International Journal of Public Health, Pharmacy and Pharmacology
Vol. 6, No.1, pp.25-38, 2021
Print ISSN: (Print) ISSN 2516-0400
Online ISSN: (Online) ISSN 2516-0419

EFFECTS OF ROAD NETWORKS AND HUMAN POPULATION DENSITY ON THE RISK OF DOG BITE INCIDENTS AND RABIES IN NIGERIA

Christianah Ibironke Odita[1], *Ishaya Sini Tekki[1], Adigun Abass[2], Israel Joshua Barde[1], Emmanuel Sunday Hambolu[1], Gyang Davou Moses [1], Joseph Alex Davou[1], Yakubu Dashe[1]; Chika Nwosuh[1,] Reuben Ocholi[1]and Maryam Mohammad[1]

1. National Veterinary Research Institute, PMB 01, Vom, Jos, Plateau State, Nigeria

2. National Centre for Remote Sensing, Jos, Nigeria

***Correspondence:** National Veterinary Research Institute, Vom, PMB 01, Vom, Plateau State, Nigeria, ishaya.sinitekki@yahoo.com, +2348036012637

ABSTRACT: *Despite efforts made to curb its spread, occurrence of rabies has continued to persist among domestic dogs in Africa. In this study we report the results of an exploratory spatial analysis and a cross-sectional study of effects of road networks and human population density on the prevalence of dog bites and rabies in Nigeria. A total of 577 dog bite cases from 17 states and the Federal Capital Territory, with their affected 55 administrative areas (2015-2019), were investigated. Logistic regression models were fit to the data and odds ratios at 95% confidence intervals were estimated. There is evidence of statistical relationship between increasing number of standard roadways and human population density, and an increased prevalence of dog bite and rabies in Nigeria. Availability of good access roads either way may contribute to the persistence of rabies in Nigeria due to massive movements of people and dogs in addition to poor attitude of dog owners towards vaccination of their dogs; or poor access to Veterinary care.*

KEY WORDS: road network, human population, dog bite, rabies.

INTRODUCTION

Rabies is an acute viral encephalomyelitis that affects all mammals (OIE, 2008). It is caused by rabies and rabies-related *Lyssaviruses*, in the family *Rhabdoviridae* (Smith, 1996). The disease is found all over the world except in countries and regions with strict quarantine system, conscientious eradication procedures or natural barriers like mountains, oceans and rivers; in addition to regular vaccinations (World Health Organization, 2013). Owing to its close relationship to man (McKenzie, 1993), the role of domestic dogs in the transmission of the virus is very critical as 85-95% of human rabies cases is caused by dog bites (Tang *et al*., 2005).

Dog bites in humans is an important public health concern especially among poor rural dwellers mostly children who are at a greater risk of infection (Ozanne-Smith *et al*., 2001).

Canine rabies, known to be endemic in many parts of Africa and Asia (Knobel *et al*., 2005), Nigeria inclusive (Boulger and Hardy, 1960; Owolodun, 1969), is associated with high rates of human exposure mainly through dog bites (Umoh and Belino, 1979). Although efforts, consisting primarily of mass vaccination of dogs, have been made, the disease continues to persist among domestic dogs. Predictors for disease occurrence are important guide to disease ecology. The capability to identify the roles of human social ecology and landscape features; which are disease predictors, in disease spread, is important for the design of better control programs (Carey et al., 1978; Weiss and McMichael, 2004). Identification of disease predictors have been documented in several studies. Ward *et al*. (2009) identified environmental features such as lakes, forests, and cultivated areas as predictors for Equine West Nile virus disease in Texas. In Romania, road connectivity was found to be associated with occurrence of highly pathogenic avian influenza H5N1 (Ward *et al*., 2008). Similarly, land use and demographic data were used as predictors for raccoon's rabies epizootics in the US (Jones *et al*., 2003). In other studies, locations of residential areas were used as predictors for elevated risk of getting Lyme disease in Baltimore (Glass *et al.*, 1995), while incidence of Ross River virus in Brisbane, Australia was associated with proportion of workers, their educational levels and vegetation density (Hu *et al*., 2007). In an effort to control, prevent and eliminate rabies however, factors associated with continued persistence of the disease need be identified and addressed. This study therefore, investigates if road networks and population density are associated with elevated risk of dog bites and hence rabies in Nigeria.

MATERIALS AND METHODS

Exploratory spatial analysis with ArcMap 10.2.1, in addition to a cross sectional study of dog bite cases (2015-2019), from the records of the National Veterinary Research Institute (NVRI), Vom, was conducted. A total number of 577 dog bite cases with complete information on locations and details of dog bite victims, involving 17 states and the Federal Capital Territory of Nigeria, Abuja (locations), including their affected 55 administrative areas, (Local Government Areas), were isolated. Risk factors considered were human population density and whether the affected administrative areas (AADAs) have standard roadways going through them or not. Dog bite locations were split into two: Category 1, locations with > 10 cases, and Category 2, locations with < 10 cases of dog bites. Logistic regression models were used to establish association between prevalence of dog bites, hence rabies; and increasing presence of standard roadways and high human population density. Welch t-test (Welch, 1951), was used to establish a significant difference in the mean number of dog bite cases in exposed (locations with standard roadways) compared to unexposed (locations without standard roadways) AADAs. Results are presented as graphs, tables and map. Ethical approval for the study was obtained from the Health Research Ethics Committee, Plateau State Specialist Hospital, Jos, Nigeria (Ref. No. NHRECPSSH/ADM/ETH.CO/2019/0), in accordance with the National Code for Health Research Ethics. (Ethical clearance Reg. No. NHREC/05/01/2010b).

International Journal of Public Health, Pharmacy and Pharmacology
Vol. 6, No.1, pp.25-38, 2021
Print ISSN: (Print) ISSN 2516-0400
Online ISSN: (Online) ISSN 2516-0419

RESULTS

The four states with more than 10 dog bite cases each, (Category 1 locations) are presented in figure 1 and are located in the North-east, North-west and North-central regions of Nigeria. Figure 2 presents 13 states and the FCT (Category 2 locations), with less than 10 dog bite cases each and are located in all the six regions of Nigeria. The spatial display of AADAs in both Categories and the standard roadways in these locations are shown in Figure 3.

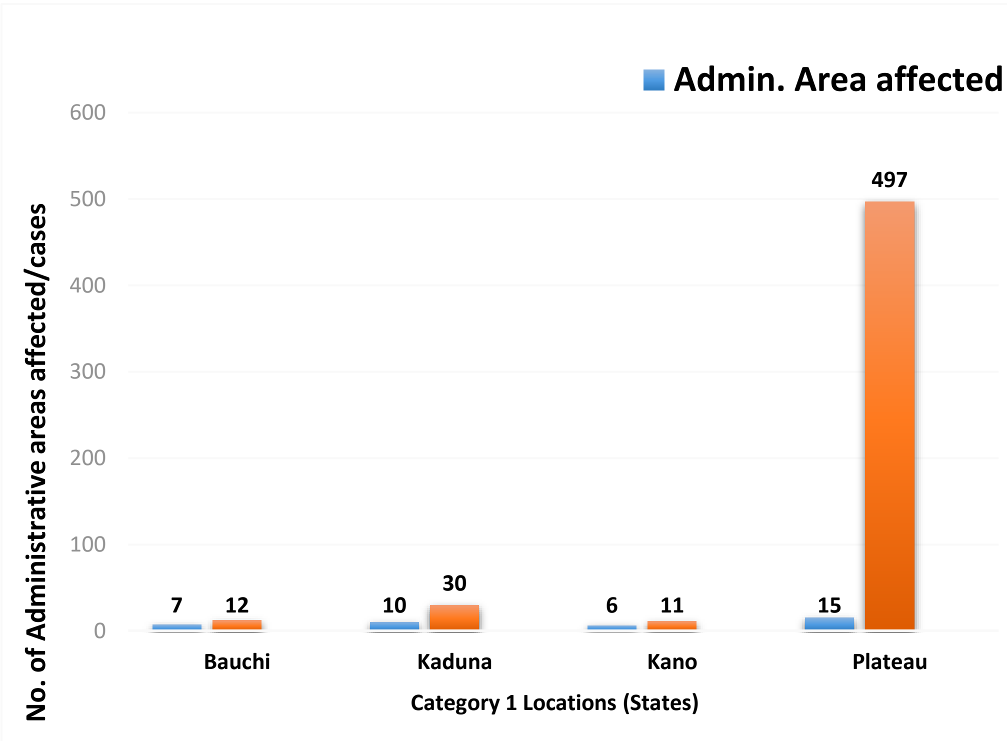

Figure 1: Distribution of dog bite cases and AADAs in Category 1 locations (> 10 cases) in Nigeria (2015 – 2019)

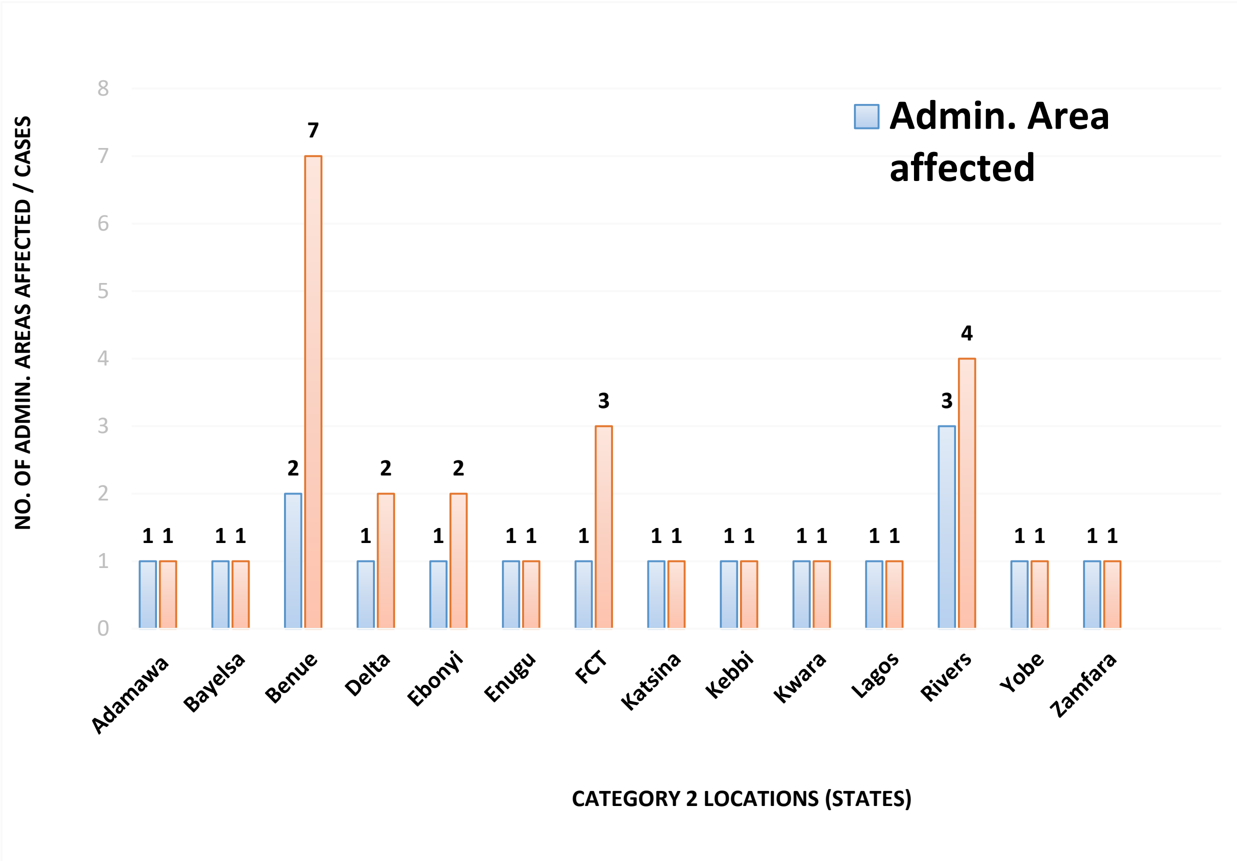

Figure 2: Distribution of dog bite cases and AADAs in Category 2 locations (< 10 cases) in Nigeria (2015 – 2019)

Vol. 6, No.1, pp.25-38, 2021
Print ISSN: (Print) ISSN 2516-0400
Online ISSN: (Online) ISSN 2516-0419

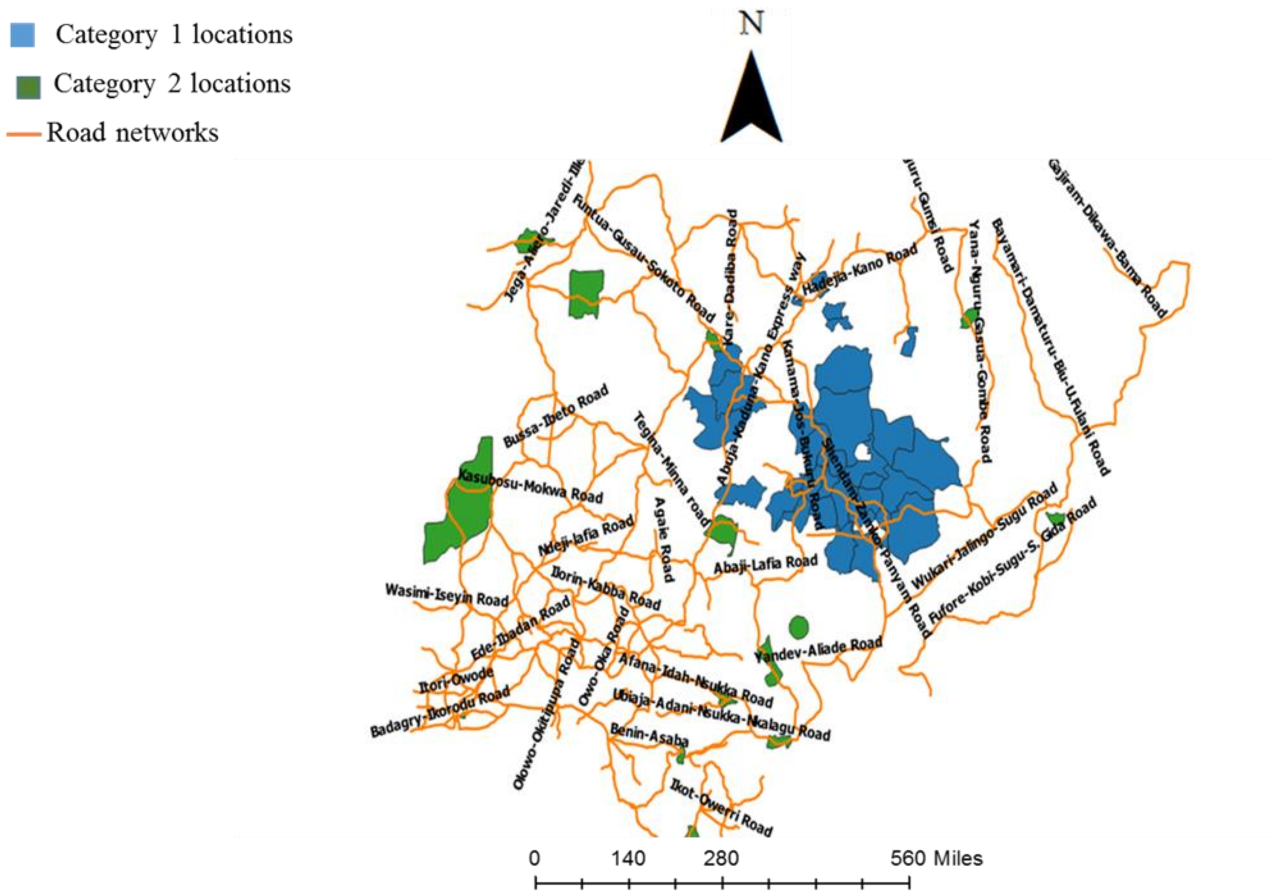

Figure 3: Spatial distribution of road networks and dog bite cases in 55 AADAs of Nigeria (2015-2019)

The total number of AADAs were 55, with 38 (69.1%) in Category 1 and 17 (30.9%) in Category 2 (Table 1). Of the 38 administrative areas in Category 1 locations, 28 (73.7%) had standard roadways while 10 (26.3%) had none. Similarly, 15 (88.2%) of the 17 AADAs in Category 2 had standard roadways while 2 (11.8%) did not have any. Of the 577 dog bite cases recorded in the AADAs in both Categories, 416 (72.1%) were positive while 161 (27.9%) were negative for rabies. There was a total of 399 (96.0%) positive cases in Category 1 and 17 (4.0%) in Category 2. Of the 399 cases in Category 1, 371 (93.0%) were from AADAs with exposure while 28 (7.0%) were from AADAs without exposure. Of the 17 positive cases in Category 2, 11 (64.7%) were from AADAs with exposure while 6 (35.3%) were from AADAs without exposure. For the negative cases, 151 (93.8%) and 10 (6.2%) were from Categories 1 and 2 respectively. One hundred and forty-three (94.7%) of the negative cases in Category 1 locations are from AADAs with exposure while 8 (5.3%) are from AADAs without exposure. Nine (90.0%) of the negative cases in Category 2 locations are from AADAs with exposure, while 1 (10.0%) was from AADAs without exposure.

International Journal of Public Health, Pharmacy and Pharmacology
Vol. 6, No.1, pp.25-38, 2021
Print ISSN: (Print) ISSN 2516-0400
Online ISSN: (Online) ISSN 2516-0419

Table 1: Distribution of dog bite cases in two Categories of locations (> 10 and < 10) based on exposure to standard roadways in Nigeria (2015 – 2019)

	Category 1 (>10 cases)			Category 2 (<10 cases)		
Characteristics	**Standard roadways (Exposed)**	**No standard roadways (Unexposed)**	**Total**	**Standard roadways (Exposed)**	**Non-standard roadways (Unexposed)**	**Total**
Administrative areas affected	28	10	**38**	15	2	**17**
Median No. of cases	3	1		1	3.5	
Min.-max. of cases	1-166	1-14		1-6	1-3	
Positive bite incidents	371	28	**399**	11	6	**17**
Negative bite incidents	143	8	**151**	9	1	**10**

The prevalence of dog bite incidents in Category 1 (95.3%) and Category 2 (4.7%) locations with odds of rabies infectivity being higher in Category 1 (2.64) than Category 2 (1.7) is presented in Table 2. Dog bite cases in high and low human population density areas in Category 1 locations were 262 and 288 respectively, while those of category 2 locations were 7 and 20. When combined with presence of standard roadways, however, dog bite cases in category 1 locations were 262 and 252 respectively and for category 2 locations, 7 and 13.

Table 2: Comparison of dog bite characteristics between Category 1 and 2 locations (2015 – 2019)

	Category 1	Category 2		
Prevalence of bite incidents (%)	95.3	4.7	Prevalence ratio	20.3
Odds of rabies infectivity	2.64	1.7	Odds ratio	1.6
Bite incidents (high-low Density areas)	262-288	7-20		
Bite incidents [high-low Density areas (exposure)]	262-252	7-13		
Average NDVI	0.3	0.4		
Average population density	1273.51	1110.751 (per 100 sqm)		

Table 3 depicts logistic regression output for effects of road network and human population density on dog bite cases in Nigeria (2015-2019). Based on exposure status, Table 4 and Figure 4 highlight differences between AADAs and effects of standard roadways respectively.

Table 3: Logistic regression output for dog bite incidents in Nigeria (2015 – 2019) in Category 1 locations compared to Category 2 locations.

	Odds ratio	Standard error	z	p-value
Effect of standard roadways	5.00(1.98, 12.60)	0.4718	3.410	0.000649
Effect of high population density	2.60(1.08, 6.25)	0.4474	2.135	0.03
Joint effects of standard roadways and high population density	1.93(0.76, 4.92)	0.4770	1.379	0.168

Table 4: Comparison of dog bite characteristics between exposed and un-exposed AADAs (2015-2019)

	Exposed AADAs	Un-exposed AADAs		
Prevalence of bite incidents (%)	92.5	7.5	Prevalence ratio	12.3
Odds of rabies infectivity	2.5	3.8	Odds ratio	0.66
Mean number of bite cases	12.4	3.6		
SEM	4.7	1.2		

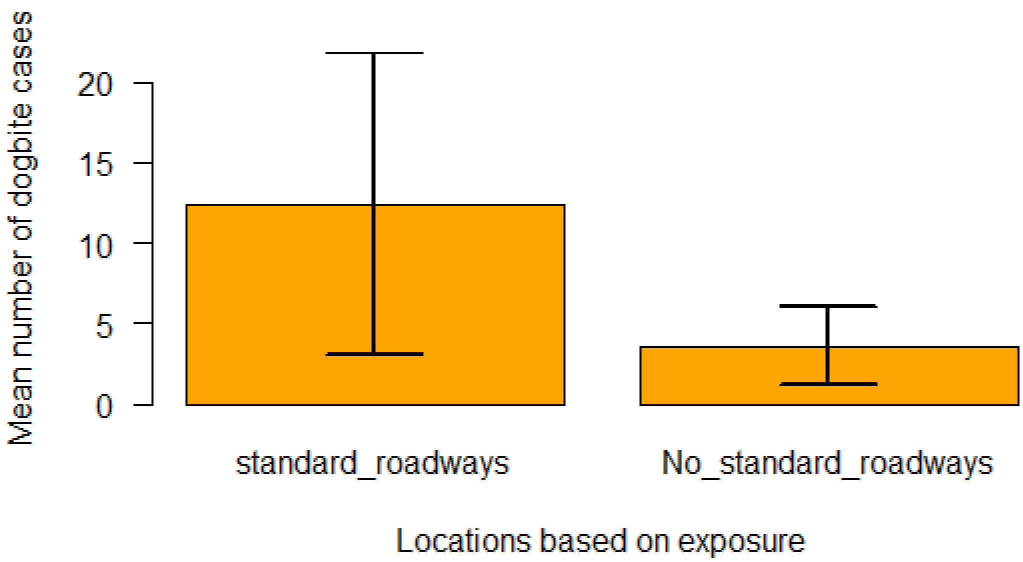

Figure 4: Error bars for dog bite cases based on exposure status

Welch t-test: `t = 7.049, df = 515.9, p-value = 5.809e-12`

`95 percent confidence interval: 7.350783 13.031357`

DISCUSSION

Exposure odds to standard roadways in Category 1 dog bite locations tend to be higher (14.28) compared to Category 2 dog bite locations (2.86) (Table1). Effect analysis shows a strong evidence for association between increasing presence of standard roadways and high prevalence of dog bite cases and hence 1.6 times more of rabies infectivity. Standard roadways is five (5) times more likely to pass through Category 1 locations (odds ratio 5; 95% CI 1.98 - 12.60; p<0.001); which also explains higher prevalence of bite cases (20.3 times more) in these locations (Plateau, Kaduna, Kano and Bauchi) compared to Category 2 locations (Adamawa, Bayelsa, Benue, Delta, Ebonyi, Enugu, FCT, Katsina, Kebbi, Kwara, Lagos, Rivers, Yobe and Zamfara). High human population density, though significantly associated with dog bite prevalence (odds ratio 2.60; 95% CI; 1.08-6.25; P=0.03), has a milder effect. However, joint effects of road networks and high population density, has no significant effect (odds ratio 1.93; 95% CI 0.76-4.92; p=0.17) on the prevalence of dog bite cases in the study locations. Category 1 locations are mostly arid tending to desert areas which are usually dry and hot (Normalize Difference Vegetation Index - NDVI 0.3) with sparse vegetation unlike Category 2 locations mainly with moderate vegetation (NDVI 0.4).

Overall, standard roadways in exposed AADAs were found to be the most important individual predictor for high prevalence of rabies in Nigeria as it is associated with 92.5% of all bite incidents, and 91.8% of all positive bite incidents when compared with unexposed AADAs (prevalence ratio of 12.3) (Table 4). In Nigeria, Federal roads (standard roadways) are owned and maintained by the Federal Government. Such roads link-up two or more state capitals and facilitate inter-state travels, thus bringing about socio-economic development. Regional trend in the distribution of bite cases in the study locations in which more cases are recorded in areas with more standard roadways and higher human population density suggests a need for an investigation of regional differences which may be associated with the disease prevalence. Although baseline data on dog population density in Nigeria is lacking, reports of rabies endemicity in high dog density areas without adequate rabies control have been published (Dye and Cleaveland, 1995; Lembo *et al*., 2008). It is probable that high human population density may influence dog population in affected areas due to the complex interactions that exists between humans and dogs, more so that rabies transmission is population density dependent (Anderson *et al*., 1981), as rapid turn-over of dog population in addition to poor vaccination practice hinder successful rabies control (Lembo *et al*. 2008; Hampson *et al*., 2009).

Odds of rabies infectivity though higher in Category 1 compared to Category 2 locations, probably due to higher number of cases of dog bites in Category 1 locations, is however lower in exposed AADAs (Table 4). This shows that rabies infectivity is not exposure-dependent. It is possible that rabies infectivity is local environment-dependent owing primarily to lack of vaccination, especially in rural areas which may be as a result of lack of knowledge about the effects of rabies, poverty and or lack of good access roads to Veterinary Services. On the other hand, good access roads may contribute to the persistence of rabies due to dog movements in addition to poor dog owners' attitude towards vaccination of their dogs. Although error bars indicate no significant difference in mean number of bite cases in exposed compared to unexposed AADAs as depicted by the overlap of the bars (Figure 4), with a mean difference of 8.8 (Table 4), Welch t-test however was significant (P value < 0.0000), with 95% CI for the difference in mean (7.35-13.03).

The results of this study corroborates the reports from recent studies which have shown that trade in stray and unvaccinated dogs for slaughter and human consumption is a major risk factor in the epidemiology of rabies in Nigeria (Ekanem *et al*., 2013; Ehimiyein *et al*., 2014), as large number of dogs are transported from one location to another. The results of our study is similar to the findings of Tenzin *et al*. (2012), in which regional trend in rabies distribution was observed in Bhutan. In their study, high human population density and road network accessibility were found to be associated with animal rabies occurrence in Bhutan. Tenzin *et al*. (2012) concluded that human rabies is usually associated with social and environmental factors that facilitate close contacts of humans with dogs. The World Health Organisation (2013) have also identified social, economic, political factors as well as incomplete understanding of disease dynamics as impediments to control of rabies in domestic dog populations. A study conducted by Laager *et al* (2018) in N'Djamena, Chad showed that endemicity of rabies was associated with series of importation of dogs. These findings suggest that rabies surveillance and control programs may need to be focussed more in high population areas with road accessibility. It is a known fact that rabies is endemic in Nigeria, and dog vaccination coverage is very low in Nigerian communities (Odita et al., 2019), thus trans-border movement of dogs (Eze *et al*., 2020), lack of adequate vaccination program, in addition to high human population density may be responsible for the persistence and hence endemicity of rabies in Nigeria. Areas where movement of humans and dogs is massive thus require heightened surveillance activities. Similarly, education of dog owners on responsible dog ownership in addition to cross border coordinated efforts targeted at trans-border movement of dogs and mandatory regular vaccination of dogs may be required to control and on the long run eliminate rabies both in humans and dogs.

Although in many parts of the world, reduction of dog population through culling is practised in the bid to reduce incidence of rabies (Beran & Frith, 1988; Windiyaningsih *et al*., 2004), the complex interaction between dogs and people have made this approach ineffective (Morter *et al*., 2013). Knowledge of risk factors that drive the transmission of the disease is essential for the development of effective and sustainable disease control protocol.

CONCLUSION

Although it could not formally conclude a causal link, the study however provides useful data to generate hypothesis about the role of standard roadways and human population density in the persistence of rabies in Nigeria. There is evidence of statistical relationship between increasing number of standard roadways and an increased prevalence of dog bite, and hence rabies in most study areas. Standard roadways may play a crucial role in the persistence of rabies primarily due to ease of transportation, and high movement of people and animals where they pass through.

Availability of good access roads may play a crucial role in the persistence of rabies in Nigeria due to massive movements of people and dogs, in addition to poor attitude of dog owners towards confining and vaccination of their dogs; and poor access to Veterinary care. The regional trend in rabies distribution observed in this study suggests that rabies surveillance and control programs may need to be focused more in high population areas with road accessibility; although not undermining areas devoid of Veterinary care. Likewise, education of dog owners on responsible ownership, cross border coordinated movement of dogs and mandatory regular vaccination of dogs are required to control and eliminate rabies in Nigeria.

RECOMMENDATIONS

We recommend that governments at all levels and all stakeholders emphasize the need to carryout intensive rabies surveillance and dog vaccination in all AADAs with more than 10 dog bite cases and strict vaccination of dogs against rabies in AADAs with less than 10 dog bite cases.

LIMITATIONS OF THE STUDY

Most of the cases were from Plateau state primarily due to proximity to diagnostic laboratory which may have biased the study results. Further, it was difficult to get good sample size from all the states that submitted samples during the period under review, because large proportion of the submissions did not provide detailed information required in the study. Consequently, only samples that had comprehensive data were included. However, finding from the study is significant as it would complement the scarce data on dog bite and rabies in Nigeria. The outcome of this study reiterates the importance of focusing on surveillance on Category 1 AADAs and on vaccination of dogs for effective control of rabies in Category 2 areas. Information generated from the study could influence government policy vis-a-vis the need to strengthen the existing rabies surveillance to interrupt the cycle of rabies virus via vaccination of at least 70% of dog population in any community in Nigeria.

REFERENCES

Anderson, R. M., Jackson, H. C., May, R. M., & Smith, A. M. (1981). Population dynamics of fox rabies in Europe. *Nature*, *289*(5800), 765–771. https://doi.org/10.1038/289765a0

Beran, G. W., & Frith, M. (1988). Domestic Animal Rabies Control: An Overview. *Reviews of Infectious Diseases*, *10*(Supplement_4), S672–S677. https://doi.org/10.1093/CLINIDS/10.SUPPLEMENT_4.S672

Boulger, L.R. and Hardy J. 1960. Virus Infections of Carnivores. *West Afric Med J* 9: 223-234

Carey, A. B., Giles, R. H., & McLean, R. G. (1978). The landscape epidemiology of rabies in Virginia. *American Journal of Tropical Medicine and Hygiene*, *27*(3), 573–580. https://doi.org/10.4269/ajtmh.1978.27.573

Dye, C., & Cleaveland, S. (1995). Maintenance of a Microparasite Infecting Several Host Species Rabies in the Serengeti. *Parasitology*, *111*(S1), S33–S47. https://doi.org/10.1017/S0031182000075806

Ehimiyein A, Audu S and Ehimiyein I. (2014). The Role of Dog Trading and Slaughter for Meat in Rabies Epidemiology with Special Reference to Nigeria- A Review. Journal of Experimental Biology and Agricultural Sciences; 2(2): 130-136.

Ekanem, E.E., Eyong, K.I., Philip-Ephraim, E.E., Eyong, M.E., Adams, E.B. and Asidi, A.A. (2013). Stray dog trade fuelled by dog meat consumption as a risk factor for rabies infection in Calabar, southern Nigeria. African health sciences; 13 (4): 1170-1173.

Eze, U.U., Ngoepe, E.C., Anene, B.M., Ezeokonkwo, R.C., Nwosuh, C.I. and Sabeta, C.T (2020). Molecular Detection of Rabies Lyssaviruses from Dogs in Southeastern Nigeria: Evidence of Transboundary Transmission of Rabies in West Africa *Viruses*, *12*, 134; doi:10.3390/v12020134

Glass, G. E., Schwartz, B. S., Morgan, J. M., Johnson, D. T., Noy, P. M., & Israel, E. (1995). Environmental risk factors for Lyme disease identified with geographic information systems. *American Journal of Public Health*, *85*(7), 944–948. https://doi.org/10.2105/AJPH.85.7.944

Hampson, K., Dushoff, J., Cleaveland, S., Haydon, D. T., Kaare, M., Packer, C., & Dobson, A. (2009). Transmission dynamics and prospects for the elimination of canine Rabies. *PLoS Biology*, *7*(3), 0462–0471. https://doi.org/10.1371/journal.pbio.1000053

Hu, W., Tong, S., Mengersen, K., & Oldenburg, B. (2007). Exploratory spatial analysis of social and environmental factors associated with the incidence of Ross River virus in Brisbane, Australia. *American Journal of Tropical Medicine and Hygiene*, *76*(5), 814–819. https://doi.org/10.4269/ajtmh.2007.76.814

Jones, M. E., Curns, A. T., Krebs, J. W., & Childs, J. E. (2003). Environmental and human demographic features associated with epizootic raccoon rabies in Maryland, Pennsylvania and Virginia. *Journal of Wildlife Diseases*, *39*(4), 869–874. https://doi.org/10.7589/0090-3558-39.4.869

Knobel, D. L., Cleaveland, S., Coleman, P. G., Fèvre, E. M., Meltzer, M. I., Miranda, M. E. G. Meslin, F. X. (2005). Re-evaluating the burden of rabies in Africa and Asia. *Bulletin of the World Health Organization*. https://doi.org//S0042-96862005000500012

Laager, M., Mbilo, C., Madaye, E. A., Naminou, A., Léchenne, M., Tschopp, A., … Chitnis, N. (2018). The importance of dog population contact network structures in rabies transmission. *PLoS Neglected Tropical Diseases*, *12*(8), 1–18. https://doi.org/10.1371/journal.pntd.0006680

Lembo, T., Hampson, K., Haydon, D. T., Craft, M., Dobson, A., Dushoff, J., … Cleaveland, S. (2008). Exploring reservoir dynamics: A case study of rabies in the Serengeti ecosystem. *Journal of Applied Ecology*, *45*(4), 1246–1257. https://doi.org/10.1111/j.1365-2664.2008.01468.x

McKenzie, A. A. (1993). Biology of the black-backed jackal Canis mesomelas with reference to rabies. *The Onderstepoort Journal of Veterinary Research*. Retrieved from https://pubmed.ncbi.nlm.nih.gov/7777322/

Morters, M. K., Restif, O., Hampson, K., Cleaveland, S., Wood, J. L. N., & Conlan, A. J. K.

(2013). Evidence-based control of canine rabies: A critical review of population density reduction. *Journal of Animal Ecology*, *82*(1), 6–14. https://doi.org/10.1111/j.1365-2656.2012.02033.x

Odita, C. I., Tekki, I. S., Moses, D. G., Barde, J. I., Egwu, K. O., Idachaba, S. E., … Shamaki, D. (2019). Dog anti-rabies vaccination coverage in Jos South LGA of Plateau State , Nigeria. *Sokoto Journal of Veterinary Sciences*, *17*(3).

OIE. (2008). *R A B I E S*. Retrieved from http://www.oie.int/fileadmin/Home/eng/Publications_%26_Documentation/docs/pdf/2.01.13_RABIES.pdf

Owolodun, B. Y. (1969). Rabies: present situation in Nigeria. *West African Medical Journal*, *18*(4), 143–144.

Ozanne-Smith, J., Ashby V, K., & Stathakis, Z. (2001). Dog bite and injury prevention - Analysis, critical review, and research agenda. *Injury Prevention*, *7*(4), 321–326. https://doi.org/10.1136/ip.7.4.321

Smith, J. S. (1996). New aspects of rabies with emphasis on epidemiology, diagnosis, and prevention of the disease in the United States. *Clinical Microbiology Reviews*. American Society for Microbiology (ASM). https://doi.org/10.1128/cmr.9.2.166-176.1996

Tang, X., Luo, M., Zhang, S., Fooks, A. R., Hu, R., & Tu, C. (2005). Pivotal role of dogs in rabies transmission, China. *Emerging Infectious Diseases*, *11*(12), 1970–1972. https://doi.org/10.3201/eid1112.050271

Tenzin, Dhand, N. K., & Ward, M. P. (2012). Anthropogenic and environmental risk factors for rabies occurrence in Bhutan. *Preventive Veterinary Medicine*, *107*(1–2), 21–26. https://doi.org/10.1016/j.prevetmed.2012.05.003

Umoh J.U and Bellino E.D. 1979. Rabies in Nigeria: a historical review. *International journal of zoonoses* 6: 41-48.

Ward, M. P., Maftei, D., Apostu, C., & Suru, A. (2008). Environmental and anthropogenic risk factors for highly pathogenic avian influenza subtype H5N1 outbreaks in Romania, 2005-2006. *Veterinary Research Communications*, *32*(8), 627–634. https://doi.org/10.1007/s11259-008-9064-8

Ward, M. P., Wittich, C. A., Fosgate, G., & Srinivasan, R. (2009). Environmental risk factors for equine West Nile Virus disease cases in Texas. *Veterinary Research Communications*, *33*(5), 461–471. https://doi.org/10.1007/s11259-008-9192-1

Weiss, R. A., & McMichael, A. J. (2004). Social and environmental risk factors in the emergence of infectious diseases. *Nature Medicine*, *10*(12S), S70–S76. https://doi.org/10.1038/nm1150

Welch, B. L. (1951). On the Comparison of Several Mean Values: An Alternative Approach. *Biometrika*, *38*(3/4), 330. https://doi.org/10.2307/2332579

Windiyaningsih, C., Wilde, H., Meslin, F. X., Suroso, T., & Widarso, H. S. (2004). The rabies epidemic on Flores Island, Indonesia (1998-2003). *Journal of the Medical Association of Thailand*. Retrieved from https://pubmed.ncbi.nlm.nih.gov/15825719/

World Health Organization. (2013). WHO Expert Consultation on Rabies. Second report. *World Health Organization Technical Report Series*, (982). Retrieved from https://books.google.com.ng/books?hl=en&lr=&id=-nKyDwAAQBAJ&oi=fnd&pg=PR7&dq=WHO.+(2008).+WHO+Expert+report+on+rabies.+Rabies-+a+neglected+zoonotic+disease.+Geneva,+Switzerland.&ots=UpmFlwVFjL&sig=x4r5O7m6JqlJdfXdYqriZEAD91I&redir_esc=y#v=onepage&q&f=fals

ACKNOWLEDGEMENTS

The authors wish to acknowledge Dr Loveness Dzikiti, Ross University School of Veterinary Medicine, Basseterre, St. Kitts for helping to review the manuscript. All individuals who have engendered the data over the years in the course of working in rabies laboratory and those who assisted in one way or another to make this work a reality, are also acknowledged.

AUTHORS' CONTRIBUTIONS

CIO designed the study, CIO and IST drafted the manuscript, IST, SHE and JAD extracted the data from diagnostic results, CIO, IST and JAD sorted the data; CIO and IST analysed the data, SEH, ICN, DY, MG, IJB and RAO edited the manuscript, RAO granted approval for publication. All authors read and approved the final manuscript.

DISCLOSURE STATEMENT

The authors declare that there were no conflicts of interest and no specific funding was received for this research

CONFERENCE PRESENTATION

Abstract presented at the Virtual Conference of the American Society for Tropical Medicine and Hygiene (ASTMH) which took place on November 15-19, 2020