Baseline epidemiology and associated dog ecology study towards stepwise elimination of rabies in Kwara state, Nigeria

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Abstract

Understanding domestic dog population dynamics and ecology is crucial to any effective rabies control program. This study was conducted as part of the baseline epidemiological studies necessary for the establishment of the Kwara Rabies Rapid Alert System "KRRAS". This study aimed to determine the dog population structure of Kwara State by assessing the dog ownership, vaccination status, and prevalence of dog bites.

A total of 1,460 questionnaires were administered to respondents in the three senatorial zones of the state using Open Data Kit (ODK) between June 2019 to January 2020.

Of the 1460 households surveyed, 293 (20.1%) owned at least one dog with an average of 2.25 dogs per household. The male to female ratio was 1.9:1 and 79.3% (n=523/659) of the owned dogs were local breeds. A total of 785 dogs was enumerated (659 dogs from 293 households and 126 free-roaming dogs) and 7811 persons which resulted in a dog-human ratio of 1:9.95. The estimated dog population is 376,789 (95% CI: 343,700 – 379,878). Only 31% (n=204/659) of households vaccinated their dogs against rabies. The prevalence of dog-bite was 13% (n=193/1460) of which only 27% of the victims (n=61/225) received post-exposure prophylaxis (PEP). Dog ownership was significantly impacted by the ethnicity of respondents. Hausa (OR: 3.76; 95% CI: 1.15 - 12.4; $p < 0.001$) and Nupe (OR: 4.48; 95% CI: 1.77-11.33; $p < 0.001$) respondents owned dogs than Yoruba respondents. The rabies vaccination status of owned dogs was significantly impacted by the level of education (OR: 5.03; 95% CI: 1.50 - 16.83; $p < 0.001$); history of previous dog bite incidents (OR: 1.74; 95% CI: 0.95 - 3.17; $p < 0.001$); the breed of the dog with exotic dogs being more vaccinated (OR: 2.79: 95% 0.64 - 12.05; $p < 0.001$). Similarly, Male dogs (OR: 1.49, 95% 1.03 – 2.86; $p < 0.001$) and partially confined dogs (OR: 1.09, 95% 0.45 – 2.11, $p < 0.001$) were found to be vaccinated against rabies.

The results of the study showed low dog vaccination coverage, and high number of free roaming dogs. Hence, a threat to public health. The low dog vaccination coverage is below the 70-80% target recommended for herd immunity by the World Health Organization.

Keywords: Rabies; KRRAS; Vaccination; Baseline dog ecology; Nigeria

Background

Rabies is one of the oldest and most terrifying diseases known to man (Horton et al., 2015). It is a fatal viral disease caused by one of the seven lineages of L*yssavirus* with a distinct "bullet" shape belonging to the family *Rhabdoviridae* (Badrane et al., 2001). Domestic dogs account for over 99% of human death from rabies (WHO, 2013).

It causes approximately 59,000 (95% CI: 25 - 159,000) human deaths annually mainly in Asia and Africa with 40% of people bitten by suspect rabid animals are children under 15 years of age (OIE, 2017a). Annually, it is responsible for 3.7 million (95% CI: 1.6 - 10.4 million) disability-adjusted life years (DALYs) and 8.6 billion USD (95% CI: 2.9 - 23.5 billion) economic losses (Hampson et al., 2015).

Rabies is endemic in Nigeria and has remained one of the most important neglected diseases of public health concern in the country. Despite the under-reporting of dog-bites incidents, about 10,000 cases of dog-bites are reported annually (NCDC, 2018). The rabies viral antigen has been detected in the brain tissues of apparently healthy dogs slaughtered for human consumption (Suleiman et al., 2020; Mohammed et al., 2019; Kia et al., 2018; Hambolu et al., 2014; Garba et al., 2010).

Several factors such as poor vaccination strategy, lack of sufficient vaccines, presence of stray (community) dogs and illegal trade of dogs within and across countries are major contributory factors to the endemicity and transboundary movement of rabies in Nigeria (Kia et al., 2018; Ogo et al., 2011; Ogunkoya et al., 2008). The epidemiology of rabies has been described in

84 Nigeria with dogs as the main reservoir of the disease (Kia et al., 2018; Ameh et al., 2014;
85 Garba et al., 2011). The presence of unvaccinated free-roaming dogs (FRD) amidst human settlements
86 is a major contributor to the high incidence and maintenance of rabies in Nigeria.

87 Mass dog vaccination is the most cost-effective strategy for preventing human rabies (OIE,
88 2017b). Parenteral vaccinations using the inactivated vaccine accompanied by the use of baits
89 for oral vaccination of dogs (Maki et al., 2017) are effective in controlling canine rabies. Dog
90 vaccination reduces human deaths attributable to rabies and the need for post-exposure
91 prophylaxis (PEP) as a part of dog bite patient care (Cliquet et al., 2018).

92 In Nigeria, there is no national or regional rabies control program. Hence, the importance of
93 projects such as the Kwara Rabies Rapid Alert System (KRRAS) cannot be over-emphasized.
94 KRRAS is a one health integrated surveillance system designed to improve the reporting of
95 dog-bite cases and enhance the diagnosis of rabies. The project is divided into three phases:
96 Baseline epidemiological assessment studies; Mass dog vaccinations; and the Surveillance of
97 dog-bite cases using the existing disease surveillance and notification officers (DSNOs) in the
98 state. This study, as well as three others, are the epidemiological basis for the KRRAS.

99 This study aimed to be the baseline epidemiological assessment study necessary for the mass
100 dog vaccinations; and am improved rabies surveillance system using the one-health approach.
101 This ecological study is critical to vaccine procurement, prioritization of intervention plans,
102 and essential for the enactment of the dog leash law in Kwara State.

103 **Methods**

104 ***Study area***

105 Kwara State is located in the southern guinea savannah zone of Nigeria between latitude
106 8.9669° N, and longitude 4.3874° E. The state has a population of 3,599,800 (NPC, 2020). It

is located in Northcentral Nigeria. The state has three agro-ecological and geographical zones (Northern, Central, and Southern) with vast land and with varying climatic conditions.

Period and course of the survey

A cross-sectional survey was carried out to generate a baseline dog population, dog to human ratio, vaccination coverage for the anti-rabies vaccine, and the pentavalent dog vaccines (DHLPP) across the state. The study also assessed the incidence of dog bites in Kwara state. We developed a structured questionnaire which comprised of: a) owner demographics b) dog ownership and vaccination status and c) incidence of dog bites and its management. The questionnaire was pre-tested in a pilot study and adjusted accordingly before being used in this survey.

The required sample size was computed using Epi-Info V.7.0 (CDC, Atlanta, USA). At a 95% confidence interval (95% CI), we hypothesized that 50% of households will have dogs in each senatorial zone (384 households per zone, 1152 for the state). Furthermore, we added a 25% non-response rate to the total required households for the state (n=288). Therefore, the minimum number of households included in this survey was 1,460.

The survey was conducted from June 2019 to January 2020 in Kwara state./ A multi-stage sampling (Kwara state → 3 senatorial zones → local government areas → communities → areas → streets → households) of the respondents was carried out from all the communities in the state. Furthermore, a systematic random sampling of households was conducted to select streets, households, and respondents. A sampling interval of five households was used for this study.

Organization of survey team and movement plan

The Kwara Rabies Research Team (Kw-RRT), supported by a team of volunteers, composed of field epidemiologists, Unilorin One Health students, and data collectors carried out the survey. They were trained on the methodology of the survey and were divided into five groups

of two members, plus a group leader. They were randomly assigned separate predetermined routes. The survey was conducted on each selected street. Due to the lack of organized road connections in semi-urban and rural areas, the polio-vaccination micro-plan was adopted, using the polio house markings as a guide. Starting from the first household on the right side, every 6th household was selected and an adult member (18 years and above) was interviewed. The survey team explained the purpose of the survey to each respondent and informed consent was sought before the administration of the questionnaire. The questionnaire was administered in English and in local language of the community when needed. The answers were recorded using the open data kit (ODK) application in mobile phone and uploaded the data to the African Field Epidemiology Network (AFENET) server.

Free Roaming Dog Enumeration Technique

We used Beck's definition of a free-roaming dog (FRD) as "Any dog observed without human supervision on public property or private property with immediate unrestrained access to public property" (Berman and Dunbar, 1983). Using the photographic recapture technique (Beck, 1973); we used photography to prevent counting a dog twice within the same area. Surveys were alternated between mornings and late evenings on two alternate days. On each day of the study, counting of dogs was carried out in the morning (between 6 and 9 a.m.) and in the evening (5.30 to 7.00 p.m.). Every dog sighted within a 5m radius of the road was photographed and recorded.

The free-roaming dog population in the three senatorial zone was estimated using the Beck (1973) formula as previously described by Mshelbwala et al (2017).

$$N = \frac{\Sigma(Mn)}{\Sigma m}$$

where N= the estimate of the dog population of Kwara state.

M= the number of dogs observed and photographed each time in the street and considered as "sighted and marked".

m= the number of dogs identified as being previously photographed, that is "re-sighted/re-captured

n= Each days' observation (M) – previously observed dogs (m) (Table 2).

Data analysis

The household survey data were analyzed using Minitab 19.1.1 (Pennsylvania, USA). Qualitative data were presented as proportions whereas quantitative data were presented as mean and standard deviation. A univariable logistic regression analysis was conducted to assess the association between the socio-demographic variables and the outcome variables [dog ownership of the household (yes vs no), and the vaccination status of the dog against rabies (vaccinated vs not vaccinated)]. Variables with p-value ≤ 0.05 were selected for multivariable logistic regression analysis using the logit function and α at 0.25. A multivariable logistic regression analysis was performed and the variables with p-value ≤ 0.05 were retained in the final model. The odds ratio (OR) and its 95% confidence interval (CI) of the variables associated with the outcome variables were derived from the final multivariable logistic regression model.

RESULTS

Demography of the respondents

The questionnaire was administered in English and translated to the local language of the respondents (where necessary). Most of the respondents (72%, n=1045/1460) had either secondary or tertiary education. Tradesmen/Artisans accounted for over 47% of the respondents. The demographic characteristics of the respondents is shown in Table 1.

Table 1. The demographic structure of respondents in Kwara state (n=1460).

Variables	No of respondents (%)
Senatorial Zone	
Kwara South	364 (25)
Kwara North	562 (38.5)
Kwara Central	534 (36.5)
Grnder	
Female	382 (26.1)
Male	1072 (73.5)
Prefer not to say	6 (0.4)
Religion	
Christianity	523 (35.8)
Islam	914 (62.6)
Others	3 (0.2)
Prefer not to say	21(1.4)
Level of education	
No western education	187 (13.5)
Primary	165 (11.9)
Secondary	581 (41.9)
Tertiary	424 (30.6)
Prefer not to say	73 (5)
Other	30 (2.1)
Occupation	
Artisan	286 (20.4)
Civil servant	128 (9.1)
Driver	20 (1.4)
Farmer	169 (12)
Fisherman	3 (0.2)
Laborer	12 (0.9)
Other professions	64 (4.6)
Security officer	17 (1.2)
Student	253 (18)
Trader/ businessman	376 (26.9)
Unemployed	72 (5.2)
Prefer not to say	60 (4.1)

Dog Ecology

A street survey estimated a total of 126 free-roaming dogs (FRDs) across the three senatorial zones (Table 2). A household questionnaire survey found a total of 659 dogs owned by 293 respondents resulting in an average of 2.25 dogs per visited household. During the survey, 7811 people were counted and a total of 785 dogs (FRD and owned)

giving a dog to human ratio of 1:9.95. Therefore, with a total population of 3,599,800; we estimated a total dog population of 361,789 (95% CI: 343,700 – 379,878) in Kwara state. The descriptive statistics of owned dogs showed that the local breeds of dogs (Mongrel) accounted for 79.3% of owned dogs. Most respondents (52%, n=198/380) kept dogs for security whereas hunting dogs accounted for another 28% (n=105/380) of owned dogs. Based on the use of the dog, 69% (n=202/302) partially/ never confine their dogs. Most of the owned dogs (56%, n=369/659) were aged between 1-3 years (Table 3).

Table 2. Estimation of free-roaming dogs using photographic mark-recapture methods in Kwara state.

Senatorial zone	Mean number of dogs sighted and photographed per area (M)	No of dogs sighted that were previously photographed (m)	n = (M-m)	N
Kwara South	17	5	11	37.4
Kwara North	11	3	8	29
Kwara Central	30	10	20	60
Total	58	18	39	126.4

Each parameter is an average of 7 chosen areas from each senatorial zone.

Dog vaccination status

Of the 293 households surveyed, only 31% (n=204/659) were previously vaccinated against rabies. Among the dogs vaccinated against rabies, only 22% (n=45/204) had received DHLPP® (a recommended pentavalent vaccine for puppies at 8 weeks of age meant to provide immunity against Canine distemper, Hepatitis, Leptospirosis, Parainfluenza, and Parvovirus). With 52% (n=48/92) of all vaccinations administered at home (Table 3).

211 **Table 3.** Characteristics of owned dog population and vaccination status in Kwara
212 state.

Variables	Frequency (%)
Do you own dogs? (n=1460)	
Yes	293 (20.1)
No	1167 (79.9)
Gender of dog [b]	
Female	231 (35)
Male	428 (65)
Breed of dog [b]	
Cross-bred	61 (9.3)
Exotic	75 (11.4)
Local	523 (79.3)
Age of dogs [b]	
< 1 year	119 (18)
1-3 years	369 (56)
3-5 years	119 (18)
> 5 years	52 (8)
Use of dog (s) [a]	
Breeding	31 (8)
Herding	5 (1)
Hunting	105 (28)
Pet	41 (11)
Security	198 (52)
Confinement of dog [a]	
Always	80 (27)
Never	152 (52)
Partial	50 (17)
Vaccination against rabies [b]	
Yes	204 (31)
No	455 (69)
Vaccination against DHLPP® [b]	
Yes	145 (22)
No	514 (78)
Where vaccination against rabies was received [a]	
At home	152 (52)
Private Veterinary Clinic	88 (30)
Gov't Vet clinic	53 (18)
Pet green book [a]	
Yes	171 (26)
No	488 (74)
Age of first vaccination [b]	
3-6 months	99 (15)
6-12 months	86 (13)
1-2 years	172 (26)
2-3 years	92 (14)
3-4 years	46 (7)

4-5 years	86 (13)
5 years +	79 (12)
Dog population management methods	
Give away	36 (55)
I Keep my pups	10 (15)
Killed	4 (6)
Sold	15 (23)

a Parameters computed based on the number of households that own dogs (n=293)
b Parameters computed based on the number of owned dogs (n=659).

Incidence and management of dog bites in Kwara state

Of the 1460 respondents, 13% (n=193/1460) had a history of dog-bite with (63%, n=154/246) being beaten once and (23%, n=56/246) were bitten twice (Table 4). About 13% (n=27/225) and 32% (n=72/225) used antibiotics and traditional methods (herbs) to treat dog-bite wounds (Table 4) However, only 27% of the dog bite victims received the post-exposure prophylaxis (PEP) and rabies immunoglobulin (RIG).

Table 4. Evaluation of dog-bite incidence and it's management (n=193).

Variable	Frequency (%)
Ever bitten by a dog?	
No	1267 (87)
Yes	193 (13)
No of bites incidents	
1	154 (63)
2	56 (23)
3	21 (9)
5	15 (6)
Outcome of dog	
Alive	72 (36)
Died	11 (6)
I don't know	12 (6)
Killed	59 (30)
Ran away	46 (23)
Treatment given to the dog-bite victim	
Antibiotics	27 (13)
Non-specific	64 (28)
PEP and RIG	61 (27)
Traditional	73 (32)

Analysis of factors affecting dog ownership and vaccination status in Kwara State.

235 The multivariable regression analysis demonstrated that the dog ownership in Kwara state was
236 found to be associated with the occupation and the ethnicity of the household respondents. The
237 Hausa (OR: 3.76, 95% CI: 1.15-12.35) and Nupe (OR: 4.48, 95% CI: 1.77 - 11.33) ethnic
238 groups are more likely to own dogs when compared with other tribes. Similarly, comparing to
239 Artisan, other types of occupation were likely to be associated with owning the dogs (Table 5).

240 The rabies vaccination status of was found to be associated with the gender and breed of the
241 dog, dog management, education level of the owner and the dog bite incident history of the
242 owner. Male dogs (OR: 1.49, 95% 1.03 – 2.86), exotic breed (OR: 2.79: 95% 0.64 - 12.05) and
243 partially confined dogs (OR: 1.09, 95% 0.45 – 2.11) are found to be vaccinated against rabies.
244 Similarly, an owner that have a history of previous dog bite incidents (OR: 1.74, 95% 0.95 -
245 3.17) and those owners that have attended school education are more likely to have vaccinated
246 their dogs against rabies (Table 5).

247

248

249 Table 5. Univariable and multivariable logistic regression analysis of the factors associated with the "ownership" and "vaccination status against
250 rabies" in dogs in Kwara State, Nigeria

Variable		Referent		Univariable analysis				Multivariable analysis			
Dog ownership				Odds Ratio (95% CI)	X^2	DF	*p-value*	Adjusted Odds Ratio (95% CI)	X^2	DF	*p-value*
	Religion	Islam	Christianity	1.05 (0.80 - 1.37)	0.13	1	0.937	-	-	-	-
	Occupation	Artisan	Civil Servant	1.49 (0.91 - 2.42)	61.17	10	0.001	1.49 (0.89 – 2.29)	60.91	10	0.0001
			Driver	2.21 (0.84 - 5.80)				2.14 (0.71 – 4.26)			
			Farmer	2.63 (1.72 - 4.03)				3.41 (1.89 – 5.03)			
			Fisherman	0.00				0.00			
			Laborer	1.37 (0.36 - 5.22)				1.09 (0.29 – 4.62)			
			Security officer	1.49 (0.80 - 2.79)				1.1 (0.69 – 3.11)			
			Student	2.24 (0.79 - 6.32)				2.14 (0.78 – 5.99)			
			Trader/ Businessman	0.91 (0.59 - 1.40)				1.1 (0.67 – 1.69)			
			Unemployed	0.90 (0.46 - 1.76)				0.78 (0.30 – 1.51)			
	Ethnicity	Yoruba	Hausa	4.37 (1.34 - 14.14)	69.67	6	0.0001	3.76 (1.15-12.35)	69.30	6	0.0001
			Nupe	2.26 (0.73 - 7.00)				4.48 (1.77 - 11.33)			
			Bokobaru	0.75 (0.53 - 1.04)				0.65 (0.44 - 0.96)			
			Fulani	0.22 (0.08 - 0.55)				0.04 (0.01 - 0.15)			
			Baruba	0.31 (0.21 - 0.47)				0.28 (0.17 - 0.44)			
			Other	4.99 (2.00 - 12.47)				2.37 (1.16 - 4.89)			
Vaccination status of dogs											
	Gender of dog	Female	Male	1.7 (0.97 - 2.98)	3.45	1	0.063	1.49 (1.03 – 2.86)	2.89	1	0.001
	Confinement of dogs	Always	Never	0.48 (0.27 - 0.86)	7.94	3	0.047	0.46 (0.25 – 0.84)	6.48	3	0.002
			Partial	1.00 (0.49- 2.06)				1.09 (0.45 – 2.11)			
			I don't know	0.56 (0.14 - 2.29)				0.50 (0.22 – 2.14)			

Breed	Cross-bred	Exotic Local	2.79 (0.72 - 10.86) 0.33 (0.15 - 0.75)	18.42	2	0.0001	2.79 (0.64 - 12.05) 0.34 (0.13 - 0.85)	15.1	2	0.001
Previous dog-bite incident	No	Yes	1.43 (0.83 - 2.46)	1.64	1	0.2	1.74 (0.95 - 3.17)	3.25	1	0.071
Use of dog	Breeding	Herding Hunting Pet Security	4.33 (0.42 - 44.43) 1.96 (0.50 - 7.69) 2.29 (0.52 - 10.21) 2.01 (0.55 - 7.33)	1.88	4	0.757	-	-	-	-
Level of education	No formal education	Primary Secondary Tertiary Others	5.03(1.50 - 16.83) 3.24 (1.08 - 9.77) 7.81 (2.50 - 24.32) 8.5 (0.44 -163.88)	16.55	4	0.002	5.94 (1.72 - 20.42) 3.04 (0.97 - 9.49) 6.99 (2.13 - 22.92) 6.15 (0.27 - 137.47)	14.4	3	0.006

%= Percentage; X^2= chi-square; DF- Degree of freedom; OR – Odds ratio; 95% CI – 95% confidence interval.

DISCUSSION

Dogs are responsible for 99% of all cases of human rabies (WHO, 2020). Therefore, understanding the domestic dog ecology and its population structure is the first step to an effective elimination program (Cleveland et al., 2006). Baseline epidemiological studies in rabies elimination cannot be overemphasized especially in vaccine procurement for mass vaccination campaigns. More so, they form the evidence-base for the Kwara Rabies Rapid Alert System -KRRAS-; a collaborative state-based project designed to achieve the global aim of eradicating dog-mediated human rabies by 2030 in Kwara state. KRRAS was designed using the five pillars of the global framework; Socio-cultural, Technical, Organization, Political, and Resources (STOP-R) in Kwara state. The total dog population is lower than reported for many other states in Nigeria. This makes Kwara State a good candidate for the first rabies elimination project in the country.

Dog ownership was not affected by religion ($p = 0.937$). This is in contrast to findings by Mauti et al (2017); Oboegbulem and Nwakonobi (1989) which showed significantly higher dog ownership amongst Christians. Most of the owned dogs were local breeds. This aligns with reports from Kwaghe et al., (2019) and Grace et al., (2018).

Male dogs were more abundant than female dogs in Kwara State (sex ratio of dogs 1.9:1). It is believed that male dogs are better guardians and hunters than female dogs (Kitala et al., 2001). This is as previously described by Otolorin et al (2014); Aiyedun and Olugasa, (2012). However, this does not agree with the findings of Kwaghe et al., (2019); Hambolu et al (2014) who reported higher female to male dog ratio. Dogs were mostly kept for security purposes. This is similar to reports from other parts of Nigeria and Africa (Kwaghe et al., 2019; Garba et al., 2017; Mauti et al., 2017). The median age of owned dogs were 1-3 years was similar to reports from all over the country that shows the average dog were older than 1 year (Otolorin et al., 2014; Hambolu et al., 2013). Also, Aiyedun and Olugasa (2012) reported 71% of dogs aged > 6 months old.

279 The dog to human ratio of approximately 1:10 is lower than 1: 7.8 reported in Abia state
280 (Otolorin et al., 2014). Similarly, Kwaghe et al., (2019) reported a higher dog-human ratio of
281 1: 6.6. Other studies like those of Hambolu et al., (2014); Atuman et. al., (2014); and Garba et
282 al., (2017) reported a dog-human ratio of 1:5.6; 1:4.1 and 1:5.4 respectively (Table S1).
283 Aiyedun and Olugasa (2012) reported a dog-human ratio of 1:139 in Ilorin; which is lower than
284 what this study has recorded in Kwara state. This might be because Aiyedun and Olugasa
285 covered the Ilorin metropolis. The dog to human ratio reported in this study is within the range
286 reported and modeled for most African countries (Knobel et al., 2005). Within Africa, several
287 studies conducted reported a dog-human ratio of 1:14 in Tanzania (Gsell et al., 2012); 1:21.5
288 in Chad (Mindekem et al., 2005); 1:15 in Kenya (Kitala et al., 2001) and 1: 16 in Zimbabwe
289 (Brooks R., 1990). Kwara State has a total landmass of 36,825 km^2, giving a total of 7.5 dogs/
290 km^2. This is within the range of 6 and 21 dogs/ km^2 that was reported by Kitala et al (2001) in
291 Kenya (Table S1). Much higher dog densities (>1000 dogs/ km^2) had been estimated for Lagos
292 (Hambolu et al., 2014) and some South American countries (Davlin and Vonville, 2012).
293 The variations in the dog to human ratio in different areas of Nigeria might be attributable to
294 the different socio-cultural, religious, and economic status of various states of the federation.
295 The rabies vaccination rate is similar to those earlier reported in other parts of the country. This
296 is much lower than the 69.6%; 64.1% and 49.5% reported in Niger (Garba et al., 2017), Lagos
297 (Hambolu et al., 2014) and Abuja (Mshelbwala et al., 2017) respectively. It is, however, higher
298 than the 26.4% and 21% reported in Bauchi (Atuman et al., 2014) and Nasarawa (Kwaghe et
299 al., 2019) respectively. This vaccination coverage falls significantly below the 70-80%
300 vaccination rate needed to boost herd immunity (WHO, 2003). With low vaccination coverage,
301 the general public is at risk of rabies exposure and the need for improved public awareness on
302 rabies, first aid for dog-bite victims, and availability of PEP especially in rural areas cannot be
303 over-emphasized.

Only 26% of the vaccinated dogs had a vaccination certificate. This is because only licensed veterinarians are allowed to issue a signed vaccination certificate and most vaccinations were administered at home (possibly- by para veterinary technicians). This has impaired proper monitoring and surveillance of dog health and welfare.

The prevalence of dog-bite and its management was evaluated as an important component of rabies epidemiology. The dog-bite incidence was lower than the 31% and 26.4% reported in Niger and Bauchi states respectively (Garba et al., 2017; Atuman et al., 2014).

There is an urgent need for public education on rabies (mission of KRRAS) as only 15% of the respondents vaccinated their dogs at the appropriate age of 3-4 months. More so, only 27% of dog-bite victims received the PEP and RIG injections from a health facility. This is especially worrying as most of the respondents (73%) treated dog-bites with antibiotics (13%), non-specific treatment (28%), and traditional (32%) concoctions. Non-specific treatment included wound cleaning and the use of antibiotics. The high level of stray/free-roaming dogs seen in Kwara state is due to the lack of dog population control programs. Hence, the need to re-introduce effective stray dog population control described under the OIE terrestrial animal health code (OIE, 2019) during our mass vaccination campaigns. This un-controlled breeding coupled with their use for hunting has introduced and maintained several genera of lyssaviruses in the environment by introducing the sylvatic (wild) rabies cycle into the urban cycle. This could potentially increase the transmission intensity and spread of rabies.

Conclusion

The results of the study showed low canine vaccination coverage. This poses a serious public health threat. It is essential to control the population of free-roaming dogs. Furthermore, public awareness needs to be raised among certain subsets of the population with special emphasis on proper dog-bite treatment regimen and availability of pre-exposure and post-exposure prophylaxis for humans.

This baseline epidemiology and ecology study forms the evidence base that can be used for implementing an effective dog Mass Vaccination Campaign in the state. Information from this study is vital for vaccine procurement, proportionate distribution within the state, and serves as a basis for a valid comparison for our post-vaccination surveys. We recommend the establishment of a rabies desk office (RDO) and include dog-bite amongst the reportable diseases by the disease surveillance and notification officers (DSNOs) to the District Health Information System (DHIS2). We equally recommend further longitudinal studies to define the health and welfare challenges of dogs in Nigeria

Declarations

- Ethics approval and consent to participate

  Ethical clearance was obtained from the various ethical review boards of the Kwara State: Ministry of Health (MoH), Agriculture and Rural Development (MoARD), and Education and Human Capital Development (MoEHCD), Ilorin - Nigeria (reference number: MOH/KS/EU/777/31). Informed consent was sought from the respondents and participants could opt-out at any time.

- Consent for publication

  Not applicable

- Availability of data and materials

  The survey instrument and datasets are available as supplementary data.

- Competing interests

  The authors declare that they have no competing interests.

- Funding

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- Authors' contributions

  AIA, AAT, FB, MO, MSO, MSB, GK, and AI were involved in planning the study and data collection. AIA drafted the manuscript. BO and AH did the overall review of the manuscript. All authors read and approved the final study.

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Supplementary data

Supplementary file 1- Survey instrument

Supplementary file 2

Table S1. Comparison of dog ecology across Nigeria and Africa

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Supplementary data

Table S1 Comparison of dog ecology across Nigeria and Africa

Location	Dog-human ratio	Dog density/km^2	Dog owning households (%)	Dogs/household	Average dog age	Male-Female ratio	Vaccination coverage (%)	References
Kwara State (NC)	1:10	7.5	20	2.25	1-3 years	1.9:1	31	This study
Bauchi (NE)	1:4.1	-	-	2.3	1-5 years	1:1.2	26.4	Atuman et al., 2014
Lagos (SW)	1:5.6	-	95	2.8	> 1 year	1:1.5	64.1	Hambolu et al., 2014
Abia (SE)	1:7.8	-	-	1.5	> 1 year	1.6:1	39.9	Otolorin et al., 2014
Bamako, Mali	1:121	56	9	0.13	3.2 years	2.8:1	-	Mauti et al., 2017

NC- North-central, NE- North-eastern; SW- South-western; SE-South-eastern Nigeria; % -percentage.