), yet its control in Uganda remains poor and unfocused (Nabukenya *et al.*, 2013). Several brucellosis studies in Uganda have reported levels of sero-prevalence between 7 and 50% among cattle and goats (Nakayuma and Opuda-Asibo, 1999; Benard *et al.*, 2005; Nabukenya *et al.*, 2013). This rather high prevalence of brucellosis in cattle is a health hazard to people who consume livestock products like milk and meat (Holt *et al.*, 2011 as well as to the abattoir workers (Nabukenya *et al.*, 2013).

The perception that milk produced in areas with a high density of wild animals is contaminated with pathogens causing brucellosis has a distinct spatial pattern in south-western Uganda. The influence of this perception on the unit price of milk is evident despite the fact that the actual role of wildlife as reservoir of brucellosis remains to be adequately understood (Muñoz *et al.*, 2010). Transmission of brucellosis among communities where animal husbandry is the main economic activity has been reported (Kabagambe *et al.*, 2001; Marcotty *et al.*, 2009). Although milk has been identified as an important route of transmission (Marcotty *et al.*, 2009), no study has investigated the influence of brucellosis on the price consumers are willing to pay for a litre of milk perceived to be contaminated with brucellosis in Uganda.

Brucellosis is an infectious and contagious bacterial disease, whose transmission might benefit from the interactions between wild animals and livestock (Tessaro, 1986; Godfroid *et al.*, 2013). The disease is caused by a facultative intracellular parasite known as coccobacilli of the genus *Brucella* (Whatmore, 2009; Olsen and Tatum, 2010). Brucellosis affects domestic and wild animals (Mwebe *et al.*, 2010), with humans being accidental hosts (Marcotty *et al.*, 2009). The fact that pathogens causing brucellosis can infect wild animals, livestock and humans alike makes brucellosis a serious public health hazard. Indeed brucellosis can persist in most affected communities in the developing world. Furthermore, conventional healthcare system has not paid adequate attention to the dynamics of brucellosis in terms of its spread and persistence in a population. Lack of integrated attempts at controlling the spread of bacteria causing brucellosis makes this disease one of the neglected endemic zoonoses in the developing world (WHO, 2006). Indeed zoonotic brucellosis is widely endemic in rural Africa (Cosivi *et al.*, 1995; Sheik- Mohamed and Velema, 1999) and should therefore be accorded substantive attention (FAO, 2009; Kabagambe *et al.*, 2001).

Once a person is infected, brucellosis presents with non-specific symptoms, including general weakness, weight loss, febrile flu-like illness, headache and frequent chills (Krause & Hendrick, 2010). However, in cattle *B. abortus* is usually spread by the vaginal discharge of an infected cow or physical contact with aborted fetuses. A few cases also exist where cows have been infected by contaminated semen. Breeding bulls can either get infected by cows or transmit the disease to cows during mating. Animal infection often results in abortion during the last trimester of the gestation period. Abortion in animals occurs due to inflammatory changes which bacterial infection causes in the foetal membranes (Kungu *et al.*, 2010). In general, the severity of brucellosis on human and animal health has important socio-economic implications. Studies suggest that brucellosis can adversely affect livelihood

of rural communities (Jones *et al.*, 2008; Marcotty *et al.*, 2009). Major economic losses associated with *Brucella spp* infections include impediment to market access for animal products such as milk and meat (Mangen *et al.*, 2002). Other losses include decreased animal productivity, where abortions and infertility result in up to 20% reduction in cattle population (FAO, 2009; Mwine, 2004). Among small holder cattle farmers in rural Africa, especially the pastoralist communities whose livelihood revolves around cattle production, such losses are often sufficient to push the affected rural households to the margins of a livelihood.

In Uganda, low-cost herding and high-cost paddock-keeping of animals have been reported as important contributing factors in the epidemiology of bovine brucellosis (Kungu *et al.*, 2010; Nizeyimana *et al.*, 2013). A study by Nizeyimana *et al.* (2013) investigated the prevalence and distribution of bovine brucellosis in cattle under contrasting grazing systems (herding and zero- grazing). The study found out that cattle raised under herding had higher prevalence of brucellosis (Nizeyimana *et al.*, 2013). However, there is no evidence of a study linking price fall of fresh milk with brucellosis seropositivity in cattle and distance from a perceived source of *Brucella spp* in Uganda. This study therefore sought to test the hypothesis that brucellosis prevalence in cattle along a distance gradient from Lake Mburo National Park (LMNP) boundary significantly influence the unit price of milk by. One possibility was that LMNP in Uganda had become an important dispersal centre for wildlife, which pastoralists perceive as vehicles of brucellosis transmission. The first study to document brucellosis prevalence in wild species of animals in the LMNP was conducted in the 1990s (Ocaido *et al.*, 1996) and it showed brucellosis prevalence in impala (*Aepyceros melampus*) and buffalo (*Syncerus caffer*). Circumstantial evidence of brucellosis transmission from wildlife to cattle has also been reported elsewhere (Tessaro, 1986; Godfroid *et al.*, 2013). Indeed, the former author argued that free ranging bison constitute a health hazard to cattle, while park confined bison do not. Godfroid *et al.* (2013). Davies *et al.* (1990) explained that brucellosis in some wildlife species is very low, but it was the behaviour of individual animals and their interaction with livestock that may actually be the most important drivers for transmission. In spite of the fact that routes of brucellosis infection in cattle might be different, the frequency of the interactions between wildlife and cattle deserve research attention. This is so, because just one infected animal could move extensively between farms thereby disseminating the pathogen.

2. MATERIALS AND METHODS

2.1 Description of the study area

The present study was conducted among pastoralists living in the rangelands around LMNP in Uganda. The study area was part of the larger Akagera ecosystem that extends from eastern Rwanda and north-western Tanzania into south-western Uganda, forming part of Uganda's cattle corridor. The climate of the study area is semi-arid and the main sources of water for the pastoral and agro-pastoral communities and their livestock are valley dams and limited number of swamps. The annual rainfall consists of 'long rains' reaching 1,270 mm between March and June and 'short rains' between September and November that together make up an average estimated at 880 mm. The minimum and maximum temperature is 15 °C and 29 °C, respectively (Averbeck *et al.*, 2009).

Wild ungulates, which are often found grazing with cattle in private farms and ranches, include buffalo (*Syncerus caffer*), zebra (*Equus burchellii*), eland (*Taurotragus oryx*), waterbuck (*Kobus ellipsiprymnus*) and impala (*Aepyceros melampus*) (Ranestard *et al.*, 2006, Averbeck, 2009;

Ocaido *et al.*, 2009; Nina *et al.*, 2015). Ankole cattle (*Bos indicus*) of Sanga origin is the most dominant breed of cattle reared in the study area. However, cross-breeds between Ankole and Friesian cattle is becoming common, while a limited number of exotic breed of cattle also exists.

2.2 Study design

A cross-sectional survey was conducted at the household level as unit of analysis to determine the sero-prevalence of brucellosis in pastoral cattle herds and history of cattle abortions along a distance gradient of 24 km from the LMNP. The survey was also used to collect qualitative and quantitative data using semi-structured questions administered in face- to- face interviews with the heads of randomly chosen pastoralist households.

2.3 Sampling and serology

To minimize chances of having false positive reactors, only animals aged 12 months and over were considered from selected pastoral households. Studies have shown that maternal antibodies are often present in calves (1 – 6 months) born of sero-positive cows (Gomo *et al.*, 2011). All cattle in herds present in selected pastoral homesteads on the day of sample collection were eligible for serum sampling. A report by Mugisha *et al.*, (2011) estimated average cattle holding per household at 60 cattle. From a total of 330 households selected for serological surveys, approximately 1,980 animals were targeted. However, using a systematic random sampling, we selected one in every 6 animals in small herds <50 and 2 in every 10 for large herds >50 (Faye *et al.*, 2005). This yielded 1,962 cattle, which were bled for blood

samples between August 2012 and June 2013. The 330 homesteads selected for cattle sampling were proportionately distributed in six zones along a distance gradient from LMNP. All blood samples were centrifuged and the sera stored at -80°C in the microbiology laboratory of Mbarara University before carrying out screening and subsequent confirmatory tests for brucellosis. Of the 1,962 serum samples stored at the laboratory, 213 were grossly haemolysed, leaving 1,749 serum samples to be analyzed for *B. abortus*.

A multi-species indirect immunosorbent assay (iELISA) using *Brucella* S-LPS antigen was developed. Serial testing of the cattle sera for anti-*B. abortus* antibodies was conducted using Rose Bengal Plate Test (RBPT) (Alton *et al.*, 1988). Both positive and negative sera were used in the indirect antibody enzyme-linked immunosorbent assay (i-ELISA) (SVANOVIR® Biotech AB, Uppsala, Sweden). Each serum sample was run in duplicate on *Brucella* antibody i-ELISA kit whereby sera samples with percentage positivity >80 were confirmed. Kappa test for agreement between RBPT and iELISA was significant ($k = 0.703$, $p < 0.001$). All sera samples were then stored in the microbiology laboratory in Mbarara for future molecular analysis.

2.4 Questionnaire data

Stratified random sampling was used to determine interview respondents and cattle serum sampling sites. Strata were six distance zones (measured in km) from the boundary of LMNP, while sampling units were households. A sample of 366 was calculated using the formula for infinite sample size determination by Kothari (2004). We then distributed the samples systematically across the six zones, and applied a computer-based random number generator to select and map households using a hand-held global positioning system (GPS) instrument (Garmin 60). A semi-structured questionnaire was administered to 366 respondents in the local language (runyankole) by trained members of the pastoralist community. The survey was carried out to assess incidences of brucellosis in cattle and the pastoralists' perceptions regarding the economic impact of brucellosis on milk production. Another study among the same communities around LMNP showed that 370 out of 371 participants (99.3%) had heard about brucellosis. However, only 70(19%) knew its symptoms in humans (Kansiime *et al.*, 2014). Socio-economic information was also obtained on a range of parameters. These included demographic characteristics, the benefit forfeited by pastoral households keeping only local breed of cattle instead of high-milk yielding exotic breed, as well as the types of non-pastoral income activities that supplement pastoralism. For economic activities and disease risks such as that of brucellosis and its symptoms in cattle information was collected using a one-month recall technique (Onwujekwe *et al.*, 2010). The variables covered included the amount of milk a pastoralist household produces each day against the number of lactating cows, the price at which a litre of milk was sold, the number of cattle abortions in the previous month, the number of surviving calves and the history of wild animals grazing with cattle in private farms/ranches.

2.5 Data analysis

The spatial association of brucellosis and abortions in cattle with distance range from the national park (LMNP) was analyzed. Since households were located using GPS, the longitude and latitude data were included and entered into ArcGIS (ESRI, Redlands, CA, USA) for spatial analysis of known incidences of abortion in cattle.

We performed descriptive tests to assess the distance zone-specific proportions of brucellosis sero-positive cattle and symptomatic abortions. The herd-level brucellosis prevalence was not calculated. However, the individual animal-level prevalence was calculated as the ratio between the number of sero-positive cattle and the total number of sampled and analyzed cattle in each distance zone (Faye *et al.*, 2005). Multiple regressions were also performed on the influence of distance, brucellosis and abortions in cattle on the unit price of milk, and the results considered significant at $p < 0.05$. Finally, the risk for any animal to be positive in a positive herd was calculated by the ratio of the number of positive animals in affected herds/total number of animals tested in affected herds. Further quantitative analysis examined the associations between all the hypothesized risk factors. The influence of risk factors on the unit price of milk were analyzed using single-factor generalized models. Only a set of highly correlated variables ($P < 0.1$) were included in the multivariate models. Qualitative analysis of risk factors for brucellosis prevalence in cattle and low unit prices of milk were carried out for all factors that the respondents perceived as a risk.

3. RESULTS

3.1 Brucellosis prevalence in pastoral cattle

Out of 1,749 sera samples analyzed for brucellosis in cattle, 766 (43.8%) were sero-positive for both iELISA and RBPT and confirmed at the 95% confidence interval (CI). Table 1 provides a descriptive summary of the results of brucellosis prevalence in cattle reared northwards along a distance gradient from LMNP boundary.

The results presented in Table 1 revealed a spatial pattern of inverse relationship between brucellosis prevalence in cattle and distance from the park boundary. Serum samples obtained from the cattle reared within 12 km range from the park boundary accounted for 62.5% (479/766) of all *Brucella* sero-positive samples. Only 37.5% of *Brucella* sero-positive

samples were from cattle reared in homesteads situated between 12 km and 24 km north of LMNP.

Based on the results of sero-positive blood samples across the six distance zones, 60.27 (58.72-61.82) out of 100 cattle were likely to be infected with *Brucella spp* within a distance range of 0-4 kilometres from the LMNP boundary. On the contrary, only 27.15 (24.75-29.55) animals were at risk of being infected with the pathogen causing brucellosis within 20-24 kilometres away from the park boundary. This implies that cattle reared within 0-4 km were more than twice the risk of infection compared to cattle reared at 20-24 km from the LMNP boundary. The influence of proximity to the national park on brucellosis prevalence in cattle and brucellosis associated cattle abortions is illustrated in Figure 2.

This study included a limited number of cattle with a history of abortion (546/1971) in the serological survey for brucellosis. The majority of cattle (81.2%) with a history of abortion that were included in the serological survey tested positive for brucellosis. However, serological results also showed that some sero-positive cattle had no incidence of abortion. Thus, the overall results showed that symptomatic effect of abortion in cattle was low compared to the brucellosis prevalence levels in cattle in the study area.

3.2 Household reporting on abortions in cattle

From the results obtained through the household survey, 80.7% (1,591/1,971) of all cattle abortions occurred within a range of 0 to 12 km. Most respondents regarded cattle abortion as a symptomatic effect of brucellosis in the study area. When the question: “In your opinion, what are some of the causes of abortion in cattle?” was posed to the respondents, most of them (89.6%) cited brucellosis, while 25.2% and 17.8% mentioned physical injuries due to roughness of the terrain and beating by herdsmen, respectively. On a scale of 100 cattle, approximately 11 abortions occurred within the first distance gradient from the LMNP in one month (Table 2).

The results of comparative analysis by distance between calves and abortions in cattle showed that more calves were born compared to abortions reported in each zone. From the cattle inventory obtained during the study, higher number of calves was recorded than the reported incidence of abortion (Figure 3). Both abortion and calving intervals were some of the symptomatic effects of brucellosis listed by the respondents.

On average, almost equal numbers of calves were born per 100 cattle in each of the six distance zones along a gradient from LMNP boundary. The results showed that the highest number of calves occurred in one of the middle zones along Masaka–Mbarara highway. The highway is dominated by trading centres, including accessible shops where veterinary drugs are sold. Figure 3 provides spatial comparisons of the mean number of calves and incidence of abortions in cattle.

3.3 Perceptions and attitudes regarding milk suspected of contamination with brucellosis

All respondents (n = 366) had heard about brucellosis prior to this study. The majority (80.6% or 295/366) reported that brucellosis in cattle around LMNP is transmitted through interactions between wild ungulates and cattle. Wild species of animals, which featured most in the responses as the culprits, were zebra, impala and buffalo. More than a third of the respondents reported that at some point they had come across aborted fetuses of these animals in their farms. The most cited symptoms of brucellosis in cattle were still birth and reduced milk volume as shown in Table 3.

The findings of the questionnaire survey revealed the farmers' conviction that brucellosis was affecting milk production as well as the unit prices of milk. The respondents explained that brucellosis-associated symptomatic abortions often happened in farms where from milk buyers access the milk. They recalled incidences where milk buyers had refused to take milk after noticing aborted foetus lying in the open. In the farmers' opinion, milk produced near the park boundary was generally perceived by the buyers as contaminated with pathogens causing brucellosis. However, cattle abortion was of the greatest concern as it made the buyer strongly suspect brucellosis.

In spite of several brokers for milk collection points and retail traders operating at the trading centres in Sanga and Lyantonde along the Masaka – Mbarara highway, the price of fresh milk per litre remained very low at the park boundary. The results of linear regression analysis ($p < 0.05$) showed that the spatial variation in the milk price can partly be explained by the distance gradient from the LMNP and the symptomatic effects of brucellosis, such as incidence of abortion and volume of the milk produced. Thus, the presence of brucellosis was reflected in the perception that milk produced at the park boundary was at a higher risk of contamination (Table 4).

The information obtained through key informant interviews with agents at the trading centres confirmed that the perception of milk safety affects the unit price of milk and that farms/ranches located far away from the park boundary were favoured. Moreover, households located far away from the park boundary also produced twice as much milk as households located adjacent to the park. In addition, spatial variations in the volume of milk produced in

the study area had some influence on the unit price.

DISCUSSION

This study reports the first information for south-western Uganda on how spatial heterogeneity of brucellosis in cattle and associated abortions might influence pastoralist household income based on the sales of milk. Respondents reported adequate knowledge on symptomatic effects of brucellosis, and demonstrated a fair understanding of how brucellosis can affect milk production. It was reported that infected female cattle produced less milk, took long to produce young ones and hardly gained weight. The level of knowledge on brucellosis demonstrated by the respondents in this study was consistent with the findings of a study conducted around LMNP by Kansiime *et al.* (2014). Symptomatic effects of brucellosis reported by the respondents were also in agreement with documented livestock health and economic impacts of zoonotic brucellosis (Marcotty *et al.*, 2009; Narrod *et al.*, 2012). Our results also highlighted the importance of distance from the LMNP boundary, as a factor contributing to vulnerability of cattle with regard to risk of infection with pathogens causing brucellosis and symptomatic abortions. Abortions in cattle are considered a potential threat to the pastoralists in terms of cattle stock holding. The impact of brucellosis on household income was felt in terms of quality and quantity of milk, as well as actual reduction of overall pastoral herd size.

The level of brucellosis prevalence in cattle reported in this study was within the range of previously reported cases in several studies conducted in Uganda (Nakayuma and Opuda-Asibo, 1999; Benard *et al.*, 2005; Nabukenya *et al.*, 2013). The study findings also show spatial disparities in mean prevalence levels of brucellosis and abortions in cattle at a small scale of four km intervals. Such disparities at micro-spatial scale, at the local level, has so far not been reported anywhere in Uganda. Despite Lake Mburo Conservation Area being an extensive grazing system, the brucellosis prevalence was high and similar to the number of reported cases in cattle reared within the confines of peri-urban areas (Nasinyama *et al.*, 2014). Thus, our results suggest that different levels of brucellosis prevalence in cattle might be explained, in part, by proximity to LMNP rather than the grazing system.

Indeed, the pastoralists who participated in this study strongly believed that brucellosis in cattle is often transmitted by wild animals. During the study wild ungulates like buffalo, zebra, eland and impala were seen grazing with cattle in private farms and ranches around LMNP (Nina *et al.*, 2015; Ranestard *et al.*, 2006). This study lacked direct data on brucellosis in wildlife, but evidence on brucellosis in impala and buffalo in LMNP has been reported previously at various occasions (Ocaido *et al.* 1996; Mugisha *et al.* 2011). Indeed, these animals have tested serologically positive for brucellosis elsewhere in South Africa (Herr and Marshall, 1981). However, due to infrequent interaction with domesticated animals, the role of these animals in the epidemiology of bovine brucellosis is supposed to be minor as said by Gradwell *et al.* (1977), a fact reiterated by Godfroid and Kasbohrer in their text book (2002). Other studies by Muma *et al.* (2006, 2007) also report brucellosis prevalence in areas of wild animals and livestock interface in Zambia. In Zimbabwe, Gomo *et al.* (2011) singled out grazing adjacent to national park as a risk factor of brucellosis infection in cattle. We further noted that several research findings mention the possibility of animal reservoirs of brucellosis

(WHO, 2006; Kalema-Zikusoka *et al.*, 2005; Godfroid *et al.*, 2013). Thus, the pastoralist communities in south-western Uganda are supported in their belief that interactions between wild animals and their livestock is a health hazard (Bengis, 2002).

On the influence of different risk factors on unit price of fresh milk, we reported significant association of the unit price of milk with the spatial pattern of brucellosis prevalence and abortion in cattle. According to the respondents, higher prevalence of brucellosis and brucellosis-related abortions in cattle at the park boundary were responsible for lower price of milk at the park boundary. However, our study showed that some abortions were not due to brucellosis, and only a limited number of sero-positive cattle had a history of abortion. In spite of limited cases of symptomatic abortions, the information we obtained from key informants at milk collection points confirmed the fear that milk buyers' perceive milk produced at the park boundary as contaminated with *Brucella spp.* The respondents' concern that cattle infected with brucellosis usually shed the pathogen in milk is supported by many authors. For example, Nicoletti (1980) and Corbel (1998) show that cattle and buffalo infected with *Brucella spp.* often excrete high concentrations of the organism in their milk, and a similar study (Holt *et al.* 2011) also observed that there is a great risk of humans becoming infected via direct consumption of dairy products in situations where interactions between wildlife and livestock occur. The behaviour of milk buyers in the study area is thus consistent with known facts regarding consumer behaviour (Grunert, 2005; Lobb *et al.*, 2007). Consumer bias against perceived risk of food safety is also explained by previous research findings of Grunert (2005) and Lobb *et al.* (2007). Some scholars have argued that consumers usually show open bias when they are faced with perceptions regarding the risk of food contamination (Brabander *et al.*, 2007; Grunert, 2005; Lobb *et al.*, 2007). This behaviour is likely when the outcome of consumer decisions regarding a particular health hazard does not have any direct economic bearing on the consumers themselves. However, such decisions usually affect the small holder farmer directly and sometimes severely even when research reports are based on limited evidence of contamination. Practical measures to avert the situation that might compromise pastoralists' cherished source of livelihood will require further research.

The overall limitation of this study is its inability to unambiguously describe the actual contribution of brucellosis to low milk prices. However, it demonstrated that negative consumer perception was a major contributing factor. Basing our argument on the number of abortions and the amount of brucellosis prevalence in cattle, as well as the volume of milk along a distance from the park, we further showed that this perception was not unfounded. Indeed consumer preference regarding location of milk production and volume of milk available, potentially affected the farmers' price bargaining power in favour of distant communities further north due to low demand near the park. Future study in the region should use similar distance gradients to investigate brucellosis in wildlife and cattle grazing areas as well as screening milk for contamination with brucellosis.

CONCLUSION

Higher milk prices in rangelands further north of the park and lower prices near LMNP has been revealed. Our study shows that high milk prices further north of LMNP coincides with low brucellosis prevalence and abortions in cattle, whereas low milk prices at the park

boundary also coincides with high prevalence levels of brucellosis and incidence of abortion in cattle.

Milk prices remained low in the southern collection points along the Masaka - Mbarara highway. However, the price increased gradually northwards across the highway. Our assessment is that the collection points and market access roads were not the major factors determining the price. On the contrary, the negative perception of the milk buyers and the low volume of milk had some bearing on low milk prices at the park boundary. Most households there produced less than 10 litres of milk per day, compared to further north where most households produced over 10 litres a day. This could be explained, in part, by the fact that brucellosis in cattle usually affects milk production, and that cattle at the park boundary were generally exposed.

Ethical issues

Ethical approval to carry out brucellosis serological surveys in cattle was obtained from Makerere University Clinical Epidemiology Unit, Faculty of Medicine Research and Ethics Committee prior to the commencement of the study. On the other hand, the consent of participants in socio-economic surveys using interview schedule was obtained from the respondents during the study.

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Figure

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LIST OF FIGURES

Figure 1: Map showing the location of six distance zones from Lake Mburo National Park boundary.

Figure 2: Relationship between distance from Lake Mburo National Park boundary and the proportion of brucellosis prevalence and incidences of abortion in cattle, and milk volume as a symptomatic effect of brucellosis.

Figure 3 shows spatial variations in proportion of mean incidences of abortion in cattle versus mean number of calves in each of the six distance zones from Lake Mburo National Park boundary.

Figure 4: Number of calves relative to reported abortions along a distance gradient from LMNP boundary

Tables

LIST OF TABLES

Table 1: Summary of *Brucellosis* prevalence in cattle

D	Se	Prevalence -
0	17	60.27(58.
4	15	51.89(50.
8	15	52.05(50.
1	11	39.04(37.
1	94	32.19(30.
2	79	27.15(24.

Table 2: Mean abortions per 100 cattle in each distance zone

Abortions in 100 cattle				
Dist		To	Mean	
0 - 4		57	10.52	
4 - 8		54	8.25	
8 -		46	8.30	
12 -		18	4.64	
16 -		11	2.96	
20 -		80	2.27	

Statistical mean of abortions in 100 cattle is significant at $p < 0.05$

Table 3: Reported pastoralists' knowledge of brucellosis and perceptions regarding consumer bias towards milk produced at the park boundary.

Category	Responses (n=366)	Frequency	%
Brucellosis symptoms	Abortions in cattle	276	76.0
	Low live weight	107	29.2
	Low milk production	189	51.6
	Delays in reproduction	99	27.0
Transmission of brucellosis	Cattle transfer in herds	73	19.9
	New stock form market	57	15.6
	Wildlife grazing in farms	295	80.6
	Grazing cattle in the park	102	27.9
Determinants of low milk prices	Less milk surplus	51	13.9
	Limited market access	109	29.8
	Poor communication	69	18.9
	Consumer and retailer bias	277	75.7

Table 4 Contribution of factors affecting unit price of milk produced in the study area.

Variables	R ²	95% CI for B	r ²	Sig.
Distance from LMNP in km	0.683	45.91-53.65	0.799	<0.001
Abortions in cattle	0.781	10.50-7.34	-0.502	<0.001
Brucellosis in cattle	0.625	58.27-38.82	-0.475	<0.001
Milk volume produced	0.529	14.85-26.48	0.344	<0.002

Model fit for variables: Adjusted R²= 0.846; Significant at **P<0.005