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Citation for published version:
Lisulo, M, Namangala, B, Mweempwa, C, Banda, M, Picozzi, K, Maciver, SK & MacLeod, ET 2023, 'Dogs' health and demographics in wildlife-populated and tsetse-infested villages of Mambwe district, eastern Zambia.', *Preventive Veterinary Medicine*, vol. 217, 105969. https://doi.org/10.1016/j.prevetmed.2023.105969

Digital Object Identifier (DOI):
10.1016/j.prevetmed.2023.105969

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Publisher's PDF, also known as Version of record

Published In:
Preventive Veterinary Medicine

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OPEN ACCESS

Download date: 11. May. 2024

Preventive Veterinary Medicine 217 (2023) 105969

Contents lists available at ScienceDirect

Preventive Veterinary Medicine

journal homepage: www.elsevier.com/locate/prevetmed

Dogs' health and demographics in wildlife-populated and tsetse-infested villages of Mambwe district, eastern Zambia

Malimba Lisulo[a,b,*], Boniface Namangala[c], Cornelius Mweempwa[d], Maxwell Banda[b], Kim Picozzi[a], Sutherland K. Maciver[e], Ewan T. MacLeod[a]

[a] Infection Medicine, Deanery of Biomedical Sciences, College of Medicine and Veterinary Medicine, The University of Edinburgh, 1 George Square, EH8 9JZ Edinburgh, United Kingdom
[b] Central Veterinary Research Institute, Ministry of Fisheries and Livestock, P.O. Box 33780, Lusaka, Zambia
[c] Department of Veterinary Services, Tsetse and Trypanosomiasis Control Section, Ministry of Fisheries and Livestock, Lusaka, Zambia
[d] Department of Paraclinical Studies, School of Veterinary Medicine, University of Zambia, P.O. Box 32379, Lusaka, Zambia
[e] Centre for Discovery Brain Sciences, Edinburgh Medical School, University of Edinburgh, Edinburgh EH8 9XD, United Kingdom

ARTICLE INFO

Keywords:
Indigenous dogs
Zambia
African trypanosomiasis
Wildlife
Health
Demography

ABSTRACT

Good dog-keeping practices and access to veterinary care are essential for the well-being of dogs. As the main causes of morbidity and mortality in the rural canine population in Zambia are poorly understood, we followed a cohort of 162 indigenous dogs for six months in wildlife-populated and tsetse-infested villages of Mambwe district, eastern Zambia to gain deeper insights. Dogs lacked basic home and veterinary care, they were often starved and burdened with ticks, and some passed live adult worms in their stool. The frequent exposure of dogs to tsetse bites and consumption of fresh raw game meat and bones puts them at greater risk of acquiring African trypanosomiasis. Nearly 20 % of dogs were lost to follow-up, with the main causes being poor health (58.1 %), predation by wild carnivores (29 %), and owner culling or euthanasia (12.9 %). We observed that indigenous dogs' general well-being and survival were largely influenced by their environment, infectious diseases, injuries sustained during interaction with conspecifics and wildlife, and community attitudes and practices associated with dog ownership.

1. Introduction

Treasured as man's best friend, dogs share a close relationship with humans worldwide (Bentley et al., 2017). Dogs are kept for various physical, emotional, and other health-related benefits and security (Edney, 1995; Wallis et al., 2018). Depending on how dogs are kept, their well-being tends to vary from one society to another (Majumder et al., 2014). There is regular care and access to veterinary services in wealthier societies where most dogs are kept as pets or companions (Wells, 2007). Yet, in poorer societies, most dogs don't have similar benefits, their well-being is often neglected, and they are deprived of basic health care. This is particularly true for village "indigenous" dogs which are an integral part of most rural African communities (Boyko et al., 2009).

Generally, indigenous dogs are left to freely roam and consume just about anything they encounter: garbage, carcasses, and to a greater extent faecal matter that has not been properly disposed of (Butler and Bingham, 2000). This exposes such dogs to all sorts of infectious agents (Proboste et al., 2015; Banda et al., 2020) including ticks, fleas (Chitimia-Dobler et al., 2017; Moonga et al., 2019), and other blood-feeding arthropods (Matsukawa et al., 1997; Dantas-Torres, 2008; Siwila et al., 2015; Medkour et al., 2020). Moreover, dogs that live near livestock and wildlife are prone to more infectious diseases (Munang'andu et al., 2011; Nonaka et al., 2011; Williams et al., 2014).

Without proper home and veterinary care, the well-being of indigenous dogs is compromised and may result in death. However, the main causes of death in rural canine populations are poorly understood. Therefore, we aimed to investigate the primary causes of morbidity and mortality in dogs living in wildlife-populated and tsetse-infested villages of Mambwe district, eastern Zambia.

* Corresponding author at: Infection Medicine, Deanery of Biomedical Sciences, College of Medicine and Veterinary Medicine, The University of Edinburgh, 1 George Square, EH8 9JZ Edinburgh, United Kingdom.
E-mail address: Malimba.Lisulo@ed.ac.uk (M. Lisulo).

https://doi.org/10.1016/j.prevetmed.2023.105969
Received 8 December 2022; Received in revised form 21 June 2023; Accepted 22 June 2023
Available online 27 June 2023
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2. Materials and methods

We emulated the research concept used to measure changes in village dogs' health and demographic outcomes in rural Western Uganda (Hyeroba et al., 2017). The essence of the study was to describe the demographic characteristics of canine populations and to identify factors associated with their morbidity and mortality. Minor adjustments were made to suit the scope of our study on indigenous dogs in wildlife-populated and tsetse-infested villages of Mambwe district, eastern Zambia.

2.1. Study area

Mambwe district is in the eastern province of Zambia. It lies along the tsetse-infested Luangwa Valley basin, a historic focus of African trypanosomiasis (AT). Mambwe district is approximately 5724.5 km^2 in size with a human population of 119,313. The current study was conducted in three chiefdoms (Malama, Mnkhanya, and Nsefu) of Mambwe district (Fig. 1).

The three chiefdoms were chosen to involve various natural and human habitats, as well as based on previous findings of trypanosomes in indigenous dogs (Lisulo et al., 2014).

i. Malama Chiefdom is in a densely wildlife-populated zone that is remotely located on the edge of the South Luangwa National Park (SLNP), it is heavily tsetse-infested and has almost zero livestock except for fowls and dogs.
ii. Mnkhanya chiefdom is on the edge of a wildlife zone (located far away from the SLNP), it has very mild wildlife and tsetse presence, both livestock and dogs are common.
iii. Nsefu chiefdom is within a moderate wildlife-populated zone, it has moderate tsetse-infestation, and both livestock and dogs are common.

The SLNP on the western border is home to numerous wildlife species (mammals, reptiles, and birds) that move in and out of the district. As an overspill or extension of the SLNP, most of Mambwe district is a game management area (GMA). The vegetation consisting of Miombo (*Brachystegia* and *Jubernardia*), Munga (*Acacia, Combretum,* and *Terminalia*), and Mopane (*Colophospermum mopane*) woodlands are habitats for a wide range of arthropod vectors (including tsetse flies) and wildlife species. Human activities such as the use of forest products (i.e., timber, charcoal, and honey), land for various agricultural practices (i.e., crops and livestock), and fishing from natural water bodies, are permitted in this wildlife interface area. Whereas some households can afford to keep large livestock, most households commonly rear fowl (mainly chickens), and dogs for security as well as hunting purposes.

Three seasons are experienced in Mambwe: a cold-dry season from May to early August, then a hot-dry season from mid-August to mid-November, with temperatures ranging from 32 to 43 ℃, and the rainy-hot season from mid-November to April.

2.2. Selection criteria

Following previous findings of AT in indigenous dogs in Malama, Mnkhanya, and Nsefu chiefdoms of Mambwe district by Lisulo et al. (2014), we allowed every dog-keeping village within these chiefdoms to participate in the current study. Participation was entirely based on the willingness of dog-keepers to get involved, those that did not consent were excluded. We, therefore, focused on 58 dog-keeping villages that showed a willingness to participate: 15 in Malama, 18 in Mnkhanya, and 25 in Nsefu chiefdom. These consisted of villages that had previously tested positive for AT in dogs and other additional villages that kept dogs. The selected villages were typically small and consisted of one or more households from the same family. All three chiefdoms are predominantly Kunda-speaking with other Zambian tribes as minority settlers. Both sexes of dogs aged above three months were enroled as a cohort. No additional households or dogs were considered after enrolment, including puppies born to females in the cohort.

2.3. Study design

The enroled cohort of dogs was repeatedly followed up for a duration of six months from June to December 2018 to capture changes in their health and demographics. During this period, the enroled dogs were visited at three different time points, once each season: the first visit or enrolment in June (cold-dry season), the second in September (hot-dry season), and the third in December (rainy-hot season). We used

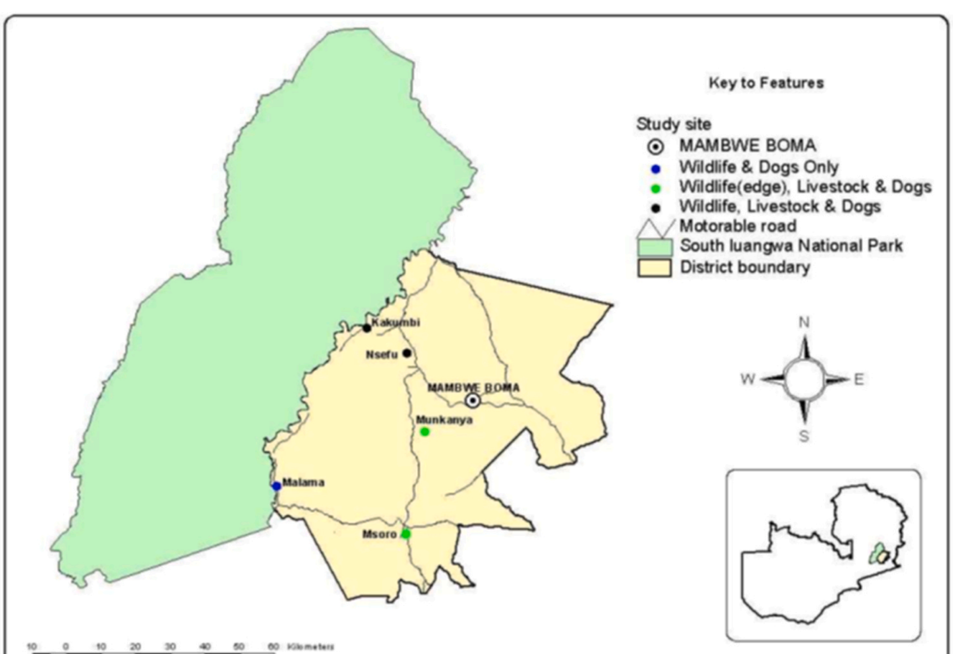

Fig. 1. Map of Mambwe district.

structured questionnaires, physical and laboratory (blood from the cephalic vein and faecal per rectum) examinations to assess the well-being of dogs.

2.4. Data collection

District veterinary staff based at Kakumbi Tsetse and Trypanosomiasis Research Station in Mambwe district helped to administer the questionnaires, conducted physical examinations on dogs, and collected samples for laboratory analysis. The officers had expert knowledge in veterinary matters, were familiar with the study areas, and could communicate with dog owners in their local languages (mainly Kunda and Chewa). A training session was held with the officers to fully explain the purpose of this study and how it supported the larger study which explored the epidemiological role of indigenous dogs in transmitting animal and human AT in Mambwe district.

2.5. Questionnaire

By using structured questionnaires, dog owners from the selected households provided information regarding the health and demographics of each enroled dog. Those with more than one dog in the cohort provided separate information for each dog they owned. The questionnaire specifically consisted of closed and open-ended questions and was divided into four sections: demography, home care, veterinary care, and the interaction of dogs with other animals.

i. Demography section captured general information on households (dog owner's tribe, age, gender, and level of education) and their dogs (name, age, sex, and the number of pregnancies for adult females, size of litter, survival, and causes of litter mortalities).
ii. Home care section captured general information on dogs' access to nutrition (i.e., consumption frequency of home leftovers, garbage foraging, animal or human faeces, carcasses, and fresh raw game meat and bones), as well as information on shelter and movement (i.e., whether dogs were confined or left to freely roam, frequency of movements and the distances covered).
iii. Veterinary care section captured general information on dogs' access to veterinary services (i.e., previous exposure to veterinary health care services), ectoparasite infestation (tick and flea infestations, what problems they caused, and control measures used), deworming and vaccination histories (we asked if dogs passed worms in stool, their deworming and rabies vaccination histories), and important diseases (dog-owners knowledge of rabies, worms, tick-borne disease, and AT, importance and occurrence of these diseases and their treatment and prevention).
iv. Interaction of dogs in the cohort with other animals captured general information on contact with other dogs, various species of livestock, and wildlife. Respondents were asked about the frequency of these interactions and if they resulted in dog mortalities, injuries, or diseases. Additionally, respondents were also asked if their dogs consumed fresh raw game meat and bones.

Dog owners were re-interviewed at each follow-up visit to capture any health or demographic incidents that occurred per dog since the last visit. Many gave rough estimates of the months in which incidences occurred i.e., illnesses, injuries (cause and effect), births and deaths, movements of dogs in and out of the population, how far each dog strayed from its homestead, and their social interactions.

2.6. Health assessment

District veterinary staff physically examined and collected biological samples of each dog in the cohort at all three-time points (i.e., at enrolment and two subsequent visits). During physical examinations, dogs were assessed for various conditions such as abnormalities, injuries, ectoparasites, body condition, and any signs of illnesses. Individual dog blood samples were collected from the cephalic vein into EDTA tubes for packed cell volume measurements (anaemic if PCV$<$37%), microscopic examination of Giemsa-stained thin smears, and PCR for the detection of hemoparasites. In addition, faeces obtained per rectum using gloved fingers were microscopically examined for helminths using the formal-ether sedimentation technique.

2.7. Statistics

Microsoft Excel spreadsheet software was used to enter and store raw data. STATA/MP 17.0 was used to analyze and interpret the data. Quantitative data were analyzed using summary descriptive statistics (frequency, percentages, confidence intervals, standard deviation, median, and means). The chi-squared test of independence and/or Fisher's exact test was used to determine associations between chiefdoms and various categorical variables. Statistical significance was considered at $P \leq 0.05$. The unit of analysis was the dog. Cumulative incidence was calculated as the number of new events or cases of diseases divided by the total number of dogs in the cohort at risk for a specific time interval (i.e., a three-month interval between each successive visit or the entire six months study duration). For the computation of incidence rates, the actual time when a loss to follow-up for any dog occurred was accounted for. This was used to determine the total dog-time of observation while at risk during the cohort study (denominator). For instance, if 10 dogs were enroled at the start of the study in June (month zero), three were lost in August (month two), four were lost in November (month five) and three survived to the end (month six), then the 10 dogs would have contributed 27 dog-months at 1st follow-up in September, 38 dog-months at 2nd follow-up in December, and overall 44 dog-months of follow-up from June to December.

3. Results

3.1. Household and dog demographics

A total of 162 indigenous dogs (82 males and 80 females) in 93 dog-keeping households were enroled for follow-up. The mean (±standard deviation) number of dogs per household was 1.7 (±1.1), with a range of one to five dogs per household. The cohort had a median age of 30 months (± 25), ranging from four to 156 months (Table 1).

The 80 females (12 young and 68 sexually active adults) produced 171 puppies during the six months follow-up period, with a mean litter size of 4.6 (± 2.1) pups that ranged from one to 12 pups. The cumulative incidence of puppy mortality during the six months of follow-up from June to December was 33.9% (Table 2). Dog owners attributed litter mortality to three main factors: (i) poor health (i.e., bloody stool, distended stomachs, inflammation, weakness, and lack of milk), with some female dogs experiencing abortion during gestation, (ii) non-health-related causes (i.e., stray dog attacks, poisoning, owner culling, and wildlife predation) and (iii) unknown causes. Although our study reports on litter birth and mortalities, these puppies were not part of the study cohort.

3.2. Home and veterinary care

Almost all dogs lacked shelter, were never confined, and freely roamed in tsetse-infested places with or without human supervision. All dogs in this study had an owner and were given food at least once a day. The most common meals were nshima (maize meal, the human staple), porridge, and fermented maize husks, but this varied amongst households. Interviews showed that 87.7 % of the dogs foraged at garbage sites, 41.3 % consumed animal or human faeces, 70.4 % scavenged for fresh or decomposed animal carcasses (i.e., livestock, birds, reptiles, and rats), and 67.3 % ate fresh raw game meat and bones. Access to veterinary care was low in all chiefdoms (Table 3). At the time of enrolment,

Table 1
Summarised household-dog descriptions in chiefdoms.

Chiefdom	HH	N° of Dogs	Males	Females	M ± SD	R	MA ± SD	AR
Malama	24	31	15	16	1.3 ± 0.7	1–3	18 ± 17	9–72
Mnkhanya	30	68	36	32	2.3 ± 1.3	1–5	24 ± 31	8–156
Nsefu	39	63	31	32	1.6 ± 0.9	1–4	36 ± 18	4–96
Total	**93**	**162**	**82**	**80**	**1.7** ± **1.1**	**1–5**	**30 ± 25**	**4–156**

HH (Household), M (Mean), R (Range), MA (Median Age), AR (Age Range).

Table 2
Births and mortalities of litters at different time points across the chiefdoms.

Chiefdoms	1st Follow-up (Jun-Sept)				2nd Follow-up (Sept-Dec)				Overall Follow-up (Jun-Dec)			
	B	M	C%	95% CI	B	M	C%	95% CI	B	M	C%	95% CI
Malama	25	1	4	1–20	13	11	85	58–96	38	12	32	19–47
Mnkhanya	32	12	38	23–55	31	14	45	29–62	63	26	41	30–54
Nsefu	30	9	30	17–48	40	11	28	16–43	70	20	29	19–40
Total	**87**	**22**	**25**	**17–35**	**84**	**36**	**43**	**33–54**	**171**	**58**	**33.9**	**27.5–41.3**

B (Births), M (Mortalities), C (Cumulative Incidence), CI (Confidence Interval)

Table 3
Dogs' source of food and veterinary care.

Outcome	Percent of dogs			
	Total (n = 162)	Malama (n = 31)	Mnkhanya (n = 68)	Nsefu (n = 63)
Garbage	87.7	77	94	81
Scavenging	70.4	58	71	76
Game meat	67.3	71	57	76
Faecal	41.4	23	57	33
Veterinary care	11.1	3	24	2
Vaccinated	8.6	0	3	19
Dewormed	6.2	0	9	6

no dog in the cohort had an up-to-date rabies vaccination, the majority were burdened with ectoparasites, and many were not dewormed and passed adult worms in their stool. As a benefit to the participating households, this study provided free dewormers and rabies vaccines to each dog in the cohort.

3.3. Dog interactions with other animals

Interviews showed that conspecific, livestock, and wildlife interactions were widespread across all chiefdoms. Conspecifics caused minor injuries during fights, sexually transmissible venereal tumours, and rabies, whilst wildlife (mainly primates and carnivores) caused severe injuries and mortalities. We observed that most dog owners did not treat or seek veterinary attention for injured dogs (i.e., Fig. 2). Over 80 % of the dogs had regular wildlife contact. Dogs in Malama experienced the highest wildlife interactions compared to other dogs in the cohort ($p < 0.0001$).

3.4. Causes of morbidity and mortality

During the six months study period, 40 (24.7 %) dogs in the cohort were completely lost to follow-up (31 mortalities and 9 relocations) while 122 dogs completed the study. Twenty-nine dogs were lost between June and September (24 mortalities and 5 relocations), and 11 were lost between September and December (7 mortalities and 4 relocations). Altogether, the cohort contributed 447 dog-months of follow-up from June to September, 784 dog-months from September to December, and 832 dog-months from June to December 2018. According to the dog owners, the main causes of mortalities were poor health (58.1 %), predation by wild carnivores (29 %, all encountered in Malama chiefdom), and owner culling or euthanasia (12.9 %). The median ages of dogs that died from poor health were (24 ± 18, range of 4–72 months), predation (18 ± 10, range of 10–36 months), and owner culling (42 ± 53, range of 24–156 months). When asked about seasonality, most dog owners indicated that disease occurrence in dogs was commonest in the hot season ($p < 0.0001$). Physical examinations and laboratory findings indicated that dogs in our cohort were burdened with infectious agents (mainly parasites) and injuries (Table 4). We observed that corneal opacity (blindness) and trypanosomes increased from the hot to the rainy season.

Fig. 2. Severe injuries caused by wildlife (vervet monkey) interaction on a female dog.

4. Discussion

Our study suggests that parasitic infections, injuries mainly caused by wildlife attacks, and ectoparasites, were among the primary causes of canine morbidity and mortality in Mambwe district. Similar results of infectious diseases (46.1 %), owner culling (30.8 %), and attacks by baboons (23.1 %) were observed in Ugandan rural dogs (Hyeroba et al., 2017).

Dogs in our study were poorly fed, and this encouraged foraging at garbage sites for any available food including faeces and decomposing carcasses. Comparable behaviour was seen in Zimbabwean dogs that supplemented 87% of their diet by scavenging on domestic and wildlife carcasses and consuming human faeces (Butler et al., 2018). By so doing dogs in Zambia get exposed to various helminths (Bwalya et al., 2011;

Table 4
Factors contributing to cohort morbidities and mortalities.

Factors	Start (n = 162)	1st Follow-up (n = 133)			2nd Follow-up (n = 122)			Overall Follow-up (n = 162)		
	Prev	C	IR[γ]	95% CI	C	IR[δ]	95% CI	Prev	IR[φ]	95% CI
Helminths[a]	69.8	13	2.9	1.7–4.9	7	0.9	0.4–1.8	82.1	2.4	1.6–3.7
Injuries	49.4	16	3.6	2.2–5.7	27	3.4	2.4–5.0	75.9	5.2	3.9–6.9
Hemoparasites[b]	54.9	10	2.2	1.2–4.1	18	2.3	1.5–3.6	72.2	3.4	2.3–4.8
Anaemia	29.0	36	8.1	5.9–11.0	22	2.8	1.9–4.2	64.8	7.0	5.4–8.9
Ectoparasites	37.0	8	1.8	0.9–3.5	21	2.7	1.8–4.1	54.9	3.5	2.4–5.0
Mortality[c]	0.0	24	5.4	3.6–7.9	7	0.9	0.4–1.8	19.1*	3.7	2.6–5.2
Emaciation	13.0	6	1.3	0.6–2.9	1	0.1	0.0–0.7	17.3	0.8	0.4–1.7
Blindness	0.6	6	1.3	0.6–2.9	4	0.5	0.2–1.3	6.8	1.2	0.7–2.2

n (number of dogs), Prev (Prevalence), C (number of new cases), IR (incidence rate per 100 dog-months), [γ] (447 dog-months), [δ] (784 dog-months), [φ] (832 dog-months),* (also cumulative incidence of mortalities during June to December), [a]Helminths included cestodes (66 %), hookworm (62 %), *Trichuris vulpis* (12 %), Strongyloides (5 %), schistosomes (4 %), and *Spirocerca lupi* (4 %), [b]Haemoparasites included *Trypanosoma spp* (62 %), *Hepatozoon* (12 %), Microfilariae (3 %), and *Babesia* (1 %).

Nonaka et al., 2011; Bruce-Miller and Goldová, 2016; Banda et al., 2020).

The evidence of hemoparasites, particularly *Trypanosoma* species that cause AT, suggests that dogs were exposed to infectious tsetse bites within their tsetse-infested localities (Lisulo et al., 2014). The risk of AT was further exacerbated by the widespread consumption of fresh raw game meat and bones in all chiefdoms, which is potentially spread through oral lacerations (Moloo et al., 1973; Raina et al., 1985; Rjeibi et al., 2015). One of the prominent features of AT in dogs is corneal opacity (Matete, 2003; Lisulo et al., 2014) which increased in the hot season onwards, and such dogs in our cohort were unremorsefully euthanized by their owners.

Almost 90 % of dogs in our cohort had no access to veterinary services. Such dogs die prematurely as demonstrated in communal lands of Zimbabwe (Butler and Bingham, 2000), rural western Uganda (Hyeroba et al., 2017), and southern Zambia (Bruce-Miller and Goldová, 2016). Previous studies in Mambwe district have shown that some dog-keepers did not seek veterinary services on the assumption that injections given to dogs reduced their hunting abilities, or that wildlife authorities connive with veterinary staff to cull dogs by injecting them with poisonous drugs (Lisulo et al., 2014). In another study that we conducted to assess the knowledge, attitudes, and practices of dog-keeping communities regarding the presence of tsetse flies and AT in Mambwe district, dogs were ranked as the least important animals, and consequently, those with diseases or injuries were left to undergo self-recovery (Unpublished data). This negligent behaviour was confirmed by the severity of injuries that were left untreated for several days (Fig. 2).

We observed that dogs in our cohort were not spayed or castrated nor confined to control the rate of reproduction. Dog owners suggested that transmissible venereal tumours, which are widespread among Zambian free-roaming dogs (Nalubamba, 2015), and rabies were common. Rabies in Zambia is maintained and transmitted by domesticated dogs (principal vectors) during the cold and rainy seasons when most dogs tend to mate (Munang'andu et al., 2011). However, only 8.6% of the dogs in our cohort had previous rabies immunisations. Such low levels of vaccination have been reported elsewhere in Nyimba district, eastern Zambia where 8.7 % of the dog population was vaccinated (Mulipukwa et al., 2017). Experts recommend that at least 70 % of the dog population must be vaccinated to prevent rabies epidemics and that anything below 30 % is ineffective (Lembo et al., 2010).

Although we did not test for viral infections, the lack of vaccination in our dog cohort increases their susceptibility to rabies (Munang'andu et al., 2011; Muleya et al., 2012; Kaneko et al., 2021), canine parvovirus (Saasa et al., 2016; Kapiya et al., 2019), and canine distemper virus (Berentsen et al., 2013), which are all endemic in Zambia, and we suspect that the situation might be the same in the Mambwe district canine population.

5. Conclusion

The findings from this study suggest that the general well-being and survival of indigenous dogs in Mambwe district are largely influenced by their environment. Infectious diseases, injuries sustained during interaction with conspecifics and wildlife, as well as community attitudes and practices associated with dog ownership were the main drivers of morbidity and mortality. Dogs lacked basic home and veterinary care, they were often starved and burdened with ticks, and some passed live adult worms in their stool. Dog exposure to tsetse bites and the consumption of fresh raw game meat and bones puts them at greater risk of acquiring AT. Although dogs thrived daily in tsetse-infested environments, the occurrence of AT in dogs was never prioritised among dog keepers.

Ethics

Ethical approval for this study was granted by the University of Zambia Biomedical Research Ethics Committee and the National Health Research Ethics Board under reference number **016–02–18**. Further permission was sought from traditional leaders to conduct research within their chiefdoms and participants gave informed consent to participate in this study.

Funding

This study was funded by the Commonwealth Scholarship Commission. The funders had no role in the study design, data collection, analysis, decision to publish, or preparation of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We are thankful to all the study participants and the staff at Kakumbi Tsetse and Trypanosomiasis Research Station in Mambwe district who were involved in this research for their assistance and cooperation.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2023.105969.

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