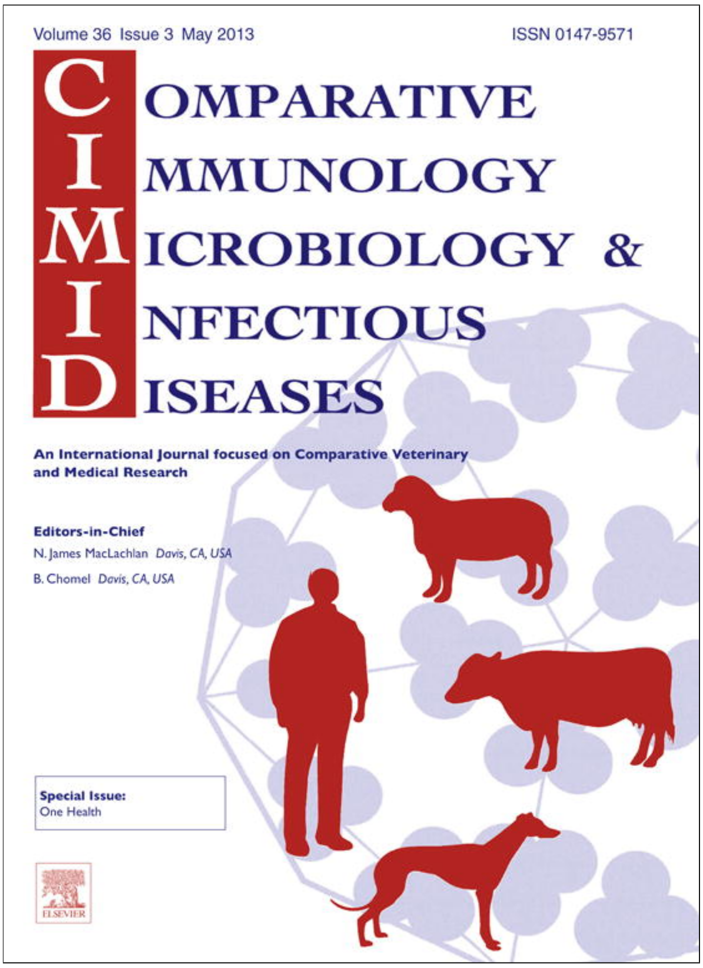
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Coexisting with wildlife in transfrontier conservation areas in Zimbabwe: Cattle owners' awareness of disease risks and perceptions of the role played by wildlife

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ABSTRACT

Diseases transmitted between wildlife and livestock may have significant impacts on local farmers' health, livestock health and productivity, overall national economies, and conservation initiatives, such as Transfrontier Conservation Areas in Southern Africa. However, little is known on local farmers' awareness of the potential risks, and how they perceive the role played by wildlife in the epidemiology of these diseases.

We investigated the knowledge base regarding livestock diseases of local cattle owners living at the periphery of conservation areas within the Great Limpopo TFCA and the Kavango-Zambezi TFCA in Zimbabwe, using free-listing and semi-structured questionnaires during dipping sessions. The results suggest that information related to cattle diseases circulates widely between cattle farmers, including between different socio-cultural groups, using English and vernacular languages. Most respondents had an accurate perception of the epidemiology of diseases affecting their livestock, and their perception of the potential role played by wildlife species was usually in agreement with current state of veterinary knowledge. However, we found significant variations in the cultural importance of livestock diseases between sites, and owners' perceptions were not directly related with the local abundance of wildlife. As the establishment of TFCAs will potentially increase the risk of Transboundary Animal Diseases, we recommend an increased participation of communities at a local level in the prioritisation of livestock diseases control and surveillance, including zoonoses.

1. Introduction

Domestic and wild animals are coming into ever-more intimate contact in many interface areas throughout the world, leading to human–wildlife conflict. Hence finding solutions to improve co-existence of wildlife with cattle emerges as a key issue for the development of rural communities and for biodiversity conservation [1]. Among various types of human–wildlife conflicts [2], disease transmission is one of the major negative consequences suffered by people, and their livestock, living at human/wildlife/livestock interfaces [3], and many

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low-income countries cannot respond adequately to emerging zoonotic diseases that affect humans as well as animals [4].

Diseases associated with wildlife may negatively affect local farmers in several ways. First, the health status of livestock owners and their families may be directly affected, as a number of zoonotic pathogens have been isolated from wild species [5]. Indeed, wildlife has been confirmed as a source of major emerging diseases such as highly pathogenic H5N1 or SARS that have resulted in pandemics during the last decades [6,7]. Human populations living at the periphery of conservation areas in tropical regions, which are considered as "hotspot areas" for potential future emergence [8], are thus particularly at risk of being infected by emerging pathogens. Second, wildlife-related diseases may cause direct mortality or reduce productivity of livestock and they are also indirectly responsible for reduced marketing opportunities. Current international rules, as compiled by the OIE in Terrestrial Animal Health Code [9], regulate the trade of animals and animal products between state members of the World Trade Organisation, in order to prevent the spread of transboundary animal diseases (TADs) between countries. Wildlife species have been demonstrated to act as reservoirs of several important TADs, such as the African buffalo acting as a natural reservoir of foot and mouth disease [10,11]. As a consequence, livestock living adjacent to areas where these wild hosts roam cannot be freely moved and marketed outside their area of origin, unless the countries have implemented specific approaches (e.g. commodity-based approaches and HACCP; see [9]) or if they have reached bilateral agreements with non-WTO members. Third, livestock is of considerable socio-cultural importance for many agro-pastoral communities living at the periphery of conservation areas, and wildlife-borne diseases may therefore threaten their livelihoods.

In the context of the developments of Transfrontier Conservation Areas (TFCAs), involving most countries in Southern Africa, disease transmission at the wildlife–livestock interface has been identified as a major challenge [3,12]. TFCAs have been promoted throughout the region as a way to reconcile conservation and development objectives, simultaneously contributing to global biodiversity conservation, regional peace and the sustainable socio-economic development of African communities, through increased cross-border collaboration and ecotourism. However, the expected increase of movements of people and animals across the boundaries of "re-connected" conservation areas presents new challenges for both public health and animal health [13]. With the growing recognition of the critical role of animal health in tropical regions, mitigation of disease transmission at the human/wildlife/livestock interface has, thus, become a major development and conservation issue [12,14].

Cattle-owners play a critical role in the implementation of veterinary disease control programmes. However, although TADs do have negative impacts on local as well as national levels in developing countries, priorities and strategies for disease control are always dictated at national and international levels, with little attention paid to the views and opinions expressed at grass-root level by cattle keepers. To that extent, community-based animal health delivery services have been promoted for the past two decades in Africa [15], in an attempt to better address priorities of local cattle owners. Participatory epidemiology has also been developed as a way to improve the involvement of animal keepers in animal disease control programmes and policies, including prioritisation of diseases [16].

The success of veterinary disease control measures largely depends on the knowledge base of cattle owners with regard to diseases [17], and farmers are demanding a greater involvement in the effective management of wildlife-associated diseases that do affect them and their livestock [18]. However, little is known on local farmers' awareness of the potential risks, and how they perceive the role played by wildlife in the epidemiology of these diseases. The knowledge bases and the perceptions of wildlife-associated diseases by southern African livestock keepers living at the periphery of conservation are likely to be heterogeneous for several reasons. First, the mechanisms involved in the epidemiology of infectious diseases is very complex [19], especially when they involve wild host reservoirs, and there are several diseases for which the role of wildlife is still open to question among wildlife epidemiologists [20]. Second, people living at the periphery of conservation areas in southern Africa are often of different ethnic origins [21], and they settled in these areas for variable periods of time, often after being displaced from their area of origin following events that may not be directly related to the existence of the conservation area [22,23]. As the cultural background of people influences their representations of illness and diseases [24], it is likely that cattle keepers living at wildlife–livestock interfaces in southern Africa have different cultural views about the importance and epidemiology of livestock diseases. It is also possible that the knowledge related to wildlife depends on the time of residence in a given ecological context, and thus recent migrants may have different perceptions of the role played by wildlife in the epidemiology of livestock diseases. Alternatively, livestock diseases might be a topic for which there is a general consensus, as a result of intense intercultural exchanges promoted by shared veterinary facilities (such as dip-tanks) and gatherings of livestock keepers and their cattle at cattle markets.

The current study investigates the knowledge of local cattle owners with regards to diseases affecting their livestock and how they perceive the role played by wildlife species in the epidemiology of these diseases in contexts of high or low abundances of wildlife in Zimbabwe.

2. Materials and methods

2.1. Study area

All questionnaires were implemented in communal lands adjacent to conservation areas in Zimbabwe (Fig. 1). Two areas were investigated: (1) The South East Lowveld (SEL) of Zimbabwe is a semi-arid ecosystem with less than 600 mm of rainfall per year on average. Part of the SEL is included in the Great Limpopo TFCA (GLTFCA), encompassing national parks, private conservancies and communal lands in Mozambique, South Africa and Zimbabwe. The

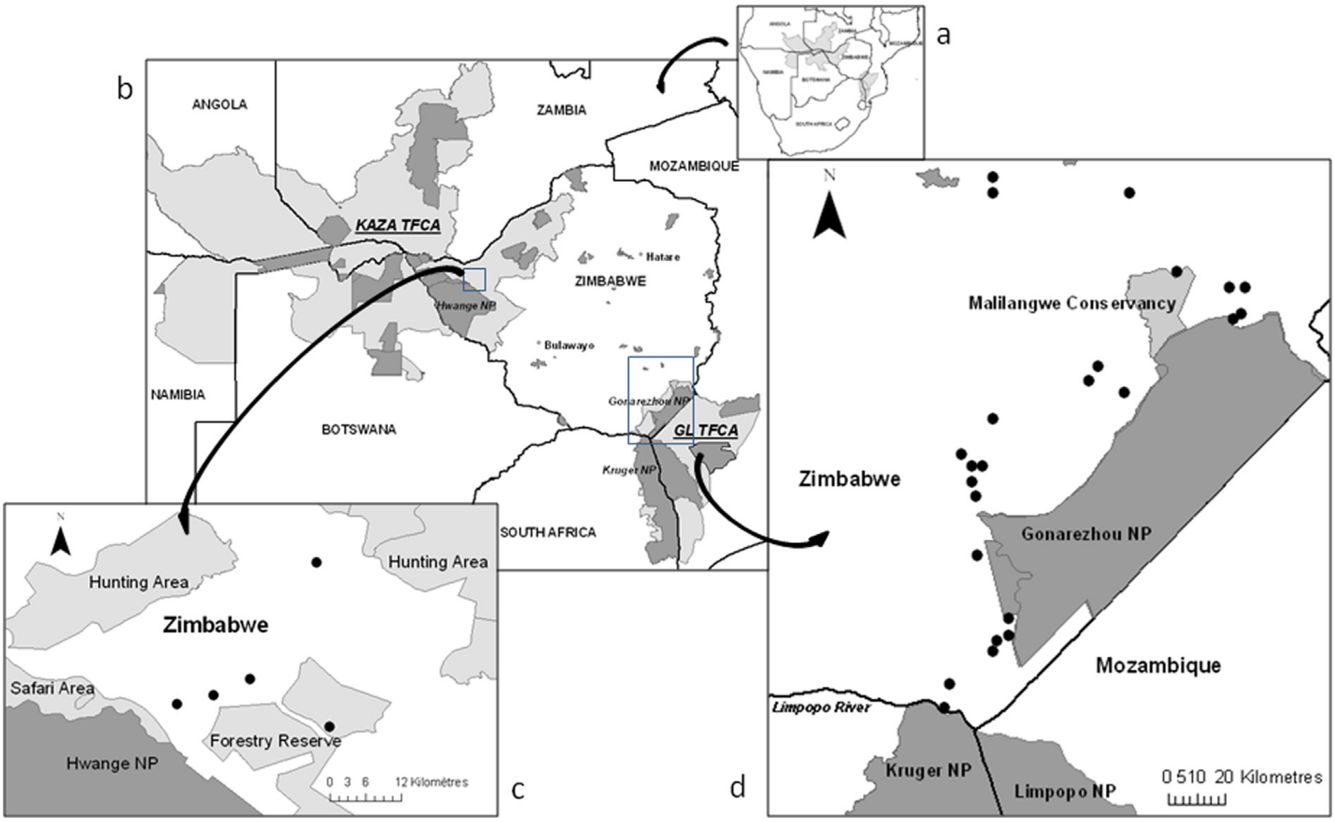

Fig. 1. Location of survey sites in Southern Africa (a) and Zimbabwe (b). Dip-tanks (black dots) visited in the KAZA-TFCA (c) and the GL-TFCA (d).

study areas were located in Zimbabwe, at the periphery of Gonarezhou National Park (GNP) and Kruger NP (KNP) in South Africa; (2) The periphery of Hwange National Park (HNP) in the Matabeleland North Province of Zimbabwe. This area is also a semi-arid area with on average 1000 mm rainfall per year. HNP and its periphery are included in the newly created (2011) Kavango-Zambezi (KAZA) TFCA, between Angola, Botswana, Namibia, Zambia and Zimbabwe.

GNP, HNP and some areas of KNP are characterised by soft boundaries (i.e. no physical barrier separating the protected area from the adjacent communal land). Veterinary fences erected along some sections of these national parks for foot and mouth disease control are used to prevent contacts between buffalo and cattle. However, due to a lack of maintenance following the economic downturn in Zimbabwe since the early 2000s, these fences have been extensively damaged by wildlife and humans' challenges and they are currently permeable to animal movements both ways.

Dip-tanks were selected in the periphery of GNP and HNP in a buffer of up to 35 km around protected area boundaries (i.e. national parks, safari areas, hunting areas, conservancies and forestry commission lands, adjacent to national park). In Zimbabwe, animal health regulations compel cattle owners in communal lands to dip their cattle weekly during the rainy season and fortnightly during the dry season for control of ticks and tick-borne diseases. Considering that over 90% of cattle owners dip their cattle (DVS Reports), dipping attendance was believed not to be a significant source of selection bias for the farmers. Hence, due to easy access to cattle owners during the dipping sessions, dip tanks were selected as the study sites for interviews with cattle owners. The selected areas (Fig. 1) included a total of 24 dip-tanks located in the SEL (Chanyenga, Chigweziwa, Chikhovo, Chikombedzi, Chishinya, Chitsa, Chizvirizvi, Chomupani, Davata, Faversham, Gurungweni, Makambi, Malipati, Maose, Matihwa, Muhlekwani, Nyabongwe, Nyangambe, Pahlela, Pesvi, Pfumare, Piri, Rupangwana, and Tsovani) and 5 dip-tanks in the Hwange area (Kamativi, Chezhou, Sialwindi, Mabale and Lupote).

2.2. Interviews at various wildlife/livestock interfaces

Questionnaires were administered by previously trained staff of governmental veterinary services ($n = 22$) to randomly selected volunteer participants during dipping sessions. The survey was conducted between February 2008 and December 2009 in the SEL, and in March 2010 in the Hwange area. The interviews were carried out individually, each cattle keeper being interviewed by the veterinary technician attached to his dip-tank, a familiar person often residing within the community.

The interviews were organised in four sections: (1) general information regarding the informant socio-economic status: main (and secondary) occupation, household composition, socio-cultural background (ethno-linguistic group, time of residence in the area), species and numbers of livestock owned; (2) "free-listing" of names of livestock diseases known by the informant [25]: this was done through a preamble which explained the procedure ("give all the names of livestock diseases that you know as they come") and clearly indicated that names could be given in any language (including local vernacular names), the informant was then invited to list all the names of livestock diseases known to him, the enumerator being in charge of the transcription of the names given orally (to avoid possible bias against illiterate respondents) each name being numbered following the order of mention by the informant (1 for 1st, 2 for 2nd...); (3) main disease characteristics according to the informant: for each name of disease listed, the informant was invited to detail what he/she believed were the main clinical signs and characteristic features of the disease (e.g. seasonal trends, age class of animals affected, ...); (4) role of wildlife according to the informant: for each name of disease listed, the informant was invited to indicate if wildlife was associated with the disease (yes/no/do not know), and if "yes" list the main wildlife species involved and how they are involved in the epidemiology of the disease in livestock.

The translation of the disease names given into English/scientific names was based on several types of information and depended on the situation: (i) when the name was given by the informant in English (e.g. Table S1 "brucellosis"), we kept it as it was regardless of the clinical signs or aetiology described by the informant (e.g. even if 'late abortion' or other typical clinical signs was not mentioned by the informant mentioning "brucellosis"); (ii) when the disease name was given in vernacular language (e.g. "Chamapundu" mentioned by 32 Shona informants; see Table S1) and several informants and/or the local staff of the veterinary services gave the corresponding English/Scientific name, we used the later name (e.g. "Lumpy Skin disease" corresponds to "Chamapundu); (iii) when a disease name was given in vernacular language by several informants (e.g. see Table 1 "Chimbwa mupengo") and when all the clinical signs given indicated clearly a disease known to occur in the study area (e.g. "salivation", "aggressive behaviour", "madness of the dog", "restless" or "dog barking", "involvement of jackal"... indicating rabies, which is endemic in the study areas), we retained the English/scientific name of putative disease; (iv) when the disease name given in English or in vernacular language and the clinical signs given only allowed the correspondence with a disease syndrome (e.g. "Kuhudha" in Shona meaning "diarrhoea"), we allocated the disease to one of the following disease syndromes (Not Identified Diseases = NID: NID Abcess, NID Abortion, NID Cutaneous, NID Diarrhoea, NID Digestive, NID Internal parasites, NID Limping, NID Ocular, NID Ocular, NID Paralysis, NID Salivation, NID Sudden death, NID Tick borne diseases); (v) when the disease name given was not specific (e.g. "Umkhuhlane" meaning "Disease" in Ndebele, see Table S1), or when it was mentioned by few informants or when the name was not readable, we allocated this name to the group "Not Identified Disease".

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cimid.2012.10.007.

Group discussions were also carried out with four dip-tank committees (Malipati, Pfumare, Pesvi, and Pahlela) several months after the completion of the survey. The discussions were aimed at presenting preliminary results on disease's relative cultural importance, list priority diseases for interventions according to the owners and check agreement/disagreement with saliency as calculated using the free-list responses, and discussing perceptions on the role of wildlife in the epidemiology of the diseases.

2.3. Data analysis

The purpose of free-list analysis is twofold: (i) establishing a list of all known diseases in a given community and (ii) discriminating the most culturally salient diseases from the less important ones. Cognitive psychologists and anthropologists have shown that the lists generated through free-listing are not randomly ordered: the frequency with which items are cited across lists and their order of mention within lists indicate their relative importance [26]. Comparing items' cultural saliency is made easier through the use of composite indexes combining both frequency and order of mention. We calculated the Sutrop index [27] defined as $S_a = F/NmP_a$, with S_a = Item a's Sutrop Index (Salience), N = number of respondents, F = items a's frequency of mention across lists, and mPa = average citation rank. The length of individual lists also reveals the degree of informants' familiarity to the domain under investigation.

The disease names were given by the informants in vernacular languages (Nambya, Ndebele, Shangani, Shona; no distinction was made between the Shona dialects, Karanga, Korekore, Manyika, Ndau and Zezuru) and in English. The original lists of vernacular names and the corresponding list of English/scientific names (putative diseases or syndromes deduced by veterinarians from the clinical signs and aetiology as described by the informant; see above) were analysed separately [28]. The latter list was generated from the first one in which all vernacular names identified as the same diagnosed disease were aggregated. We have then ranked each diagnosis disease accordingly to its frequency of mention (e.g., high ranks indicate high occurrence across lists).

We built a composite variable indicating the relative abundance of wildlife at each site, using three sources of information: (1) perception of veterinary livestock technicians based in the area; (2) the shortest distance between the GPS position of the area and the closest protected area with known presence of wildlife; (3) expert knowledge by key informants (wildlife managers or researchers). The final "composite wildlife abundance" variable was categorised as 0 (no wildlife/livestock contact), 1 (rare wildlife/livestock contacts due to low wildlife densities or to the presence of well maintained ungulate proof fences) and 2 (medium to high density of wildlife and absence of barrier preventing contacts).

Each respondent was allocated to one of the major ethno-linguistic groups ("Ethnic origin": Nambya, Ndebele, Shangani, Shona or Tonga) according to the language he used for the list of disease names and the information given on his mother language. A synthetic variable with 4 classes indicating the "history in the area" of the informants was

Table 1
Names of livestock diseases most frequently mentioned by cattle keepers ($n = 254$) in Zimbabwe. Only names mentioned by more than 5 respondents are shown in this table. Frequency (Freq.), percentage of respondents mentioning the name (%) and value of Sutrop Index (see text and [27]) for each ethno-linguisitc group considered.

Vernacular name	Disease/syndrome	All respondents ($n = 254$)			Ndebele ($n = 31$)		Shona ($n = 69$)		Shangani ($n = 135$)		Other minorities ($n = 11$)	
		Freq.	%	Sutrop Index	%	Sutrop Index	%	Sutrop Index	%	Sutrop Index	%	Sutrop Index
Foot_and_Mouth	Foot_and_mouth	153	60.24%	0.246	64.52%	0.403	52.17%	0.241	62.96%	0.352	54.55%	0.364
Blackleg	Blackleg	84	33.07%	0.179	38.71%	0.129	30.43%	0.145	31.85%	0.144	27.27%	0.117
Heartwater	Heartwater	76	29.92%	0.080	48.39%	0.191	28.99%	0.109	27.41%	0.083		
Lumpy_Skin	Lumpy_Skin	67	26.38%	0.068	25.81%	0.129	20.29%	0.079	27.41%	0.098	36.36%	0.182
Anthrax	Anthrax	50	19.69%	0.156	9.68%	0.029	18.84%	0.044	19.26%	0.059	27.27%	0.102
Redwater	Babesiosis	39	15.35%	0.094	6.45%	0.022	21.74%	0.054	13.33%	0.035	18.18%	0.061
Chamapundu	Lumpy_Skin	30	11.81%	0.033	6.45%	0.022	18.84%	0.049	11.11%	0.039		
Chamahwanda	Foot_and_mouth	25	9.84%	0.045	3.23%	0.011	17.39%	0.075	8.15%	0.031		
Gall_sickness	Anaplasmosis	24	9.45%	0.094	22.58%	0.066	7.25%	0.015	7.41%	0.021		
Chipfau	Blackleg	23	9.06%	0.055			17.39%	0.087	8.15%	0.033		
Lumpskin	Lumpy_Skin	22	8.66%	0.024	9.68%	0.058	7.25%	0.030	9.63%	0.037		
Rabies	Rabies	22	8.66%	0.012	6.45%	0.011	8.70%	0.013	9.63%	0.020		
Chebandauko	NID_Limping	18	7.09%	0.018			13.04%	0.059	5.93%	0.025		
Foot_Rot	Foot_Rot	17	6.69%	0.017	6.45%	0.009	7.25%	0.018	6.67%	0.018		
Chimbwa_mupengo	Rabies	15	5.91%	0.011	3.23%	0.011	4.35%	0.016	8.15%	0.018		
Mastitis	Mastitis	15	5.91%	0.013	3.23%	0.004	2.90%	0.010	8.15%	0.020		
Kusvodza	Brucellosis	13	5.12%	0.021	3.23%	0.004	8.70%	0.020	4.44%	0.010		
Nyongo	Anaplasmosis	12	4.72%	0.047	9.68%	0.026	2.90%	0.014	4.44%	0.013	9.09%	0.091
Chimee	Heartwater	11	4.33%	0.012	3.23%	0.032	4.35%	0.007	5.19%	0.013		
Quarter_evil	Blackleg	9	3.54%	0.025			2.90%	0.006	4.44%	0.033	9.09%	0.011
Isikwekwe	Dermatophilosis	8	3.15%	0.023	19.35%	0.073					18.18%	0.121
Newcastle	Newcastle	8	3.15%	0.006	6.45%	0.016	1.45%	0.003	2.96%	0.005		
Tungundu	Anthrax	8	3.15%	0.028	3.23%	0.004	5.80%	0.017	2.22%	0.007		
Chigwadara	Anthrax	7	2.76%	0.024	3.23%	0.016	1.45%	0.005	3.70%	0.013		
Chikwekwe	Ticks	7	2.76%	0.005	3.23%	0.016	2.90%	0.007	2.22%	0.007	9.09%	0.045
Opthlamia	Contagious_Opthalmia	7	2.76%	0.012	3.23%	0.005			2.22%	0.007	9.09%	0.013
Contagious_abortion	Brucellosis	6	2.36%	0.008					3.70%	0.009		
Scours	Scours	6	2.36%	0.004	3.23%	0.005			2.22%	0.008		

created, including information on time of residence in the area and place of birth of parents and grandparents. In summary, the following socio-economic data of the informant was collected: local resident (parents and grandparents borne in the area), old migrant (parents borne in the area), middle range migrant (parents not borne in the area, but informant resides for >20 years in the area), recent migrant (immigration <20 years).

Non-parametric analysis of variance (Kruskal–Wallis test) was used to compare the number of diseases listed by informants in relation to the "Composite wildlife abundance", "ethnic origin" and "history in the area" variables. Chi-square tests were used to compare proportions of answers (e.g. "Is this disease related to wildlife?") or proportions of answers in agreement with available veterinary knowledge for different values of "Composite wildlife abundance", "history in the area" and "ethnic origin". All statistical analyses were performed using R software [29].

3. Results

A total of 254 individual questionnaires were administered between February 2008 and December 2009 in the SEL ($n = 218$), and in March 2010 in the Hwange area ($n = 36$). All respondents were directly involved in livestock keeping (7 did not answer that question), with the majority of them mentioning farming as their only professional activity ($n = 132$) or some involvement with agriculture extension services ($n = 94$), while less than 10% indicated that they had another significant activity ($n = 21$). Using the "Free-listing" task, a total of 1059 different names of livestock diseases were collated from the 254 respondents. 49.6% of the respondents acknowledged Shangani as their mother language but only 2.8% of the disease names were given in Shangani, whereas 20.1% named Shona as their mother language, and 21.6% of the disease names were given in this language. Ndebele speaking people represented 9.4% of the farmers interviewed, and 2.4% of diseases names were given in this language, whereas 72.4% of the disease names were given in English. The remaining minority languages mentioned by the respondents as their mother tongue represented less than 6% of the sample (Nambya, 5.9%; Tonga, 1.9%; other minorities 2.0; and no response, 11.4%), and no disease name was given in these languages (except for 1 name in Nambya). The full list of names given in English and in vernacular languages is given as supplementary material (Table S1), along with the most frequently associated putative disease (or syndrome), as identified by veterinarians based on the symptoms described by the respondents and the knowledge of livestock diseases prevailing in the areas (e.g. [3,14,30]; see also reference to unpublished results Table 4).

The most frequently cited vernacular name for a given disease/syndrome was usually the same for the majority of respondents, regardless of their ethno-linguistic group (Table 1). "Foot and mouth" disease for instance, was the most frequently and early mentioned term by cattle owners of all ethnic groups systematically attaining the highest score for the sutrop index (Table 1) with the majority of Ndebele (65%), Shona (52%), Shangani (63%) and other minority groups (55%) using the English name. However, there was also evidence that shared intercultural semantic domain regarding cattle diseases involved the use of other vernacular languages. For instance, a Shona name referring to foot and mouth disease ('Chamahwanda') was mentioned by 17% of the Shona respondents, and also by 8% of the Shangani and 3% of the Ndebele (Table 1). Similarly, the English word 'Lumpy skin' (also spelled 'Lumpskin') was the most frequently mentioned for lumpy skin disease (LSD), used by 27–37% of Ndebele/Shona/Shangani/Other language (Table 1); but a Shona word ('Chamapundu') referring to the same disease was used by 19% of Shona respondents, 11% of Shangani and 6% of Ndebele (Table 1), and the Shangani spelling ('Chamabhunzu') was also used by 3% of the Shangani respondents ($n < 5$, result not shown in Table 1). As a last example, the Ndebele term 'Isikwekwe', which seems to refer to dermatophilosis according to the symptoms described by the cattle keepers interviewed, was mentioned by 19% of the Ndebele and 18% of the other minorities (mostly Nambya in this case), whereas the English word 'Dermatophilosis' was only used once, and no other name was used to refer to this disease, which is apparently mostly encountered in the western part of Zimbabwe [31].

The number of diseases listed by the respondents ranged 1–9, with only 8.3% of the respondents listing more than 7 names. The length of the lists did not differ significantly between ethnic groups of farmers ($n = 246$, $\chi^2 = 1.5$, $df = 3$, $p = 0.681$). However, the length of the lists differed significantly according to: (1) the "Composite wildlife abundance" variable ($n = 254$, $\chi^2 = 34.7$, $df = 2$, $p < 0.001$) with longer lists given in areas where wildlife abundance ("Composite wildlife abundance" variable) was lower; (2) the "history in the area" of interviewees ($n = 235$, $\chi^2 = 9.5$, $df = 3$, $p = 0.024$), with medium and recent migrant giving on average longer lists than old migrant and local farmers.

The relative importance of diseases and syndromes identified from the list of names given by the cattle owners interviewed varied between localities. The most frequently cited diseases across all interviewees are listed in Table 2. Within the 12 different groups of dip-tanks, defined according to their geographic proximity and the local relative abundance of wildlife (see definition of 'Composite wildlife abundance'), we have ranked each diagnosed disease by their frequency of mention (the highest ranked disease is the most often cited within a dip-tank group). Foot and mouth disease was the exception, as it was consistently the most often mentioned disease, often 1st or 2nd, by cattle owners from all dip-tank groups. But the ranking of the disease listed after FMD was variable between groups of dip-tanks. There was some consensus regarding LSD, Blackleg and Heartwater, usually ranked 2nd, 3rd and 4th, respectively, although some discrepancies were apparent between groups of dip-tanks (e.g. Blackleg ranking [1–5]). For most other diseases, however, large variations in ranking were apparent between dip-tank groups, with some disease ranks ranging enormously: e.g. [3–7] for Anthrax, [4–12] for Foot rot and [1–10] for Babesiosis. Some diseases were mainly mentioned from a few dip-tank groups, such as Theileriosis (mentioned in 4 DT) or Dermatophilosis, which was only mentioned at the group of DT located at

Table 2
Ranking of livestock diseases/syndromes by cattle owners ($n = 254$) in Zimbabwe Transfrontier Conservation areas. Most frequently cited diseases/syndromes (overall % of citations) and mean rank (based of frequency of citation) calculated for 12 groups of dip-tanks (DT#1 = Chanienga, DT#2 = Chikhovo/Makambe, DT#3 = Chomupani/Gurungweni/Pfumare, DT#4 = Faversham/Nyabongwe/Nyangambe, DT#5 = Chizvirizvi, DT#6 = Davata/Maose, DT#7Piri/Tsovani; DT#8 = Chezhou/Mabale/Sialwindi; DT#9 = Malipati/Muhlekwani, DT#10 = Pahlela, DT#11 = Pesvi; DT#12 = Chikombedzi/Chigweziwa).

Disease	Freq. (%)	DTG#1	DTG#2	DTG#3	DTG#4	DTG#5	DTG#6	DTG#7	DTG#8	DTG#9	DTG#10	DTG#11	DTG#12
Foot and mouth	0.78	1	1	1	1	2	1	1	1	1	1	1	1
Lumpy Skin	0.50	2	2	2	2	3	2	3	4	2	5	2	3
Blackleg	0.49	1	3	3	3	1	3	2	5	4	2	3	4
Heartwater	0.35	2	2	4	5	6	4	4	4	3	5	4	4
Anthrax	0.29	4	4	6	4	5	5	3	7	6	5	5	3
Babesiosis	0.24	6	9	10	4	4	7	3	9	7	6	6	1
NID Limping	0.16	7	6	10	6	9	7			11	3		2
Anaplasmosis	0.15	4	7	10	10		5		6	5	3	5	
Rabies	0.15	3	5	4	8	7				9	6		
Brucellosis	0.10	7	7	8	7	8				7	6		4
NID Neurological	0.08	7	8	7	10		6	5					3
Foot Rot	0.08		8	10	9	6	7	5	9	12	6		4
Mastitis	0.07					4	7			11	4	4	
NID Ocular	0.06	5			10	6	7		9	11	6		
Ticks	0.04	7	9	9	10	10			6		6		
NID Digestive	0.04	7	9	9		8							4
NID Diarrhoea	0.04	7	9	11		7			9	12	5		
NID Cutaneous	0.04	7		9	10	9			8	10			
Newcastle	0.04	7	9			10	7	5		10			
NID Respiratory and death	0.03		9		9		7						4
NID Paralysis	0.03		8			8	7		8	12			
NID Salivation	0.03		9	10	10	9	7						
Dermatophilosis	0.03	7							3				
Theileriosis	0.01					10	7			12		6	

Table 3
Most frequently cited ($n \geq 7$) livestock diseases by cattle owners in Zimbabwe ($n = 1050$ citations). Perceived involvement of wildlife: "Don't know", "No" and "Yes" refers to farmers' replies to the question "Is this disease related to wildlife?" (NA = not available). "Species citation" refers to the number of time a wildlife species has been cited as playing a role in the epidemiology of the disease, and names of often most cited wildlife species (percentage of "wildlife citation").

Disease/syndrome	Disease citation	Do not know	No	Yes	Species citation	Main wildlife sp. cited	Second most cited wildilfe species
Foot and mouth	190	18%	4%	77%	171	Buffalo (82%)	Wildebeest (6%)
Lumpy Skin	127	52%	26%	22%	35	Buffalo (54%)	Wildebeest (17%)
Blackleg	122	39%	29%	32%	50	Buffalo (62%)	Wildebeest (14%)
Heartwater	89	39%	37%	24%	26	Buffalo (62%)	Wildebeest (11.5%)
Anthrax	67	46%	22%	31%	34	Buffalo (47%)	Wildebeest (15%)
Babesiosis	43	33%	47%	21%	10	Buffalo (80%)	Eland, Elephant (10%)
Anaplasmosis	42	38%	33%	29%	14	Buffalo (57%)	Elephant (14%)
NID	42	48%	24%	29%	14	Buffalo (64%)	Greater kudu, Wildebeest (14%)
Rabies	38	8%	0%	92%	41	Jackal (78%)	Wild dog (12%)
NID Limping	28	46%	32%	21%	6	Buffalo (67%)	Eland, Elephant (17%)
Brucellosis	23	39%	48%	13%	4	Buffalo (50%)	Greater kudu (25%), All wild animals (25%)
Foot Rot	19	42%	37%	21%	4	Buffalo (75%)	All antelopes (25%)
Mastitis	17	53%	35%	12%	5	Buffalo (40%)	Eland, Greater Kudu Sable (20%)
NID Ocular	16	44%	44%	13%	3	Buffalo (67%)	Elephant (33%)
NID Neurological	15	40%	53%	7%	0	NA	NA
NID Cutaneous	14	50%	29%	21%	4	Bushpig (50%)	Wildebeest (50%)
NID Diarrohea	14	57%	29%	14%	2	Buffalo (100%)	NA
Ticks	13	46%	0%	54%	9	Wildebeest (33%)	Bushpig (22%)
Dermatophilosis	10	40%	20%	40%	4	Buffalo (50%)	Bushpig, Wildebeest (25%)
NID Digestive	10	50%	30%	20%	1	Buffalo (100%)	NA
NID Paralysis	10	40%	0%	60%	7	Buffalo (71%)	Impala, Warthog (14%)
Newcastle	8	63%	25%	13%	1	Buffalo (100%)	NA
Contagious Opthalmia	7	14%	57%	29%	2	Buffalo (100%)	NA
NID Salivation	7	57%	43%	0%	0	NA	NA
Theileriosis	7	57%	0%	43%	5	Buffalo (60%)	Wildebeest, Elephant (25%)

the periphery of Hwange, with a high frequency of mention (24.4%) ranking 3rd.

Out of 55 diseases and syndromes identified, 29.1% are known to be related to wildlife, 29.1% are not known to be related to wildlife and for 41.8% of them (including the 20 syndromes) no available knowledge exists on the role of wildlife (Table 3). Interviewees cited diseases or syndromes known to be related to wildlife in 61.9% of cases, diseases or syndromes not known to be related to wildlife in 18.1% of citations and diseases or syndromes with a lack of knowledge in 20.0% of cases.

Overall, 36.6% of the respondents perceived that wildlife was involved in the transmission of diseases listed, but 24.8% said that wildlife did not play any role (38.5% did not know or did not respond to the question). These proportions were not significantly different for each value of the "Composite wildlife abundance" variable ($n = 1059$, $\chi^2 = 6.9$, df = 4, $p = 0.139$). The proportion of farmers' perceptions in agreement with available veterinary knowledge about the role of wildlife in the epidemiology of livestock diseases listed did not differ according to "history in the area" ($n = 974$, $\chi^2 = 0.8$, df = 4, $p = 0.933$) and "Composite wildlife abundance" in the area ($n = 974$, $\chi^2 = 1.2$, df = 2, $p = 0.538$). However, when considering the most cited disease (Table 4), different patterns were observed: (1) Farmers in strong agreement with current epidemiological knowledge (e.g. foot and mouth disease, rabies); (2) Farmers unaware of the role of wildlife in the epidemiology of the disease (e.g. brucellosis, Newcastle disease); (3) As current knowledge about the role of wildlife in the epidemiology of the disease is not clear (i.e. the disease has been directly or indirectly identified in wildlife species but the transmission between wildlife and domestic species has not yet been proven), farmers' answers is close to random selection (between 3 options, "yes", "no" and "do not know") (e.g. tick-borne diseases, such as heartwater, babesiosis, anaplasmosis, or anthrax).

4. Discussion

The knowledge base related to livestock diseases of cattle keepers living in TFCAs in Zimbabwe was relatively homogenous between respondents from various localities. As for many semantic domains related to the environment or to technical issues, few 'specialists' held most of the knowledge (longer lists of disease names given) at each dip-tank surveyed, although this was not very apparent as the maximum number of disease names given was relatively small. These 'specialists' may have been people associated in some ways with the veterinary or agricultural extension services (dip-tank attendant, member of the dip-tank committee, Agritex staff), with a relatively high level of education which allowed them to name diseases in English. Although the questionnaire procedure adopted was meant to emphasise the fact that names given in any vernacular languages could be included in the list, our results may have been biased towards English and Shona languages. The enumerators trained to administer the questionnaire were all veterinary and livestock technicians attached to the Animal Health Centre servicing the dip-tanks surveyed and, although most of them had lived within the communities for months or years, the majority of them were

Table 4
Relative frequency and laboratory confirmation for the most frequently mentioned diseases by livestock owners in two districts (Chiredzi and Hwange) of Zimbabwe included in TFCAs. Notifiable diseases according to Zimbabwe regulations are indicated. Number of diseases cases reported by the Government Veterinary Services of Zimbabwe (GVS unpub. Data) for cattle in Chiredzi and Hwange districts during the period January–December 2010 and January 2005–July 2007. Reference for laboratory confirmation of livestock cases is also indicated (Refs. [31,40,41]; unpublished data).

Disease		Notifiable	Disease cases reported in cattle in Chiredzi district			Disease cases reported in cattle in Hwange district		
Name	Citation	Disease	January–December 2010 (GVS unpubl.)	January 2005–July 2007	Laboratory confirmation of livestock cases (Ref.)	January–December 2010 (GVS unpubl.)	January 2005–July 2007 (Marange and Marimwe 2008)	Laboratory confirmation of livestock cases (Ref.)
Foot and mouth	190	Notifiable	1425	2054	Serology ELISA SAT and NSP (Miguel et al. submitted [42])	43	194	Serology ELISA SAT and NSP (Miguel et al. submitted [42])
Lumpy Skin	127	Notifiable	118	5	Serology VNT (Caron et al. [14])	53	958	–
Blackleg	122	Notifiable	0	10	–	0	0	–
Heartwater	89	Notifiable	119	11	Serology IFAT (de Garine-Wichatitsky et al., unpubl)	30	0	-
Anthrax	67	Notifiable	68	0	Culture (Chikerema et al. [41])	0	1	Culture (Chikerema et al. [41])
Babesiosis	43	–	13	4	Serology IFAT (de Garine-Wichatitsky et al., unpubl)	6	0	–
Anaplasmosis	42	–	92	7	Serology ELISA (de Garine-Wichatitsky et al., unpubl)	19	55	–
Rabies	38	Notifiable	0	0	IFA (Pfukenyi et al. [40])	0	4	IFA (Pfukenyi et al. [40])
Brucellosis	23	Notifiable	0	0	Serology and culture (Gomo et al. [30,43])	1	27	–
Foot Rot	19	–	–	–	–	–	–	–
Mastitis	17	–	–	–	–	–	–	–
Ticks	13	–	–	–	–	–	–	–
Dermatophilosis	10	Notifiable	0	0	–	382	455	Laboratory examination (Chatikobo et al. [31])
Newcastle	8	Notifiable	21	0	–	0	0	–
Contagious Opthalmia	7	–	–	–	–	–	–	–
Theileriosis	7	Notifiable	26	0	Serology IFAT (Caron et al. [14])	48	88	Serology IFAT (Miguel et al. unpublished)

Shona people originating from other parts of the country. Despite this possible language bias, we found evidence of extensive intercultural exchanges of information related to livestock diseases between cattle keepers. Most of the disease names were given in English, which might be related to the fact that veterinary and agricultural extension officers in Zimbabwe are trained in English; but many names were also given in Shona, Ndebele or Shangani by livestock keepers from different socio-cultural groups. In fact, belonging to a given ethno-linguistic group, or being a migrant vs. local farmer, did not seem to influence the knowledge base or the relative importance of livestock diseases by cattle keepers living in TFCAs in Zimbabwe, which does not seem to indicate the importance of a "cultural epidemiology" [24] in this case.

We found, however, great variations in the local perception of priority diseases among cattle keepers attached to different dip-tanks, as indicated by the variations in diseases saliency. Foot and mouth disease was an exception, as it was systematically cited by cattle owners on top of the list at all dip-tanks. This can be explained by the important and constant actions carried out by the veterinary services of Zimbabwe during the past decades in an attempt to control FMD at the periphery of conservation areas in order to export beef from FMD-free areas of the country to the lucrative European Union market (e.g. [32]). The high and consistent ranking of this disease probably does not reflect the importance of its direct impact, as FMD has minor direct impacts and seldom results in mortality of infected cattle compared to other diseases. But it shows the importance of the indirect consequences of the control measures put in place, which have direct consequences on cattle owners, including compulsory vaccination, restriction of the movements of cattle outside the area and the erection of FMD-fences to prevent contact of cattle with buffalos. Apart from FMD, the perceptions of livestock diseases priority varied greatly between dip-tanks. This result has some important consequences for the strategies of disease control. In some cases, the priority given to a disease may be justified by explicit reasons, such as the buffalo-derived theileriosis that was most frequently mentioned by cattle keepers living close to conservation areas with permeable fences, or dermatophilosis that was only mentioned by farmers living in KAZA-TFCA, as the disease has apparently not spread to the GLTFCA area in Zimbabwe. In other situations, the consensual priority diseases or syndromes that have emerged at dip-tank level among cattle keepers might not be explicitly justified or might not correspond to the priorities of the national veterinary services or wildlife managers. These priorities should be assessed at local (dip-tank) level and taken into account when designing and implementing livestock disease control operations, and participatory epidemiology may provide the appropriate methods to ensure the involvement of local communities in the prioritisation exercise [16].

Perceptions of livestock keepers on the epidemiological role of wildlife in livestock diseases usually corresponded to the "state of the art" in veterinary wildlife epidemiology. For some diseases such as foot and mouth disease and rabies, the involvement of wild reservoirs (African buffalo *Syncerus caffer* and wild carnivores, respectively) in the epidemiology of the disease was usually well known and explained to the enumerators. Buffalo was mentioned as the main wildlife reservoir for almost all the cattle diseases or syndromes listed and, although this statement does not always agree with current scientific evidence, veterinarians have often come to the same conclusions after investigating the epidemiological role of buffalo, "the usual suspect" [33]. Other wildlife species, such as elephant *Loxodonta africana*, Cape eland *Taurotragus oryx*, civet cat *Civettictis civetta*, and ground hornbill *Bucorvus leadbeteri* may have been mentioned in relation to their symbolic and cultural values, as their putative role as wildlife reservoirs of cattle disease is not backed by current scientific evidence. However, local knowledge may provide very interesting explanations or research hypothesis about the epidemiology or clinical signs of some diseases that are still poorly studied by conventional veterinary studies in the complex situation of wild/domestic interactions. For example, tick-borne diseases, such as Heartwater and Anaplasmosis, were often mentioned by farmers, but they indicated in equal proportions that wildlife was/was not/did not know in the epidemiology of these diseases. This reflects a current knowledge gap, because although the pathogens responsible for these diseases have been isolated from wild ungulates [34,35], there is still an uncertainty regarding the potential role of wildlife species as a reservoir of these vector-borne diseases for livestock. Another example is the epidemiology of bovine brucellosis that was mentioned by most farmers, interviewed in Chiredzi district, who indicated in majority that they did not think that wildlife was involved in the spread of brucellosis to cattle. Indeed, a recent survey in the area [30] indicated that wildlife was apparently free of the infection, as opposed to buffalo populations in neighbouring Kruger national park in South Africa [36].

Discrepancies between local farmers and veterinary experts opinions regarding the epidemiological role of wildlife were often associated with diseases for which there is only incomplete scientific knowledge ([20]; e.g. lumpy skin disease), or for which the role played by wildlife has been only recently confirmed (e.g. brucellosis), or with diseases which have complex mechanisms of disease transmission that do not necessarily involve wildlife (e.g. ticks and tick-borne diseases). During a survey on cattle owner's awareness of BTB in Zambia, Munyeme et al. [37] found that the level of awareness of the disease among farmers was higher in areas where the prevalence was high. Similarly, we expected that knowledge of the epidemiological role of wildlife in cattle disease would be higher in areas with higher occurrence of wildlife, but this was not the case. The fact that there was no significant variation in knowledge and perception on the role of wildlife between farmers living with locally abundant wildlife/no wildlife, or between recent migrants/local farmers is noteworthy. First, this shows that information regarding livestock health, an important issue indeed for cattle keepers in the GL-TFCA and KAZA-TFCA, is circulating fast and efficiently, within and between groups of farmers associated at dip-tank level. This possibly happens through discussions at cattle markets (which gather farmers from several dip-tanks) and also possibly reflects the efficiency of the veterinary extension network which are present even in remote areas. Second, in contrary to other types of human–wildlife conflicts (e.g. predation on livestock by wild carnivores; [2]), it seems that cattle farmers living closer to conservation areas do not perceive an increased disease burden on their cattle due to the close proximity of wildlife. Concern had been raised that the attitudes of local farmers towards TFCA initiatives could be affected by a perceived possible increase in disease spread with increased animal movements [13,38], such as the recent emergence of bovine tuberculosis from South Africa to Zimbabwe [39]. Only one respondent cited (bovine) tuberculosis in the list of livestock diseases, and no mention was made spontaneously about an increased risk of diseases linked with the establishment of the GL-TFCA or KAZA-TFCA, although we did not specifically ask that question.

Cattle keepers living at the periphery of conservation areas in the GL-TFCA and the KAZA-TFCA in Zimbabwe generally have a good knowledge base about livestock diseases and the epidemiological role played by wildlife. However, priority diseases perceived by cattle keepers vary greatly between sites, and independently of local abundance of wildlife. There is a need to involve cattle owners in decision-making processes regarding priorities for disease control, which may be achieved by adopting participatory epidemiology methods.

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