Tanzania Veterinary Journal

(The Tropical Veterinarian)

Volume 30, Number 1, 2015 ISSN 0856 - 1451

Rabies trends and surveillance capabilities in Zambia

J. Kabaso[1], S.I. Kimera[1], J.B. Muma[2] and A.M. Lupindu[1]

[1]Department of Veterinary Medicine and Public Health, Sokoine University of Agriculture, P.O. Box 3021, Morogoro, Tanzania, [2]The University of Zambia, Faculty of Veterinary Medicine, Department of Disease Control, P.O. Box 32379, Lusaka, Zambia
Email: kabasojones2009@gmail.com

SUMMARY

The main objective of this study was to assess the trends, distribution and positivity rate of rabies cases in Zambia. A retrospective study for the period of 10 years between 2004 and 2014, was conducted by using rabies case reports. The data were analyzed with descriptive statistics and geo-coded in Quantum Geographical Information System (QGIS) with the help of shape files. The geo-referenced data were then used to map the trend and spatial distribution of the disease on maps in a Geographical Information System (GIS) platform. The findings showed that 61.5% (462/751, 95% CI=57.9- 65.0) of the samples were positive. Canines accounted for 81.6% (95%, CI=77.7- 85) of the total positive samples followed by Bovines 9.1% (95%, CI= 6.7- 12.2). A mean monthly occurrence of canine rabies was 2.9. The average provincial positivity rate was 0.7. Positivity rates equal to or closer to one indicate poor surveillance; with rates equal to or closer to zero indicate good surveillance. One on one in-depth interview was conducted with one officer from each of these institutions i.e. The University of Zambia (UNZA), National Livestock and Epidemiological Information Center (NALEIC) and Central Veterinary Research Institute (CVRI) in order to familiarize with the current rabies surveillance systems in Zambia. The findings were that; sample submission is done by veterinarians and livestock officers and only UNZA and CVRI have capability for rabies diagnosis with NALEIC as a data storage institution. Rabies is endemic in Zambia and the dog is maintenance host for the disease in human and livestock populations. Therefore, controlling rabies in dogs indirectly overcomes the problem in human and livestock.

Keywords: Zambia, rabies, endemic, positivity rate, surveillance

INTRODUCTION

Rabies is an infectious zoonotic viral disease caused by *Rhabdovirus* of the genus *Lyssavirus* that causes acute encephalomyelitis and is transmitted via bites from a rabid animal. It is one of the world's oldest recorded infectious diseases (OIE, 2014) with most outbreaks attributed to dog-bite cases resulting in 59 000 human deaths per year worldwide (Hampson *et al*., 2015). Infection through inhalation of the virus has been documented, for example, in the environment of densely populated bat colonies in caves (OIE, 2014). The animals which are mainly reported to be main sources of rabies include dogs, raccoons, skunks, bats and foxes (Yousaf *et al*., 2012). Rabies in Zambia is endemic with an average monthly occurrence of canine rabies of 2.9 (95% CI=2.6 -3.3) (Munang'andu *et al*., 2011). Zambia has 10 provinces, with Lusaka Province reporting the highest number of outbreaks (Munang'andu *et al*., 2011).

Central Veterinary Research Institute (CVRI) is the government's main rabies diagnostic and research center in Zambia, processing rabies samples countrywide.

The University of Zambia (UNZA) receives rabies samples countrywide for research and diagnosis. Fluorescent Antibody Test (FAT) is the main diagnostic tool for the confirmation of rabies. Molecular techniques, such as the polymerase chain reaction (PCR), are easier and more reliable (Muleya *et al*., 2012). These methods however have not yet been established in Zambia due to the fact that they are expensive and need specialized manpower, especially in rural areas (Muleya *et al*., 2012) make it difficult to adopt them.

Control of canine rabies can only be achieved by mass dog rabies vaccination and improved local capacity in rabies surveillance (Lembo *et al.*, 2010). In Zambia, there is no official rabies control program. Therefore, a reactive approach is often adopted in rabies control, whereby domestic animals are only vaccinated against rabies in areas where outbreaks have occurred. This approach makes it difficult to eliminate the disease in Zambia. Control of wildlife rabies can be achieved by Trap-Vaccinate and Release (TVR) method, euthanasia of infected animals in Point Infection Control (PIC) method (Rosatte *et al.*, 2009) and use of vaccine baits.

Analysis of reported rabies data from African countries identifies major discrepancies that are indicators of poor surveillance (Nel, 2013). Data management is still a challenge, especially in African countries (Nel, 2013). Dog-bites and rabies are under-reported in developing countries as such, there is a poor understanding of the disease burden (Zaidi *et al*., 2013) and this poses a challenge in designing effective control methods.

MATERIALS AND METHODS

Study area

A retrospective study was conducted in Zambia which is located south of the equator in South-Central Africa. It has a total area of 752,618 sq km and a human population of 14,638,505 (CIA, 2013). Zambia has an estimated dog population of 483,628 (Muleya *et al*., 2012) and cattle population of 3,932,217.

Study Designs

A retrospective study was conducted in which analysis of rabies reports for the period 2004-2014 was done. A case in this study was defined as a submission of a rabies sample for diagnosis along with the outcome of the diagnosis from CVRI or UNZA. The study was developed using data from National Livestock Epidemiological Information Center (NALEIC), CVRI and UNZA which covered diagnosis of animal rabies and animal populations for the period 2004 to 2014 in Zambia. The variables collected for the study were animal species, sex, year, month, location and the rabies test results. Only animal populations were obtained from NALEIC.

The data was then geo-referenced using Quantum Geographical Information System (QGIS 2.2.0, Boston, USA) and digital map files (shape files) from The Central Statistic Office (CSO), with geo-political and administrative boarders for Zambia. The rabies surveillance database in Geographical Information System (GIS) platform was then used to map distribution of the disease and the trends (Oviedo-Pastrana *et al*., 2015). Familiarization with the current rabies surveillance strategies was achieved by conducting one on one in-depth interview with experts from CVRI, UNZA and NALEIC.

Data analysis

All quantitative data was entered in excel spread sheets and analyzed using Epi Info (Epi Info™ 7.1.5.0, Atlanta, GA USA). Analysis of trend was performed by descriptive statistics in which proportions, positivity rates, frequencies and means during the period under review for the various provinces in Zambia were determined. Other measures such as incidence of rabies at species level were calculated for the study period for all the provinces in Zambia.

The level of reporting of rabies surveillance data was measured from the positivity rates of individual provinces in Zambia. Those with positivity rates equal or close to one express less surveillance actions, and values equal or close to zero indicate an increase in surveillance activities (Oviedo-Pastrana *et al*., 2015).The different measures were demonstrated by plotting of charts, graphs and tables. Spatial analysis was performed on the maps generated by QGIS2.2.0 in Epi Info™ 7. Using Spearman's correlation coefficient, the correlation of dog rabies occurrence and human population density for all the provinces in Zambia was determined at 5% statistical significance and confidence interval calculated.

RESULTS

Trend analysis

The Rabies surveillance found that, of the 751 samples submitted to CVRI and UNZA during the period under review, 462 equivalent to 61.5% (95% CI= 57.9-65.0) were positive (Table 1 and 2). The year 2004 recorded the highest rabies cases which were 60 of 91 samples submitted and the year 2014 recorded the lowest cases out of 35 samples 14 were positive. In general, there has been a decline in the number of rabies reported cases in Zambia (Figure 1). This decline was more evident during the periods 2004 to 2007. A slight increase in the number of cases was reported in 2008 but this again was followed by reduction in rabies occurrence till the end of the study (Figure 1).

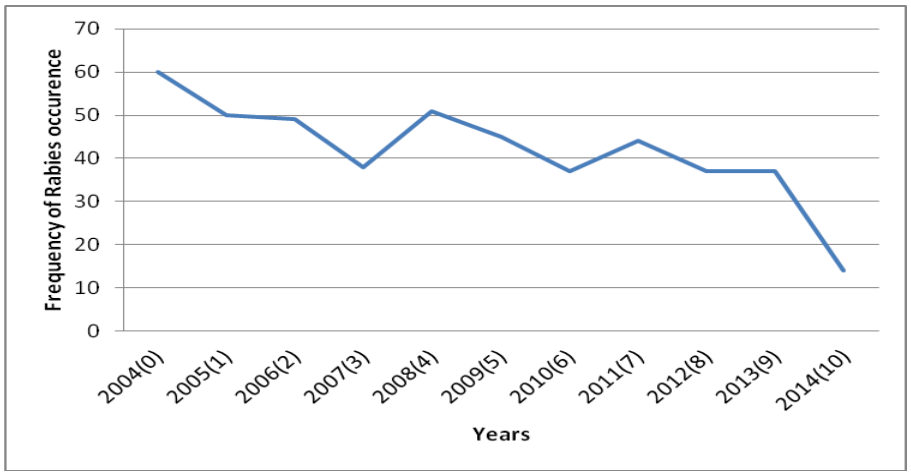

Figure 1. Rabies occurrence in Zambia (2004 to 2014)

Table 1. Provincial rabies distribution and positivity rates (2004 to 2014)

Province	2004 (n/N)	2004 (n/N)	2004 (n/N)	2004 (n/N)	2004 (n/N)	2004 (n/N)	2004 (n/N)	2004 (n/N)	2004 (n/N)	2004 (n/N)	2004 (n/N)	Positivity rate (n1/N1)
Lusaka	33/52	17/33	21/45	15/37	17/37	25/41	14/25	8/15	14/20	7/14	3/5	174/324
Central	11/15	12/17	10/21	13/18	12/14	10/11	8/10	18/21	6/13	2/6	1/3	103/149
Copperbelt	4/6	8/13	9/12	2/3	3/5	3/3	5/7	5/6	2/6	6/8	3/6	50/75
Northern	0	2/2	2/3	0	2/2	0	0	3/4	4/5	1/1	0	14/17
N/Western	0	1/1	0	3/5	1/1	0	1/2	1/1	1/1	2/3	0/3	10/17
Southern	12/17	9/12	5/9	5/8	7/7	4/6	6/10	6/11	5/6	11/15	4/8	74/109
Western	0	1/1	0	0	3/5	1/4	2/2	2/3	1/2	1/3	0/2	11/22
Eastern	0/1	0/1	1/1	0/1	4/5	1/0	1/1	1/2	1/3	5/5	1/3	14/23
Luapula	0	0	1/1	0	2/2	2/2	0	0	3/3	1/1	1/4	10/13
Muchinga	0	0	0	0	0	0	0	0	0	1/1	1/1	2/2
Total	60/91	50/80	49/92	38/72	51/78	45/67	37/57	44/63	37/59	37/57	14/35	

N;Total samples for that year. n; Total positive cases that year. N_1; Total provincial samples n_1;Total provincial positive cases

Provincial rabies distribution

Lusaka province had the highest number of samples submitted amounting to 43.1% (324/751) of the total samples, followed by Central province with 19.8% (149/751) and Southern province was third with 14.5% (109/751) (Table 2). Muchinga province had the least number of samples submitted but also had highest positivity rate of one. Western province had the lowest positivity rate of 0.5 and the average positivity rate for all the provinces was 0.7 (Table 2 and Figure 2).

However, Lusaka province had the highest number of positive cases amounting to 174 followed by, Central province with 103 and Southern province was third with 74. Dog rabies was highest in Lusaka province with 126 cases, followed by Central province with 93 and Southern province was third with 68 (Table 3).

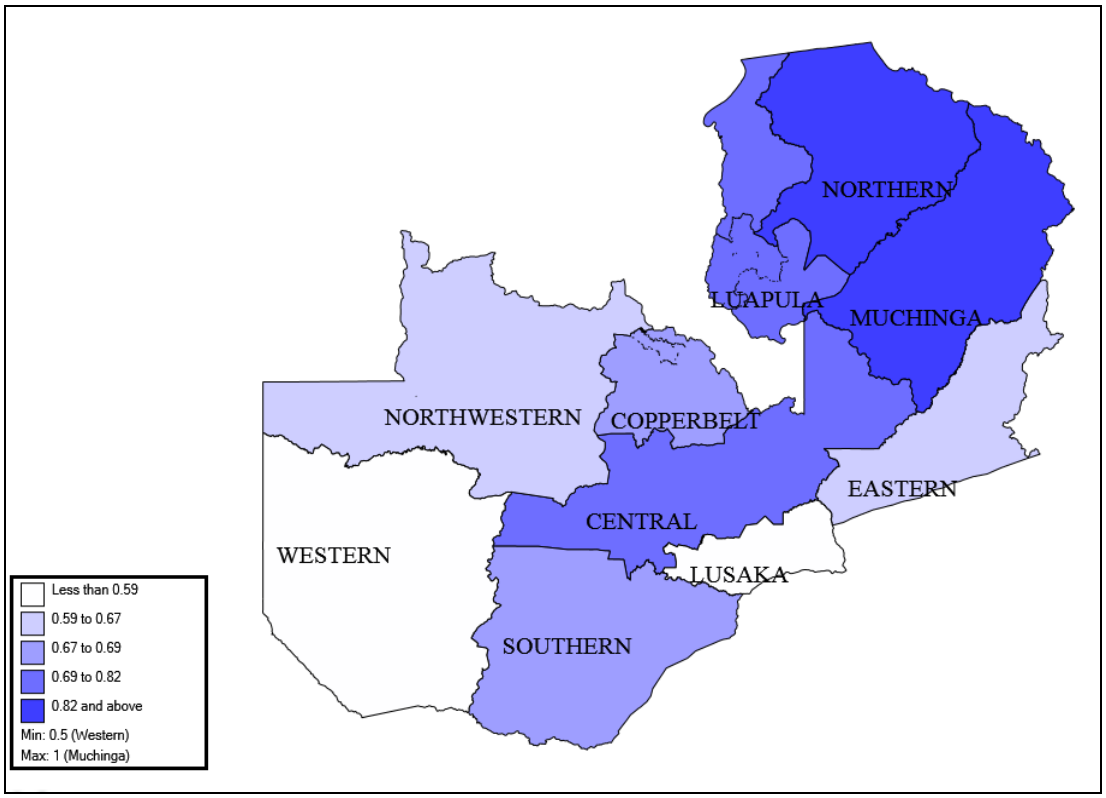

Figure 2. A map of Zambia showing positivity rates of rabies cases for all the provinces for the period 2004 to 2014.

Table 2. Provincial rabies distribution (2004 to 2014)

Province	Samples	Positive	Proportion of samples (%)	Positivity rate
Copperbelt	75	50	9.99	0.67
Central	149	103	19.84	0.69
Lusaka	324	174	43.14	0.54
Northern	17	14	2.26	0.82
Southern	109	74	14.51	0.68
Western	22	11	2.93	0.50
N/western	17	10	2.26	0.59
Luapula	13	10	1.73	0.77
Eastern	23	14	3.06	0.61
Muchinga	2	2	0.27	1.00
Mean	75.10	46.20	10.00	0.69
Max	324	174	43.14	1.00
Min	2	2	0.27	0.50
Total	751	462	100.00	

Rabies distribution in dogs and others species

Canine rabies was the highest and accounted for 81.6% (591/751) (95% CI=77.7 - 85.0) of the total positive samples followed by Bovine rabies 9.1% (61/751) (95% CI=6.7- 12.2). Figure 3 demonstrates how widely distributed canine rabies was during the period under review. A monthly mean occurrence of Canine rabies was 2.9 for the period under review. Dog rabies occurrence was highest in September with 41 cases followed by May and August each with 39 cases during the period under review (Figure 4). Canine rabies and general species distribution data are presented in Tables 3 and 4 respectively. Feline rabies accounted for 2.2% of the total positive samples, while wildlife accounted for 2.0% and human rabies was 0.2%. A correlation coefficient of r= 0.31 (p=0.42) was calculated using the Spearman's rank correlations between the provincial human population density and canine rabies (Table 3).

Table 3: Canine rabies (2004 to 2014) and human population density 2010 census

Province	Canine rabies (rank)	Human population density (rank)
Copperbelt	40 (4)	62.5 (2)
Central	93 (2)	13.4 (6)
Lusaka	126 (1)	100.4 (1)
Northern	14 (5)	11.9 (7)
Southern	68 (3)	18.8 (5)
Western	10 (6)	7 (8)
N/western	9 (7)	5.6 (9)
Luapula	9 (7)	19 (4)
Eastern	8 (8)	24.6 (3)
Total	377	17.3

Rabies surveillance systems in Zambia

Rabies samples for diagnostics are collected and delivered to CVRI and UNZA by Veterinary Surgeons, Veterinary Assistants (VAs) and Livestock Officers. No diagnostic work is done at NALEIC only suspected clinical cases are reported and stored in the Laboratory Information System. The test done for confirmation of rabies at CVRI is FAT and for UNZA it is Direct Florescence Antibody Testing (DFAT) and PCR. Data storage at UNZA is by entry into a laboratory note book and the results reported back to the client and no analysis of rabies data is done just like at NALEIC and CVRI. At CVRI data is entered in a Laboratory Information System (SILAB) and results reported back to the client.

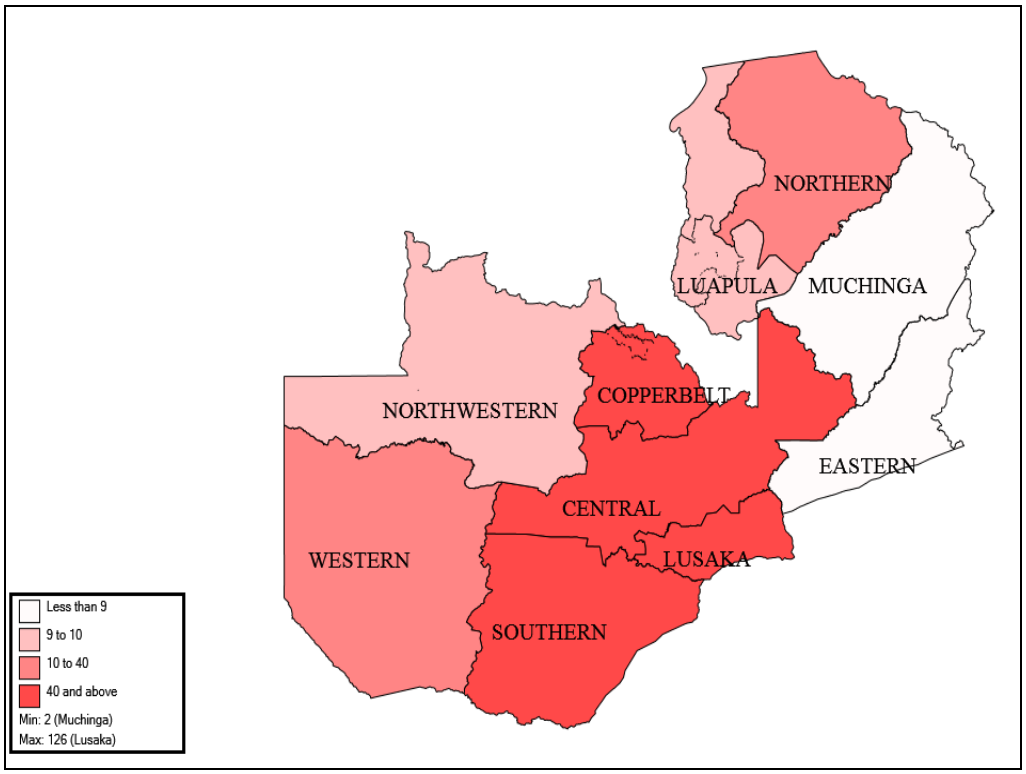

Figure 3. Canine rabies distribution for the period 2004 to 2014 in Zambia

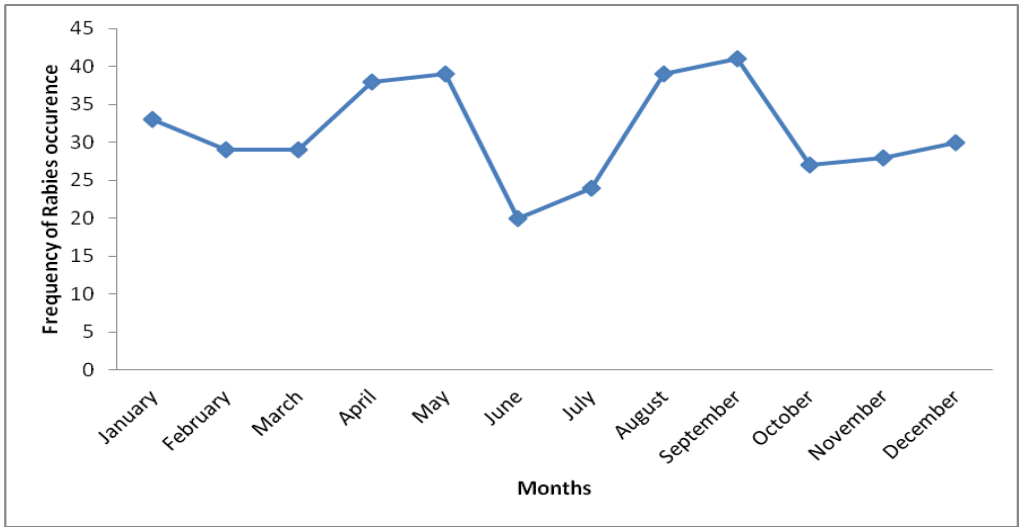

Figure 4. Monthly Canine rabies occurrence in Zambia (2004 to 2014)

Table 4. Species sample submission and rabies proportions (2004 to 2014)

Animal species	Number of samples	Proportion (%)	Positive cases	Proportion of positive cases (%)	Population
Bat	2	0.3	0	0.0	
Bovine	61	8.1	42	9.1	3,932,217
Canine	591	78.7	377	81.6	218,563
Caprine	7	0.9	4	0.9	3,023,586
Civet	1	0.1	0	0.0	
Equine	1	0.1	1	0.2	
Feline	24	3.2	10	2.2	
Fox	5	0.7	5	1.1	
Human	2	0.3	1	0.2	13,256,260
Jackal	4	0.5	3	0.7	
No species	42	5.6	15	3.3	
Ovine	1	0.1	0	0.0	219,296
Porcine	5	0.7	3	0.7	1,515,790
Primate	3	0.4	1	0.2	
Rabit	1	0.1	0	0.0	
Raccoon	1	0.1	0	0.0	
Total	751	100	462	100	

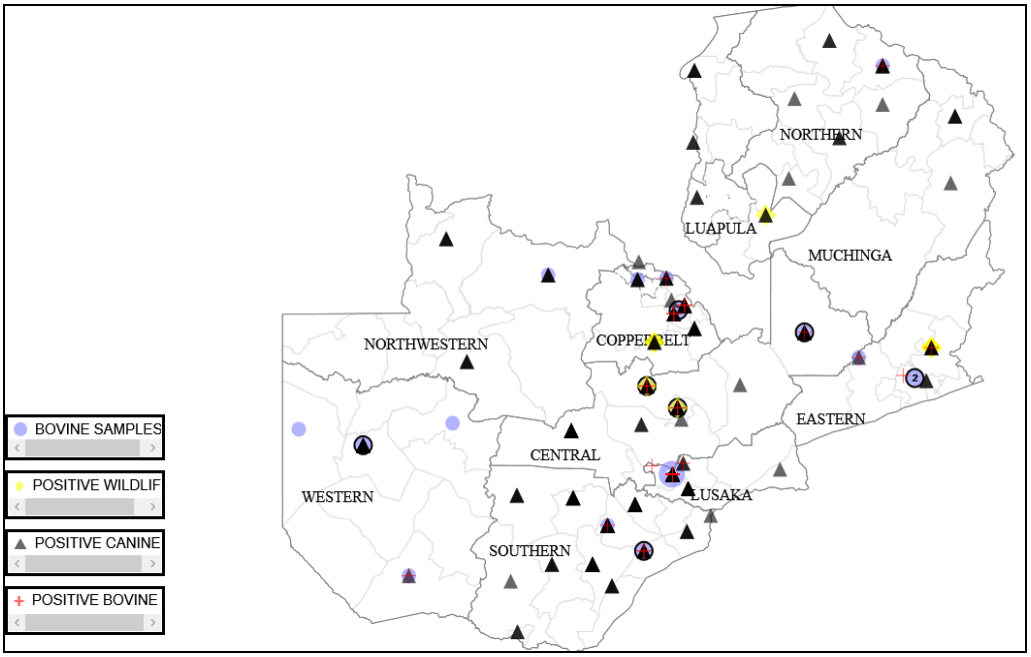

Figure 5. A map of Zambia demonstrating the distribution of Bovine, Jackal, Fox and Canine rabies for the period 2004 to 2014

DISCUSSION

Rabies trend analysis in Zambia during the period under review observed an increase in sample submission and positive cases in urbanized provinces of Lusaka, Central, Southern and Copperbelt provinces. This can be attributed to easy access to the laboratory facilities and adequate trained manpower (Munang'andu *et al*., 2011). Commemoration of the World Rabies Day, international day on rabies disease awareness, is observed in the cities and this increases awareness among people in these areas. Muchinga Province had the lowest number in terms of rabies sample submission and also positive cases attributed to long distance to CVRI. This province, which was previously part of Northern Province until 2012, is the most recent province in the Country. Therefore, the recorded number of submitted cases and positivity rate may not reflect the real situation on the ground. Rabies in Zambia is a notifiable disease (GRZ, 2010). However, there are official control programs for control of rabies by The Government, through a statutory instrument, which has designated the disease as "a management disease" (GRZ, 2014). By definition, "a management disease" is a disease for which the Government has no policy of official control. Control of such a disease is assumed to be the responsibility of the owner of the animal. This implies that, prevention of rabies is to be undertaken by the owners of the animals and this has also contributed to the high incidence of the disease as some people can either not afford to vaccinate their dogs or are ignorant about rabies control. Few samples reached the laboratory decomposed and these amounted to about 3% (20/751) of the total samples. Provincial distribution of these samples did not give any reasonable pattern and can likely be attributed to late engagement of veterinary officers since most if not all veterinary offices have fridges to maintain the cold chain.

Dog rabies is widely distributed in Zambia as it has been demonstrated in Table 4 and Figure 3. These findings coincides with earlier studies conducted in Zambia by Munang'andu *et al*., (2011). There is an observed reduction in the monthly canine rabies occurrence of 2.86 cases per month compared to an earlier study by Munang'andu *et al*. (2011) which was 2.93. This reduction can be attributed to the increase in the number of Veterinary Surgeons in the country that are graduating at UNZA every year and also commencement of rabies vaccine production at CVRI. There is a gradual increase in dog rabies occurrence starting from June and droping in October (Figure 4). This could have been attributed to the increase in interaction between the dogs during mating season (Gavrilovic *et al*., 2008; Munang'andu *et al*., 2011). A positive correlation was found between dog rabies and human population density to be r=0.31 (p=0.42) implying an increase in human population gives an increase in dog rabies due to the dependancy of dogs on humans for food (FAO, 2011; Munang'andu *et al*., 2011). However, provinces like Copperbelt with relatively high population density have relatively lower dog rabies. This is due to the increase in private veterinary practices and more importantly the support rendered by the mines to provide free annual rabies vaccinations for dogs in the Copperbelt. Proactive annual rabies vaccination is key to elimination of rabies according to studies conduted by Hampson *et al*. (2015) in Tanzania. Under reporting is a big problem in most low income countries like Zambia (Hampson *et al*., 2015) hampering efforts for control of rabies. For rural provinces like Luapula, communities take it upon themselves and kill rabies

suspected dogs without reporting to the DVO in the area.

From Table 4, it has been demonstrated that Bovine is the highest interms of sample submission and positive samples amongst livestock amounting to 8.1% and 9.1% respectively. This was the case even in earlier studies conducted by Munang'andu *et al*., (2011). Dogs are the major transmitters of rabies to cattle in relation to jackals and foxes as it can be demonstrated in Figure 5. All the areas with Canine rabies have Bovine rabies but this is not the case with wildlife, this pattern is the same as observed in an earlier study by Munang'andu *et al*. (2011). However, areas with wildlife rabies have canine rabies bringing up another possibility that wildlife is the reservior of rabies which is then maintained in livestock and human populations by dogs. The Agriculture sector contributes 21.5% to the Gross Domestic Produce (GDP) of Zambia of which 28% of the Agricultural GDP come from Livestock subsector (ADF, 2013). From this study, it can be percieved that rabies is a disease of economic importance due to the large number of animals lost by farmers during the period under review from the disease. Therefore, there is need for the government to increase funding in the control of the disease in efforts to diversify the economy from copper export dependance to other areas like livestock and agriculcture. However the economic loses incured due to the disease have not been quantified in this paper and this can be taken up as another study.

Rabies surveillance systems in Zambia are poor as can be potrayed by the average positivity rate for all the provinces which is at 0.7. Lusaka and Western provinces have relatively lower positivity rates compared to other provinces (Table 2), implying better rabies surveillance. However, this can not be conclusive for Western province which has low sample submission indicating poor surveillance. Lusaka province has diagnostic facilities within reach and private veterinary practices and these factors help for better surveillance of the disease. Rural provinces like Luapula, Northern and Muchinga have very high positivity rates (Table 2 and Figure 2) indicating very poor surveillance. This can be attributed to long distance to CVRI for rabies diagnosis and under staffing of veterinarians. Urbanised provinces like Copperbelt,Central and Southern provinces have relatively lower positivity rates (Table 2) compared to rural provinces due to adequate veterinary staffing levels and nearness to CVRI.

In Zambia rabies data is reported at the national level to NALEIC by the Provincial Vetrinary Officer (PVO) and District Veteriary Officer(DVO), however this data is entered as clincal rabies data. Therefore there is need to come up with an online system that will link NALEIC system to CVRI system in order to be able to track samples from the field till their confirmation. As observed by Wahl *et al*. (2012) this system has been found to be very effective for dissemination of near real time data to approprate organiazations due to the fact that all the key players in disease surveillance are all included in the system. To avoid possibilities of double entries from the district and province, system development should have three lavels of data entry. Such levels should include district, province and national level as reported by Wahl *et al*. (2012) about the structure of Electronic Intergrated Disease Surveillance System (EIDSS) which was deployed in Azerbaijan, Kazakhstan and Georgia. Digital pens could be used as hand held gadgets at district level due to their efficiency in data transfer in near real time as observed by FAO, (2014) in Kenya on reporting of Livestock diseases. It is

also important to train the field staff in this case Veterinary Surgeons, Veterinary Assistants and Livestock Officers on the use of the digital pen and also what kind of data is required for them to collect in order to avoid collection of useless data (Lewis and Chretin, 2008). District Veterinary Offciers (DVOs) should also sensitize the private veterinary practitioners about their need to report disease surveillance data to their offices on a monthly basis and immediately in case of notifiable diseases like rabies for immediate action. This has not been the case by most private veterinary practitioners leading to loss of a huge amount of disease surveillance data.

The province must have an epidemiological section which can be mandated for receiving disease surveillance data from both the district and the regional laboratory and then report to NALEIC, this is not the case at the moment. Some provinces have regional laboratories, though most of them are not functional to full capacity. Therefore, there is need to make these regional laboratories functional in order to improve on rabies surveillance and control (Townsend *et al*., 2013). Reliance on CVRI leads to under reporting due to eratic funds for disease surveillance since samples can only be delivered to CVRI if funds are available. Timely analysis of rabies data should be performed with statistical software on a quarterly and annual basis by NALEIC.

In conclusion, rabies is endemic in Zambia with a monthly occurrence of 2.9 canine cases for the period under review. Rabies surveillance is poor in Zambia with an average positivity rate of 0.7 for all the provinces during the review period. Further studies should be conducted to ascertain the magnitude of rabies in human populations and also how many animal contacts results from a single human dog bite case as this can also act as an important variable to assess surveillance of rabies.

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to INTRA-ACP Mobility project (Grant N^{o} 2012-3166) for financial support which made it possible for me to carry out this research. I also acknowledge the contributions of Dr Paul Fandamu, Chief Veterinary Officer at the Central Veterinary Research Institute, Lusaka, Dr. Martin Simuunza, Head of Department in Disease Control at the School of Veterinary Medicine at The University of Zambia, Mr. Aaron Phiri of Central Statics Office and Dr. Ceasar H. Lubaba of NALEIC who provided secondary data.

REFERENCES

African Development Fund (ADF). Livestock Infrastructure Support Project: Project Preparation Facility, 2013. http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Zambia_Preparation_activities_of_the_Livestock_Infrastructure_Support_Project_-_Appraisal_Report.pdf. Site visited on 22/01/2016.

Central Intelligence Agency (CIA). The World Factbook. https//www.cia.gov/library/…/the-world-factbook/…/countrypdf_za.pdf. Site visited on 02/07/2015.

Food and Agriculture Organisation (FAO). Digital pen technology a case study in Kenya. www.fao.org/emergencies. Site visited 19/01/2016.

Gavrilovic BB, Andersson K, Forsberg CL. Reproductive patterns in the domestic dog — A retrospective study of the Drever breed. *Theriogenology* 70: 783–794, 2008.

Government of the Republic of Zambia (GRZ). Chapter 247 the control of dogs act. faolex.fao.org/docs/pdf/zam47317.pdf. Site visited 14/07/2015.

Government of the Republic of Zambia (GRZ). Statutory instrument No. 24 of The Animal Health Act, 2010. http://faolex.fao.org/docs/pdf/zam139130.pdf . Site visited 17/01/2016.

Government of the Republic of Zambia (GRZ). The animal health Act-2010, Zambia. http://faolex.fao.org/docs/pdf/zam102118.pdf . Site visited 17/01/2016.

Hampson K, Coudeville L, Lembo T, *et al*. Estimating the Global Burden of Endemic Canine Rabies. *PLOS Negl Trop Dis* 9(4): 1-20, 2015.

Karunanayake D, Matsumoto T, Wimalaratne O, Nanayakkara S, Perera D, Nishizono A, Kamruddin A. Twelve Years of Rabies Surveillance in Sri Lanka, 1999–2010. *PLoS Negl Trop Dis* 8(10): 1-14, 2014.

Lembo T, Hampson K, Kaare MT, Ernest E, Knobel D, Kazwala RR, Haydon DT, Cleaveland S. The feasibility of canine rabies elimination in Africa: Dispelling doubts with data. *PLoS Neglected Tropical Diseases* 4(2): 1-9, 2010.

Misael EO, Camila FOS, Capanema OR, Nicolino RR, Oviedo-Socarras JT, João Paulo AH. Trends in Animal Rabies Surveillance in the Endemic State of Minas Gerais, Brazil. *PLOS Negl Trop Dis* 9(3): 1-13, 2015.

Muleya W, Namangala B, Mweene A, *et al*. Molecular epidemiology and a loop-mediated isothermal amplification method for diagnosis of infection with rabies virus in Zambia. *Virus Res* 163: 160–168, 2012.

Munang'andu HM, Mweene AS, Siamudaala V, Muma BJ, Matandiko W. Rabies status in Zambia for the period 1985-2004. *Zoonosis Pub Health* 58: 21–27, 2011.

Nel LH. Discrepancies in data reporting for rabies, Africa. *Emerg Inf Dis* 19(4): 529–533, 2013.

Rosatte RC, Donovan D, Allan M, *et al*. The control of raccoon rabies in Ontario Canada: proactive and reactive tactics, 1994-2007. *J Wild Dis* 45(3): 772–784, 2009.

Sheri HL, Chretien JP. The Potential Utility of Electronic Disease Surveillance Systems in Resource-Poor Settings. *Johns Hopkins APL tech dig* 27(4): 366-373, 2008.

Tom GW, Aleksey VB, Andrey OO, Azamat KZ. Electronic Integrated Disease Surveillance System and Pathogen Asset Control System. *Onderstepoort J Vet Res* 79(2): 1-5, 2012.

World Organisation for Animal Health (OIE). OIE Terrestrial Manual for Rabies, 2013. www.oie.int/fileadmin/Home/eng/Health/tahm/2.01.13_RABIES.pdf. Site visited on 14/07/2015.

World Organisation for Animal Health (OIE). Rabies: General Disease Information Sheets. http://www.oie.int/fileadmin/Home/eng/Media_Center/docs/pdf/Disease_cards/ RABIES-EN.pdf. Site visited on 25/06/2015.

Zaidi ASM, Labrique AB, Khowaja S, Lotia-Farrukh I, Irani J, Salahuddin N, Javed AK. Geographic Variation in Access to Dog-Bite Care in Pakistan and Risk of Dog-Bite Exposure in Karachi: Prospective Surveillance Using a Low-Cost Mobile Phone System. *PLoS Negl Trop Dis* 7(12):