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ORIGINAL RESEARCH

Animal rabies in Mozambique: a retrospective study with focus on dog rabies and vaccination coverage

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Rabies, a highly preventable zoonotic disease, remains a major public health problem in Mozambique with approximately 50 human fatalities per annum due to dog-mediated rabies. This study analysed animal rabies cases and dog vaccination coverage, confirmed between 2001 and 2021, based on history, clinical signs, and/or diagnostic tests. During this period, 955 animal rabies cases were reported with the highest occurrence in Maputo (n = 283; 29.6%) and the lowest from Zambézia and Sofala provinces (n = 30; 3.1%). A significant number of animal rabies cases occurred in 2005 (n = 180; 18.8%). Most cases were identified in domestic dogs (n = 766; 80.2%). During the same period, 4.6 million dogs were vaccinated against rabies and the countrywide coverage was 10.4%. The total number of vaccinations administered increased over the 21-year period, from 46 301 in 2001 to a peak of 464 780 in 2018 before slightly declining in subsequent years. Rabid dogs are still important reservoirs and vectors species in Mozambique. More effective control measures, surveillance, reporting and enhanced awareness programmes are needed to address this neglected disease and consequently meet the global strategic plan to end human deaths due to dog-mediated rabies by 2030.

Keywords: animal, dog, rabies, Mozambique, vaccination coverage

Introduction

The benefits of keeping dogs include physical, social and emotional development of children and the well-being of their owners, especially the elderly (Robertson et al. 2000). In sub-Saharan Africa, the rise in free-roaming dogs, associated with rapid urbanisation and mobility of the human population, increased their epidemiological importance and contribution to the transmission, maintenance and dispersal of rabies (Taame et al. 2017; Kenu et al. 2018). Rabies is an acute, progressive and fatal infectious disease that affects all warm-blooded mammalian species, including humans (Hankins & Rosekrans 2004; WHO 2005). The disease is caused by viruses of the genus *Lyssavirus*, family *Rhabdoviridae*, which officially comprises 18 species including, *Lyssavirus rabies* (RABV) and four putative species, *Phala bat lyssavirus*, *Taiwan bat lyssavirus 2*, *Divaea bat lyssavirus* and *Kotalahti bat lyssavirus* (ICTV 2024). RABV is responsible for an estimated 59 000 human deaths worldwide annually (Hampson et al. 2015; Cleaveland and Hampson 2017). Ninety-five per cent of these deaths occur in Africa and Asia, with about 40% of cases affecting children under the age of 15 (WHO 2010). In these continents, the domestic dog is the main vector and reservoir (Cliquet & Picard-Meyer 2004; Hampson et al. 2015). Rabies is one of the oldest known infectious diseases and attracts considerable academic, political, and financial investment in its prevention and control, in alignment to the United Nations' Sustainable Development Goals (Dürr et al. 2017). However, it remains a neglected disease in many developing countries, including Mozambique (Salomao et al. 2017; Mapatse et al. 2022a), where it has been endemic since at least 1908 (Dias 1992). In Mozambique, particularly in urban areas, more than 88% of confirmed rabies cases were in domestic dogs (Dias et al. 1985; Dias & Rodrigues 2003; WHO 2013). In rural areas, the main cause is the same as in urban areas, with rabid stray dogs being the main public health hazard (Pinto 1999; Salomao et al. 2017; Mapatse et al. 2022b).

Due to constraints in epidemiological surveillance, there is under-reporting of both human and animal rabies, and a gross underestimation of the current burden of the disease in Mozambique, particularly in rural areas (Coetzer et al. 2017; Salomao et al. 2017; Ministry of Health and Ministry of Agriculture and Rural Development 2019; Mapatse et al. 2022a). This arises from failures in mandatory notification as well as poor clinical and laboratory diagnostic capacity (Coetzer et al. 2017; Salomao et al. 2017; Sabeta et al. 2021). In 2010, the government of Mozambique approved a National Strategy Plan for Rabies Control (Government of Mozambique 2010), with responsibilities shared between the Ministry of Agriculture and

Rural Development (MADER), Ministry of Health (MISAU), and Ministry of State Administration (MAEFP). The plan set a target of reducing animal rabies to less than 10 cases per year and to limit the transmission and spread to humans.

Challenges in plan implementation due to financial constraints, and a rise in reported human cases from 15 222 dog bites and 94 deaths in 2016 to 20 419 dog bites and 84 deaths in 2017, prompted the government to extend the plan to 2020–2024 (Ministry of Health and Ministry of Agriculture and Rural Development 2019).

Current, official sources of rabies information, for example, repositories, articles and records, do not accurately reflect the true situation of the disease in Mozambique. Thus, our objective was to update and systematically organise and standardise epidemiological data on animal rabies and vaccination coverage in Mozambique over a period of 21 years (2001–2021). With this information, we would be in a better position to provide veterinary and health authorities with valuable information that can contribute to the improvement of on-going actions to end human dog-mediated rabies deaths by 2030.

Materials and methods

Case definition of animal rabies in Mozambique

In Mozambique, animal rabies is defined *as an animal presenting with an acute neurological syndrome (encephalitis) with predominantly excitability (furious form) or a paralytic form (dumb form) culminating in coma and death usually from respiratory failure within 7–10 days* (Ministry of Health and Ministry of Agriculture and Rural Development 2019).

Suspected animal rabies case

A suspected case is *an animal that may display symptoms or have a history of potential exposure to rabies but has not yet been definitively diagnosed.* These may include one or more of the following:

An animal that has had occasional or potential contact with an infected animal in the last 14 days and has stopped eating and drinking water.

An animal showing any of the following clinical signs indicative of rabies: sudden signs of apprehension or nervousness, irritability, hypersensitivity, hydrophobia, muscle paralysis, nervous signs, persistent barking, biting objects, excessive exertion.

An animal with a clinical presentation suggestive of rabies encephalitis, with a history, or not, of exposure to rabies virus infection (Ministry of Health and Ministry of Agriculture and Rural Development 2019).

Probable animal rabies case

This category might overlap with some of the suspected rabies cases but could include:

Animals showing behavioural changes without displaying the specific clinical signs mentioned in the suspected case definition.

A mammal, other than man that has been exposed to or been in contact with an infected animal within the previous 14 days.

A mammal that stops eating and drinking water or tends to isolate itself to dark or hidden places (Ministry of Health and Ministry of Agriculture and Rural Development 2019).

National surveillance system for rabies

According to Mozambique's Animal Health Regulation (Decree 26/2009) (Bulletin of the Republic of Mozambique 2019), rabies is a notifiable disease and all suspected, probable and laboratory-confirmed rabies cases must be reported. The largest centre for laboratory confirmation is the Central Veterinary Laboratory (CVL), Maputo, which can diagnose rabies using the gold standard direct fluorescent antibody test (dFAT), direct Rapid Immunohistochemical Test (dRIT), Seller's stain (Negri bodies) (no longer recommended by the World Organisation for Animal Health [WOAH] for diagnosis of rabies due to low sensitivity) or conventional reverse-transcription polymerase chain reaction (RT-PCR). Regional laboratories are located in Gaza, Nampula and Manica provinces, with the former two using Seller's stain while the Manica laboratory performs the dFAT and RT-PCR. The veterinary sector at district level in all provinces has a notification form in which epidemiological data from a case of animal rabies is collected by the veterinarian or agro-livestock technician who followed-up the case. The completed report is sent to the Provincial Animal Husbandry Services and from there to MADER.

Data collection

Data on the occurrence of animal rabies were gathered from the annual disease record books at the former National Veterinary Directorate (DINAV) and at the Directorate of Animal Science (DCA) to which the CVL is subordinated. These record books are maintained as part of the routine disease surveillance and reporting process overseen by these entities. For the number of domestic dogs vaccinated annually and by province, data were obtained from the MADER Livestock Statistics bulletins.

Rabies cases and vaccination records

Rabies cases were identified based on a combination of laboratory testing, clinical signs, and historical data.

Rabies data included province as the locality of origin of the cases reported, year of occurrence, animal species of origin and the diagnostic method used to confirm the diagnosis.

Data collected from the DINAV were cross-checked with those collected at the DCA to compare entries in both record books for consistency in information reported and compiled at national level. For each rabies case, a double manual check was undertaken to standardise the data categories and to ascertain if there were errors of information from the same or different sources (date of reported cases, location, animal species involved, diagnostic methods). The data obtained from DINAV was used to calculate vaccination coverage.

Data processing and analysis

Both laboratory-confirmed cases and rabies cases classified based on clinical signs and history were included in the analysis.

Rabies data collected covered a 21-year period (2001–2021). IBM-SPSS version 18.0 for Windows (SPSS Inc., Chicago, Ill., USA) was used for descriptive statistics. Figure 1 was created using QGIS (version 1.8). The spatial polygons for the provinces were obtained from CENACARTA (National Cartography and Remote Sensing Centre) of Mozambique. To calculate and establish the thresholds for classifying rabies cases as low, moderate, and high, the mean and standard deviation of the total dog rabies cases reported during the study period were used. For each province, cases were classified as low (≤ 64 cases), moderate (64 < cases ≤ 134) or high (> 134 cases). Linear regression was used to estimate trends in animal rabies cases over the study period. The annual total number of cases was used as the dependent variable, and the year was used as the independent variable. A p-value of less than 0.05 was considered statistically significant at the 95% confidence level.

The incidence rate was calculated by the number of cases divided by the number of dog years at risk and standardised to every 100 000 dog years at risk. These rates were calculated based on the annual provincial population.

The dog population at risk was estimated on the basis of demographic projections on the Mozambican human population (data by year and by province), obtained from Mozambique's National Statistics Institute (INE) (INE 2010). To this end, a ratio of 11.1:1 (humans per dog) was considered for the population at risk (PAR) estimates, as reported by Rautenbach et al. (1991) for southern Africa. The PAR was specific to each year, reflecting the annual fluctuations in the dog population.

Results

Rabies cases per province and per animal species

Figure 1 shows the map of Mozambique and provinces with animal rabies occurrences.

Of the 955 animal rabies cases reported during the study period, 710 (74.3%) were based on laboratory tests and the remaining on history or clinical signs. Maputo had the highest number of cases (n = 283; 29.6%), followed by Nampula (n = 143; 15%) and Gaza (n = 139; 14.6%). In the same period, the lowest occurrence of the cases was recorded in the provinces of Zambézia and

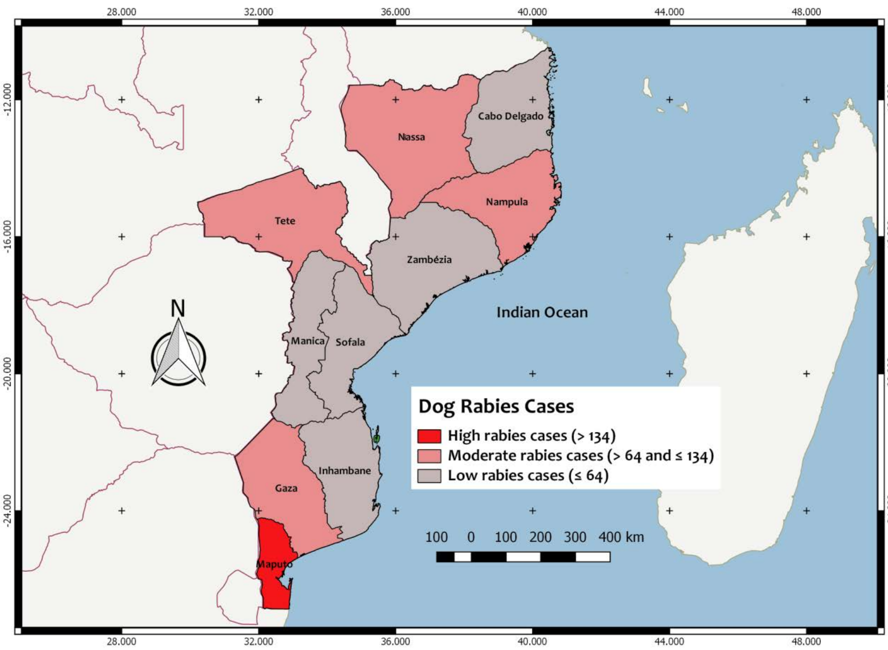

Figure 1: Map of Mozambique showing the distribution of dog rabies cases across different provinces in Mozambique from 2001 to 2021

Table I: Number of animal rabies cases by species and province (2001 to 2021)

Animal species	Provinces										
	Cabo Delgado	Niassa	Nampula	Zambézia	Tete	Manica	Sofala	Inhambane	Gaza	Maputo	Total
Domestic dogs	4	96	110	24	82	62	16	40	79	253	766
Domestic cats	0	0	11	3	0	0	10	0	0	20	44
Domestic cattle	32	0	19	0	0	0	0	4	12	7	74
Domestic pigs	0	0	3	3	0	0	0	0	44	0	50
Domestic goats	4	0	0	0	0	0	4	4	4	0	16
Wild animal	0	2	0	0	0	0	0	0	0	3	5
Total	40	98	143	30	82	62	30	48	139	283	955

Table II: Number of animal rabies cases by species and year (2001–2021)

Animal species	Year																					
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Domestic dogs	4	12	76	80	132	16	28	106	48	44	12	40	20	28	16	48	20	6	6	18	6	766
Domestic cats	0	0	0	6	0	0	0	16	4	4	0	0	14	0	0	0	0	0	0	0	0	44
Domestic cattle	0	0	0	12	4	4	0	32	4	12	0	0	0	0	3	0	0	0	0	3	0	74
Domestic goats	0	0	0	4	0	0	8	0	0	0	0	0	0	0	4	0	0	0	0	0	0	16
Domestic pigs	0	0	3	0	44	0	0	0	0	0	0	0	3	3	0	0	0	0	2	0	0	50
Wild Animal	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	5
Total	4	12	79	102	180	20	36	154	56	60	12	40	37	31	23	48	20	6	8	21	6	955

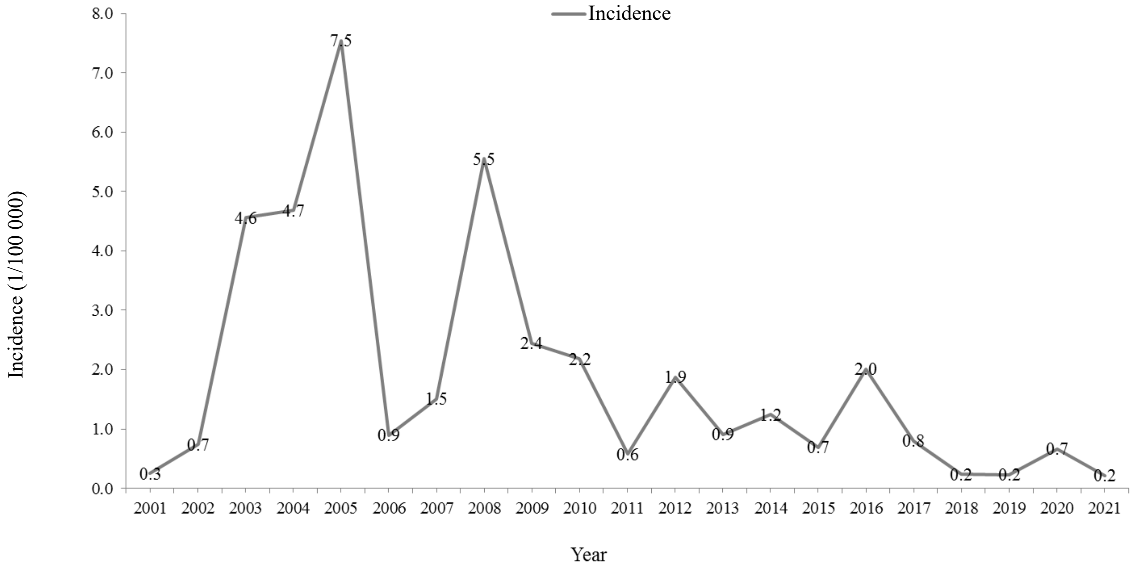

Figure 2: Incidence rates of dog rabies in Mozambique (2001–2021)

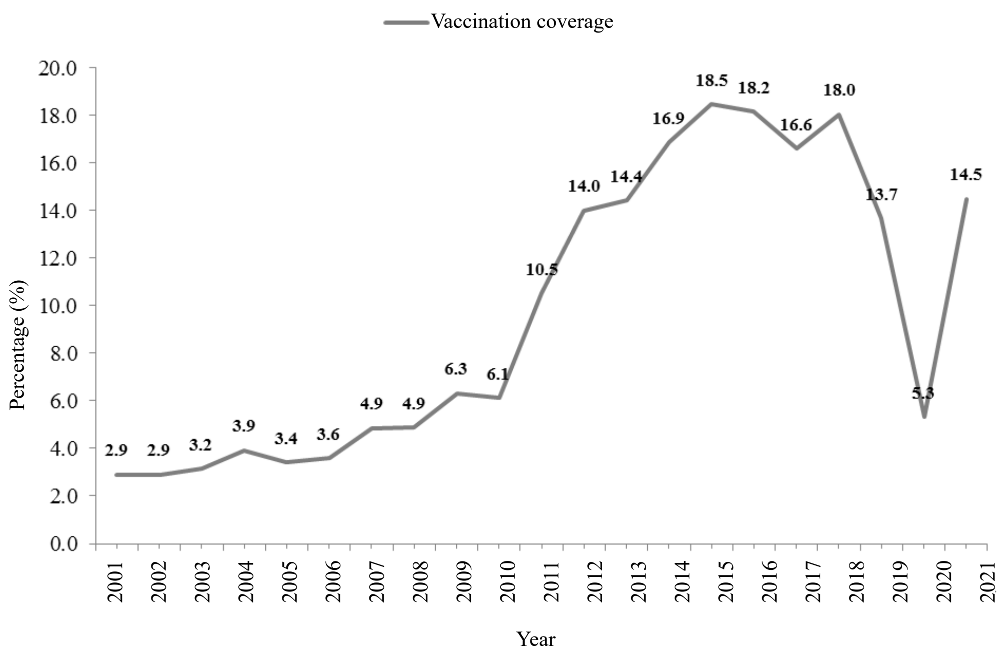

Figure 3: Dog vaccination coverage per year

Table III: Total number of dogs vaccinated by year and province (2001–2021)

Provinces	Year																					Total
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Niassa	2116	1903	2203	2188	1194	1728	1711	1832	1907	2106	2232	3587	4539	6217	7963	8211	9147	11269	8135	3128	14015	97331
Cabo Delgado	1522	2090	1640	1707	2060	4999	4677	4764	6466	4871	9814	8320	9597	8995	8726	10793	11398	12392	6909	1903	5501	129144
Nampula	4221	3846	1907	5625	5284	6877	5142	8750	13306	10943	10803	18489	27505	29207	35092	45995	31528	29442	16006	4201	18576	332745
Zambézia	4000	2670	7795	4903	8494	11448	8347	11053	10559	15853	4072	15323	23620	23952	29578	10125	21958	21885	22309	6450	24053	288447
Tete	3431	6758	4305	6010	7964	5641	20820	12466	11741	15585	12403	13551	17074	18479	22727	26704	26934	23683	9404	5255	17178	288113
Manica	4552	2787	7298	9253	5080	11349	8711	12826	21308	24821	22439	24834	28456	36230	35612	34277	30694	33241	29519	21707	28012	433006
Sofala	5069	13514	4725	12236	7132	6500	10286	13585	15555	15630	15464	17175	22942	29143	35005	35401	34976	37096	40914	21249	31173	424770
Inhambane	3620	5559	3920	3598	4135	3390	4078	6869	9804	10230	8970	15314	8703	14511	14942	16862	14717	14525	14204	1293	15511	194755
Gaza	6419	1801	5046	4671	6780	5114	6807	9231	15328	9584	15259	17207	10332	10471	15589	18938	17581	19688	11887	2515	23444	233692
Maputo	11351	5886	13801	16802	11536	7422	19744	11991	18248	14287	116805	165437	163895	203605	224253	226472	218028	261559	201696	76761	225345	2214924
Total	46301	46814	52640	66993	59659	64468	90323	93367	124222	123910	218261	299237	316663	380810	429487	433778	416961	464780	360983	144462	402808	4636927

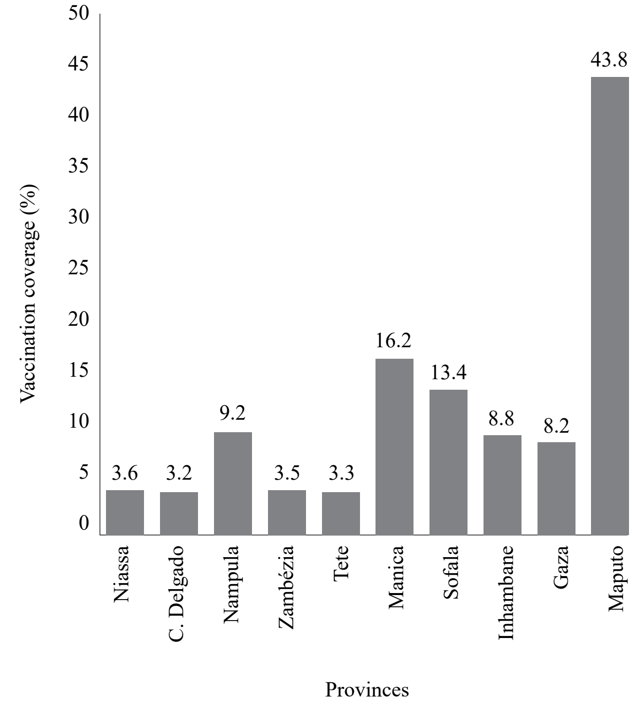

Figure 4: Dog vaccination coverage per province

Sofala (*n* = 30; 3.1%). A total of 26.5% (*n* = 253) rabies cases in dogs were registered in Maputo alone (Table I). Figure 1 shows the counts of dog rabies cases in each province of the country.

Number of animal rabies cases by species and year

Table II shows the number of animal rabies cases by species and year. The annual mean was 45.5 with a range of four (in 2001) to 180 (2005). Most cases were confirmed in domestic dogs (*n* = 766; 80.2%), and the remainder in domestic cattle (*n* = 74; 7.7%), domestic pigs (*n* = 50; 5.2%), domestic cats (*n* = 44; 4.6%), goats (*n* = 16; 1.7%) and five cases in unspecified wild animal species (0.5%). The highest occurrence in domestic dogs was observed in 2005 (*n* = 132; 13.8%). The total number of animal rabies cases covering a 21-year period (2001–2021 decreased on average by approximately 3.17 cases each year ($p = 0.065$). Since 2010, there has been a downward trend in the proportion of animal rabies cases ($p = 0.023$).

Dog rabies incidence rates per year

Figure 2 illustrates the incidence of dog rabies during the period covered by this study and the respective incidence rates. The year 2005 had the highest incidence rate (7.545 cases per 100 000 dog years at risk), while the year 2021 had the lowest incidence rate (0.216 cases per 100 000 dog years at risk).

Proportion of dogs vaccinated per year and province

Table III illustrates the number of dogs vaccinated per year and provinces. During the period of study (2001–2021), approximately 4.6 million dogs were vaccinated, with the year 2018 having more vaccinated dogs (*n* = 464 780; 10%), while 2001 had less vaccinated dogs (*n* = 46 301; 1%).

Of the 4 636 927 dogs vaccinated, Maputo had the highest proportion (*n* = 2 214 924; 47.8%) of vaccinated animals, while Niassa had the lowest proportion (*n* = 97 331; 2.1%).

Vaccination coverage per year and per province

Figures 3 and 4 illustrate the vaccination coverage for dogs by year and province, respectively. Vaccination coverage was highest in 2015 (18.5%). During the period in analysis, Maputo was the region with the highest vaccination coverage (43.8%).

Discussion

The major epidemiological driver of rabies in Mozambique is the domestic dog, as it is the primary reservoir and vector species, closely interacting with humans due to cultural practices of keeping dogs as pets and for security, as well as for herding and protecting livestock, especially in rural areas (Mapatse et al. 2022b). Limited resources for proper containment and management lead to the frequent presence of dogs around homes and public areas, increasing the risk of rabies transmission through close human-dog interactions (Knobel et al. 2005; Cleaveland et al. 2006). Understanding these dynamics is crucial for developing effective rabies control strategies. In terms of historical perspective and despite the fact that in recent years, there has been some investment by the government and partners to improve actions aimed at controlling rabies in Mozambique, during the period under study, the country has encountered persistent challenges in the surveillance and reporting of animal rabies cases. These challenges have been influenced by various factors, such as limited resources, infrastructure constraints, evolving of new reporting protocols, and fluctuations in surveillance practices. Other factors that may have led to a variation in the data over time include decentralised reporting systems, inconsistencies in data management practices, or limitations in technology and resources.

The high population density that accompanies rapid urbanisation and increases in the dog population, mainly in the suburban areas of the big cities such as Maputo and Nampula are major contributors to the occurrence of rabies in these regions (Salomao et al. 2017). In the suburban areas of these cities, there is also a lower educational level and a higher proportion of stray and unvaccinated dogs. In Maputo City, the notification of dog bite cases per inhabitant is the highest in the country (Salomao et al. 2017) but it is not clear if this merely reflects population density rather than any improved surveillance or reporting. Notwithstanding the human and dog ratio characteristic of some rural areas in African countries such as Zambia, Kenya and Mozambique (De Balogh et al. 1993; Kitala et al. 2001; Gsell et al. 2012; Mapatse 2021), the higher contribution of dogs to the occurrence of animal rabies should not be underestimated. As Maputo is the region where the largest veterinary diagnostic laboratory is located, it may also mean that the number of samples received from all corners of the country and tested at CVL is higher. In sub-Saharan countries, the growth in the dog populations is not accompanied by effective rabies control and prevention programmes (Kaare et al. 2009). This was seen in Mozambique, where the National Strategic Plan for Rabies Control was approved only in 2010 to fill such gaps. For provinces with lower occurrences of animal rabies cases, such as Zambézia, Sofala or Cabo Delgado, under-reporting and the lack of an effective disease notification system, particularly in remote (rural) areas, may be the cause of the low number of reported cases, especially in 2001 and 2002. This perception was also reported by Coetzer et al. (2017) and by Sabeta et al. (2021), who highlighted that in the 25 years from 1988 to 2012, laboratory detection of RABV in Mozambique was consistently hampered by limited sample submissions and lack of local diagnostic capacity. The contribution of other species, notably cattle, to overall animal rabies cases in some provinces of the country, such as Cabo Delgado, must be critically analysed because apart from suggesting spillover events, it may also mask the primary role of the dog in the maintenance of animal rabies cycle. Again, this arises from poor active surveillance to detect epidemiological events of lesser impact. Little is known about the involvement of wild carnivore species in rabies cycles in Mozambique. However, in rural areas, there are reports of wild carnivores such as jackals, mongooses, African wild dogs and hyenas showing typical symptoms of rabies (WHO 2013; Ministry of Health and Ministry of Agriculture and Rural Development 2019).

Between 2003 and 2005, there was a notable increase in the number of animal rabies cases, which can be attributed to improved communication, information and disease notification systems, associated particularly with improved mobile phone services throughout the country. Other studies have documented similar trends, where enhanced communication infrastructure has led to better disease reporting and surveillance (Mtema et al. 2016; Njenga et al. 2021). These improvements likely contributed to the observed increase in reported rabies cases during this period. Prior to 2003, all specimens from the central and northern regions of the country were processed and analysed at the CVL in Maputo. The decentralisation of laboratory diagnostic services has greatly contributed to an increase in the reported rabies cases. However, during the same period, rabies control through parenteral vaccination of dogs remained well below the 70% target levels recommended by the World Health Organization (WHO) to attain significant herd immunity in dog populations. This may have contributed to the increase in the numbers of dog rabies cases observed. The vaccination coverage varied significantly over the study period. From 2008 to 2017, there was a downward trend in the cases of rabies in the country. Again, under-reporting of cases, non-submission of samples for laboratory confirmation and limited diagnostic capacity may have contributed to such a decrease. Nevertheless, during this period, there were major interventions of the veterinary services to improve disease control through public-private partnerships (Ministry of Health and Ministry of Agriculture and Rural Development 2019). Other control measures included capture of stray dogs and enhanced public awareness in suburban communities and schools. According to data disclosed in the National Strategy Plan for Rabies Control (2010–2014) (Government of Mozambique 2010), there was a slight increase in vaccination coverage in dogs at risk in the country from 4.9% in 2007 to 14% in 2012, derived from increased provision of the vaccine by government and partners. However, despite these improvements, other factors may have masked the true situation of rabies during the period under review. According to Bragança (2005) and Mapatse et al. (2022b), in certain regions of the country, some habits and customs, in which aggressive dogs are driven away or even destroyed by the local communities, are still practiced, hence, the cause of animal death cannot always be confirmed. The vaccination coverage dropped substantially between 2018 and 2020, suggesting a regression rather than an improvement in recent years. Various potential factors, such as logistical challenges, funding limitations, and shifting public health priorities, may have contributed to this decline. These potential factors have been discussed in the context of rabies control programmes in other regions (Lembo et al. 2010; Davlin & VonVille 2012). This trend underscores the necessity for renewed efforts and strategies to enhance vaccination coverage and sustain rabies control programmes. Furthermore, one should note that in rural areas, notification and active or passive epidemiological surveillance systems for animal rabies is almost non-existent (Barreto et al. 2004; Salomao et al. 2017). In addition, a confirmed rabies case usually requires post-mortem laboratory confirmation (Franka et al. 2008; WOAH 2023). However, in the National Strategic Plan for Rabies Control in Mozambique (2020–2024) (Ministry of Health and Ministry of Agriculture and Rural Development 2019), it is not specified that laboratory confirmation is necessary to define animal rabies cases.

Limitations

First, while both laboratory-confirmed rabies cases and those classified based on clinical signs and historical data were included, the reliance on non-laboratory-based classifications introduces variability in the accuracy of rabies diagnosis. Cases classified on clinical signs or history may not always represent true rabies cases, potentially affecting the reliability of the data. Moreover, due to the overlap in clinical presentations between confirmed and suspected cases of animal rabies, classification bias might also have occurred. Data on the animal population at risk must also be taken into account when interpreting the results of the incidence rates and vaccination coverage, since this has been estimated. Finally, laboratories in Nampula and Gaza still use the Seller's stain, a test with low sensitivity that has been discontinued by the WOAH, could mean that there is a likelihood of some false negative results.

Despite these limitations, the study provides valuable insights into the current status of animal rabies and dog vaccination coverage in Mozambique and highlights areas where further improvements are needed to achieve the global goal of zero human rabies deaths by 2030.

Conclusions

The domestic dog is the main vector species reported with rabies in Mozambique. Maputo recorded the most confirmed animal rabies cases. Efforts to control rabies are not yet yielding the desired effects, although the number of animal rabies cases is decreasing. The observed decrease could be attributed to low sample submissions considering that the national vaccination coverage for rabies was lower than the 70% recommended by the WOAH. The systems for collecting, recording and reporting rabies data in the two ministries (Health and Agriculture and Rural Development) do have their limitations, but the One Health approach for rabies should be strengthened and advocated.

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Conflict of interest

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

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Ethical approval

This retrospective study on the occurrence of animal rabies, was approved by the Scientific Council of the Veterinary Faculty, Eduardo Mondlane University (CC-FAVET 28.06.2017).

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.

This article does not contain any studies with human or animal subjects.

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