2025, Scienceline Publication
World's Veterinary Journal
World Vet J, 15(3): 647-655.
ISSN 2322-4568

DOI: https://dx.doi.org/10.54203/scil.2025.wvj65
PII: S232245682500065-15

Spatial Analysis of Rabies Cases in West Sumatra Province, Indonesia during 2021-2024

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ORIGINAL ARTICLE
Received: June 25, 2025
Revised: July 29, 2025
Accepted: August 29, 2025
Published: September 25, 2025

ABSTRACT

The West Sumatra Province, Indonesia, has been an endemic rabies region since its initial rabies incident in 1953. This study aimed to analyze spatial patterns for rabies cases in animals in 19 districts/cities in West Sumatra Province, Indonesia. Secondary data on rabies-positive cases in animals were identified in 198 samples through the Fluorescent Antibody Test (FAT) obtained from the Bukittinggi Veterinary Center's database from 2021 to 2024. Statistical and spatial analyses were conducted in R Software v.4.4.2. The Moran's Index revealed a cluster distribution of rabies cases throughout the study period. The highest prevalence occurs in Lima Puluh Kota District (28.79%). The index indicated four regions as high-high quadrants, three regions as low-high quadrants, 11 regions as low-low quadrants, and one region as a high-low quadrant. However, Lima Puluh Kota District was consistently found as a region with substantial local spatial autocorrelation. In conclusion, the prevalence of rabies cases in animals in West Sumatra Province fluctuated during 2021-2024. Spatial analysis with Moran's Index and Local Indicator of Spatial Autocorrelation (LISA) indicated a cluster distribution of the disease. The current study underscored the need for targeted, location-specific control measures in these high-risk clusters to effectively mitigate the spread of the disease.

Keywords: Fluorescent Antibody Test, Moran's Index, Rabies, Spatial analysis

INTRODUCTION

Rabies is a fatal zoonotic disease caused by the rabies virus (RABV), a neurotropic virus classified within the genus *Lyssavirus*, from the *Rhabdoviridae* family (Kumar et al., 2023). It is a part of the *Mononegavirales* (MNV) order, which comprises single-stranded RNA viruses with non-segmented genomes. RABV is highly neurotrophic in mammals and causes encephalomyelitis after the virus infects the animal and reaches the brain (Marston et al., 2018). Rabies is one of the major zoonotic diseases, classified as a strategic priority disease in Indonesia due to its significant impact on public health and the socio-economic sector (Kemenkes RI, 2017). The overall yearly economic losses from rabies were projected to be 84.1 billion Rupiahs in Bali (Batan et al., 2015). This virus not only attacks animals such as dogs, bats, monkeys, foxes, and cats but is also zoonotic (Samad et al.,2024). This disease is mainly transmitted through dog bites (Kumar et al., 2023). Rabies has an incubation period of approximately 2 weeks to 6 years, with an average of 2 to 3 months (Samad et al., 2024).

The mortality rate of rabies in Indonesia remains relatively high, with 100 to 156 deaths in humans reported annually and a Case Fatality Rate (CFR) approaching 100%. Indonesia has experienced an average of 80,861 cases of rabies animal bites and 105 deaths per year (Kemenkes RI, 2020). From January to July 2024, Indonesia reported 71 human rabies fatalities (WHO, 2024). This report illustrated that rabies is still a serious threat to public health in Indonesia, making it one of the rabies-endemic countries; only 12 out of 34 provinces are free of rabies (Kementan RI, 2024).

The incidence of rabies initially occurred in 1953 in West Sumatra, which is still not free from rabies (Kemenkes RI, 2024). The total number of human casualties in 2024 was 7.369 cases, 3 of whom died of rabies in West Sumatra (Dinkes, 2024). Rabies-positive cases were identified through laboratory confirmation using the Fluorescent Antibody Test (FAT), the gold standard technique recommended by the World Health Organization (WHO) for rabies diagnosis in animals (Rupprecht et al., 2018). West Sumatra Province, Indonesia, is an endemic region with limited spatial epidemiological data on rabies cases. There have been no reports of spatial analysis of rabies cases applied to both global and local spatial autocorrelation. Therefore, this study aimed to analyze the spatial pattern and clustering trends of laboratory-confirmed rabies cases in West Sumatra Province from 2021 to 2024 using Moran's Index and Indicator of Spatial Autocorrelation (LISA).

To cite this paper: Amira K, Susetya H, and Tjahajati I (2025). Spatial Analysis of Rabies Cases in West Sumatra Province, Indonesia during 2021-2024. *World Vet. J.*, 15(3): 647-655. DOI: https://dx.doi.org/10.54203/scil.2025.wvj65

MATERIALS AND METHODS

Ethical approval

This study has been conducted in accordance with institutional guidelines and has passed ethical clearance from the Medical and Health Research Ethics Committee (MHREC), Universitas Gadjah Mada, Indonesia, under certificate number KE/FK/0551/EC/2025.

Data source

This study used 198 samples submitted for rabies testing at the Bukittinggi Veterinary Center, Indonesia, from 2021 to 2024, obtained from 19 districts/cities in West Sumatra Province, Indonesia (Figure 1). The samples were animal brain specimens collected by district veterinary officers using passive surveillance and outbreak reporting systems. The Fluorescent Antibody Test is considered the gold standard for rabies diagnosis, providing consistent results in more than 95% of the cases (Rupprecht et al., 2018; Kachhawaha and Tanwar, 2024). This study was conducted from April to May 2025.

Figure 1. The location of study in West Sumatra Province, Indonesia

Statistical analysis

The data required for this autocorrelation analysis included information on rabies-positive cases in animals and official maps of West Sumatra Province. The first step was to merge the West Sumatra Province map with the rabies case dataset. The data integration process generated georeferenced rabies surveillance data, combining laboratory-confirmed case counts with their spatial distribution across the infected areas. The second stage was to create a spatial weighting matrix to determine the observed weights between locations based on the relationship between locations (Kosfeld et al., 2006). The statistical and spatial analysis of Moran's Index and Local Indicator of Spatial Autocorrelation were fed into R Software (v.4.4.2). Spatial autocorrelation measurements were calculated using Moran's Index. Spatial randomness can indicate the presence of clustering patterns or forming trends in space. The Moran's Index method was employed with a standardized spatial weighting matrix W through the following equation (Moraga, 2023; Wibowo et al., 2024).

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\ (x_{i-}\bar{x})(x_{j-}\bar{x})}{\sum_{i\neq j}^{n} w_{ij}\ \sum_{i=1}^{n}(x_{i-}\bar{x})}$$

The LISA statistic for each region *i* was formulated as follows (Wibowo et al., 2024).

$$I_i = \frac{z_i}{m_2}\sum_{j=1}^{n} w_{ij}\, z_j$$

$$z_i = (x_i - \bar{x})$$

$$z_j = (x_j - \bar{x})$$

$$m_2 = \sum_{i=1}^{n}\frac{(x_i - \bar{x})^2}{n}$$

Moran's Index (I) measures spatial autocorrelation, indicating whether similar values cluster or disperse geographically. It compares values (x_i, x_j) against the mean ($\bar{x}$), weighted by proximity (w_{ij}) with values ranging from -1 to 1. Positive values ($0 < I \leq 1$) show clustering of similar values, negative values ($-1 \leq I < 0$) indicate dispersion, and $I \approx 0$ suggests randomness. Moreover, extreme values ($|I| \geq 1$) reveal strong patterns (Moraga, 2023; Wibowo et al., 2024).

The Moran's Index results were visualized using a Moran Scatterplot to analyze rabies case patterns. The scatterplot plots each location's Z-score against its neighbors' average Z-scores, revealing spatial correlations (Zhukov, 2010). The Z-score was computed as $Z(I) = [I - E(I)]/\sqrt{VAR(I)}$, where I is the observed Moran's Index, E(I) is its expected value (null hypothesis), and VAR(I) is its variance. The regions were classified into four quadrants.

While Moran's Index measures overall spatial autocorrelation, it cannot identify localized patterns between individual locations and their neighbors. The LISA addresses this limitation by analyzing spatial associations at each specific observation point and its immediate surroundings to better understand the local spatial relationships at each location. Moreover, information derived from LISA is essential. The LISA statistic I used to measure local spatial autocorrelation at location i, computed from n observations (x_i, x_j), their mean $\bar{x}$, and their spatial weights w_{ij}. The null hypothesis (H_0: $I_i = 0$) was rejected when $|Z(I_i)| > Z_{a/2}$, indicating significant local clustering/dispersion (Lee and Wong, 2001).

RESULTS

During the period from 2021 to 2024, 198 positive rabies cases were identified in the animals under study. Details of annual positive rabies cases in West Sumatra Province are presented in Table 1. Based on Table 1, the proportion of rabies-infected cases confirmed by the Bukittinggi Veterinary Center is an average of 58.22%. In 2021, there were 47 positive cases of rabies (61.04%); in 2022, there were 37 cases (59.68%); in 2023, there were 54 cases (50.94%); and in 2024, the highest number of cases was 60 (61.22%).

Rabies cases in West Sumatra Province during the observation period showed an uneven distribution in each district/city. Lima Puluh Kota District recorded the highest number of cases, namely 57 cases, which is approximately 28.79% of the confirmed cases. Agam District and West Pasaman District ranked second, each with 31 cases (15.66%), while Sijunjung District recorded 22 cases (11.11%). Several other areas, such as Tanah Datar District, Payakumbuh City, Padang Pariaman District, and Bukittinggi City, indicated a lower number of infected cases, ranging from 3 to 6 cases. However, there are several areas with very low incidence rates or no cases at all, such as the South Pesisir District and Solok District, as well as the Kepulauan Mentawai District, which possesses a rabies-free status.

The value of Moran's Index designates a clustered pattern, including 0.2202 in 2021, 0.327 in 2022, 0.3212 in 2023, and 0.2893 in 2024. The pattern of rabies cases in West Sumatra Province, Indonesia, based on Moran's Index (0.2805) from 2021 to 2024 has the same pattern, i.e., the clustered pattern (positive autocorrelation).

Table 1. The prevalence of rabies-infected cases in animals during 2021-2024 in West Sumatra Province, Indonesia

Year	Number of Samples	Positive	Prevalence (%)
2021	77	47	61.04 %
2022	62	37	59.68 %
2023	106	54	50.94 %
2024	98	60	61.22 %
Total	343	198	58.22 %

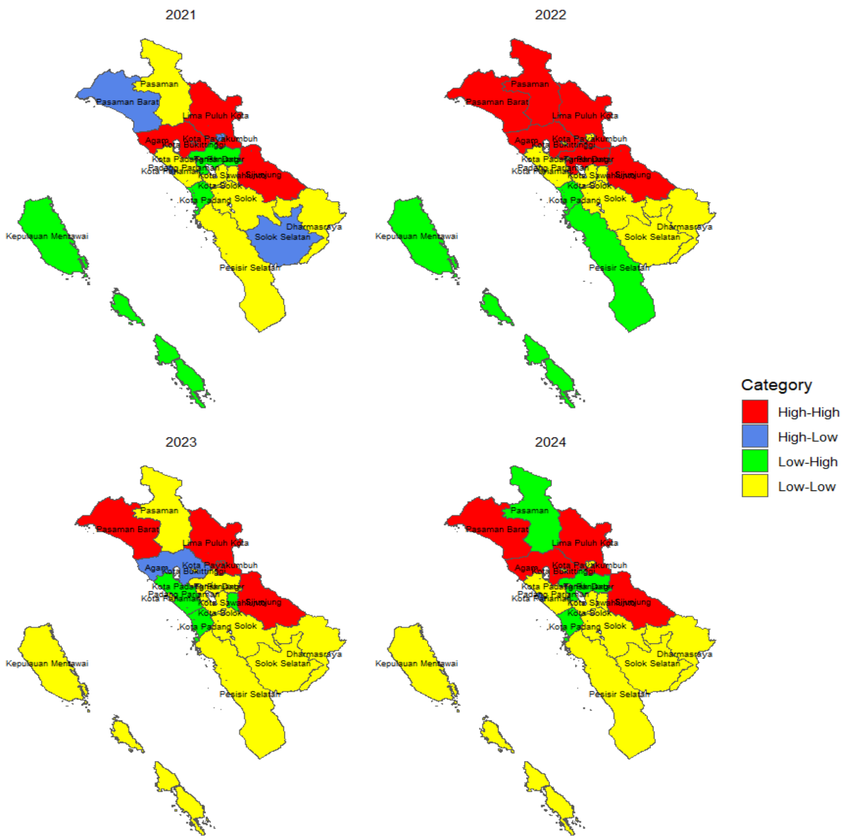

Figure 2. Moran Scatterplots showing global spatial autocorrelation of rabies cases during 2021-2024 in West Sumatra, Indonesia

Figure 2 shows the dynamics of the spatial distribution of rabies cases based on Moran's I quadrant classification during the 2021-2024 period. The region was classified into 4 quadrants, including high-high (HH), low-high (LH)/coldspot, low-low (LL), and high-low (HL)/hotspot, based on their spatial patterns (Shrestha et al., 2023). The Hotpot quadrant is an area with high cases surrounded by areas with low cases, while a coldspot is an area with low cases surrounded by areas with high cases (Ekowati et al., 2021). The number of districts/cities classified as high-low (hotspots) and low-high (coldspots) fluctuates annually. Overall, the results indicated that the rabies hotspot (high-low) areas most often appear in Pariaman City in 2021 and 2024. In 2023, only the Agam District was included in the hotspot, and no region was identified as a hotspot area in 2022. However, Padang city was consistently a coldspot area with Kepulauan Mentawai and Tanah Datar Districts as areas where a coldspot could most often be identified.

The results of the analysis of the spread of the spatial pattern of annual rabies cases are presented in Figure 2. A comparison of these results with those of cumulative observations over four years, presented in Figure 3, shows that there is only one district (Payakumbuh), which is included in the hotspot category, and there are three districts identified in the coldspot category (Padang, Pasaman, and Tanah Datar) from 2021 to 2024. The areas classified as hotspots, coldspots, and those in Quadrant I and Quadrant III for rabies cases in West Sumatra Province are shown thematically in figures 2 and 3, and further detailed in Table 2.

The identification of spatial autocorrelation at the local level was carried out using the LISA method, with the LISA value of each district/city in West Sumatra presented to show the strength and pattern of spatial relationships between districts/cities. High and positive LISA values in the Lima Puluh Kota District suggest the presence of local spatial autocorrelation. According to this research, there is a geographical clustering pattern in the frequency of rabies cases in these locations, which tends to be comparable to that of nearby places. In 2022, such trends were also noted in the districts of Agam and Lima Puluh Kota (Figure 4). Overall, Lima Puluh Kota District demonstrated consistency as an area with notable local spatial autocorrelations between 2021 and 2024 (Figure 5).

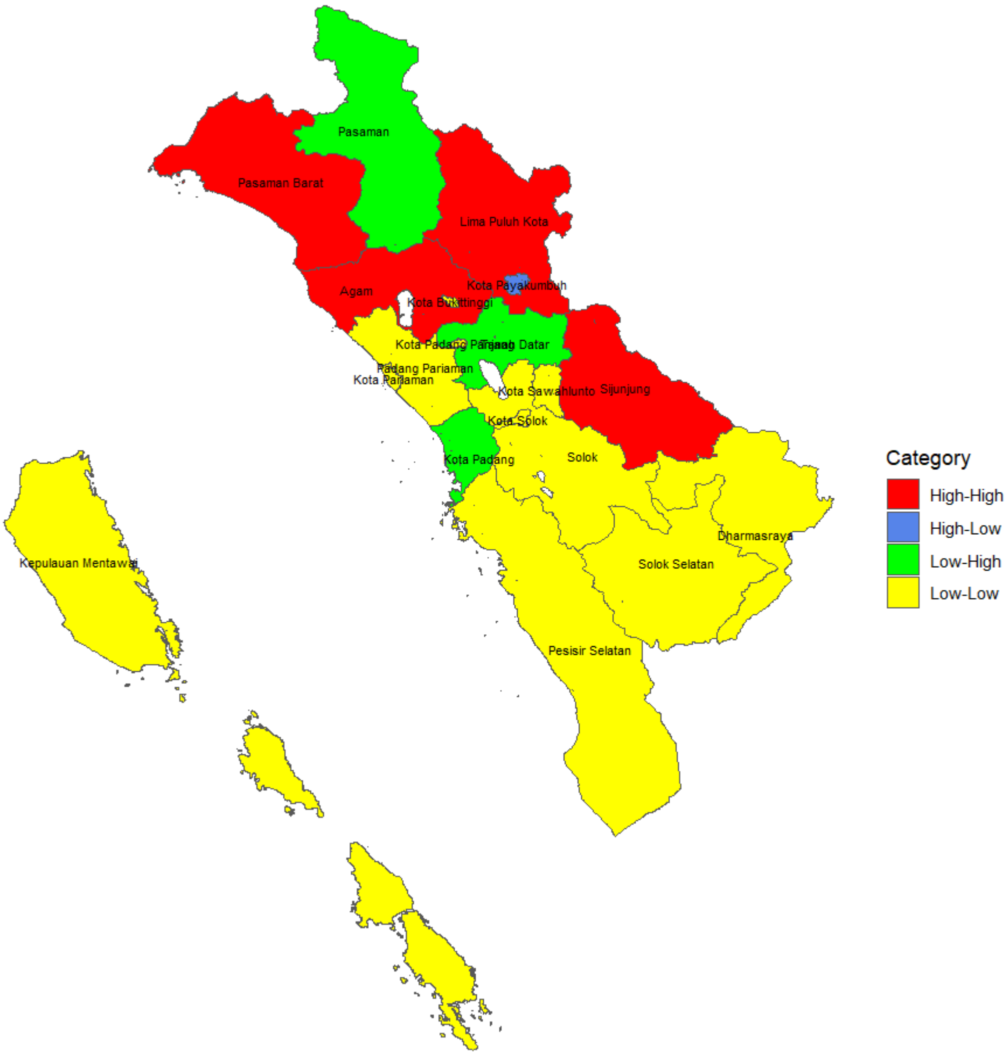

Figure 3. The distribution of rabies cases for four years of observation (2021-2024) in West Sumatra Province, Indonesia, based on Moran's Scatterplot.

Table 2. Districts/cities that are hotspots, coldspots, quadrant I, and quadrant III of rabies cases during 2021-2024 in West Sumatra Province, Indonesia

Year	Quadrant	Districts/Cities
2021	Quadrant I (High-High)	Bukittinggi, Agam, Lima Puluh Kota, Sijunjung
	Quadrant II (Coldspot)	Kepulauan Mentawai, Padang, Tanah Datar
	Quadrant III (Low-Low)	Dharmasraya, Padang Panjang, Sawahlunto, Solok, Padang Pariaman, South Pesisir, Pasaman, Kota Solok
	Quadrant IV (Hotspot)	Payakumbuh, South Solok, Pariaman, Pasaman Barat
2022	Quadrant I (High-High)	Pasaman, Tanah Datar, Agam, Lima Puluh Kota, Pasaman Barat, Sijunjung
	Quadrant II (Coldspot)	Kepulauan Mentawai, South Pesisir, Padang
	Quadrant III (Low-Low)	Dharmasraya, Bukittinggi, Padang Panjang, Payakumbuh, Kota Solok, Sawahlunto, Padang Pariaman, Solok, South Solok, Pariaman
	Quadrant IV (Hotspot)	-
2023	Quadrant I (High-High)	Payakumbuh, Lima Puluh Kota, Pasaman Barat, Sijunjung
	Quadrant II (Coldspot)	Sawahlunto, Padang Pariaman, Padang
	Quadrant III (Low-Low)	Dharmasraya, Kepulauan Mentawai, Bukittinggi, Padang Panjang, Solok, South Pesisir, South Solok, Pasaman, Tanah Datar, Pariaman, Kota Solok
	Quadrant IV (Hotspot)	Agam District
2024	Quadrant I (High-High)	Agam, Lima Puluh Kota, West Pasaman, Sijunjung
	Quadrant II (Coldspot)	Padang, Pasaman, Tanah Datar
	Quadrant III (Low-Low)	Dharmasraya, Kepulauan Mentawai, Bukittinggi, Kota Solok Padang Panjang, Payakumbuh, Sawahlunto, Padang Pariaman, South Pesisir, Solok, South Solok
	Quadrant IV (Hotspot)	Pariaman
2021-2024	Quadrant I (High-High)	Agam, Lima Puluh Kota, West Pasaman, Sijunjung
	Quadrant II (Coldspot)	Padang, Pasaman, Tanah Datar
	Quadrant III (Low-Low)	Dharmasraya, Kepulauan Mentawai, Bukittinggi, Padang Panjang, Sawahlunto, Solok, Padang Pariaman, South Pesisir, South Solok, Pariaman, Kota Solok
	Quadrant IV (Hotspot)	Payakumbuh

Figure 4. The LISA Moran's I rabies cases in West Sumatra Province, Indonesia during 2021-2024

Figure 5. The LISA Moran's I rabies cases in West Sumatra Province, Indonesia, during 2021-2024

DISCUSSION

Based on Statistics West Sumatra Province (2023), there were 19 regencies/cities in West Sumatra Province, Indonesia, and only Kepulauan Mentawai Regency is currently rabies-free (Kementan RI, 2024). Based on the results of the present study (2021-2024), the pattern of rabies cases in West Sumatra was a cluster pattern, where the districts with high positive cases were the neighboring districts. These findings aligned with existing study demonstrating clustered spatial distributions of rabies cases in Indonesia, particularly along Sumatra's Western and Eastern coasts, West Java, East Java, West Nusa Tenggara, and Kalimantan (Ward, 2014). The clustering pattern shown by both Moran's I and LISA statistics suggests spatial dependence among the districts. This means that districts with high case numbers are often surrounded by similarly high-case neighbors, possibly due to shared ecological, cultural, and human-animal interface factors (Ekowati et al., 2021). Spatial analysis of rabies in Bali and North Tapanuli, Indonesia, revealed important patterns and factors influencing disease spread. The studies in Bali and North Tapanuli showed that rabies cases in both regions had a spatially clustered pattern, with high-risk areas surrounded by low-risk areas, and vice versa (Ekowati et al., 2021; Simanjuntak et al., 2024).

Moran's Index data revealed that the most prevalent rabies hotspots were in Lima Puluh Kota District, Sijunjung District, Agam District, and the west Pasaman District. Lima Puluh Kota and Sijunjung Districts had the maximum number of cases of bites and were the hotspots for rabies cases in West Sumatra province from 2021 to 2024. The LISA method showed consistency in the Lima Puluh Kota District as a region with significant local spatial autocorrelations. These findings indicated that Lima Puluh Kota District and its surroundings are rabies cluster areas that require special attention in the formulation of spatial disease control and prevention strategies. According to Fadillah et al. (2021), the practice of dog owners in Lima Puluh Kota District reflected a lack of socialization and communication, information, and education activities. Further emphasis on rabies control programs is needed for dog owners who focus on responsibility for dog ownership. Targeted vaccination and movement control programs should prioritize these high-risk clusters, particularly in districts like Lima Puluh Kota, where rabies has persisted for several years. Risk factors associated with rabies incidence include animal care practices, vaccination status, and human behavior (Saepudin et al., 2022).

Direct contact with infected dogs is the only way to determine if rabies is being transmitted in West Sumatra. Although bites and scratches are two definite ways that rabies is spread, animal licking can also cause instances (WHO, 2023). The high frequency of infectious rabies in West Sumatra is intimately related to the community's long-standing custom of raising dogs to hunt wild boars (Rahmah et al., 2017; Dalimunthe et al., 2025). Community traffic activities and the buying and selling of dogs are contributing factors to the rise in rabies cases. Most dogs from outside West Sumatra province came from Sukabumi Regency in West Java Province, which remains rabies-free (Wicaksono et al., 2018).

Various efforts have been made to suppress the incidence of rabies. The primary goal of rabies eradication targeted the vaccination and elimination of dogs, but this initiative is hindered by the lack of public awareness regarding pet health. For instance, many people have never vaccinated their pets, the management system remains ineffective and is inadequately supervised, and there is insufficient community outreach on rabies prevention.

CONCLUSION

The prevalence of rabies-infected cases in animals from 2021 to 2024 in West Sumatra Province was 58.22 %, identified from 198 rabies-positive samples in animals. Spatial analysis of rabies cases in West Sumatra Province revealed significant clustering patterns (positive autocorrelation) based on Moran's Index. Hotspot areas with high case concentrations were identified in Agam, Lima Puluh Kota, West Pasaman, and Sijunjung Districts. LISA analysis (2021-2024) particularly highlighted Lima Puluh Kota District as a persistent area of significant local spatial autocorrelation, confirming its status as a core rabies transmission zone. These results underscore the need for targeted, location-specific control measures in such high-risk clusters to mitigate disease spread effectively.

DECLARATIONS

Funding

This study is not funded by any external entity.

Availability of data and materials

All data generated or analyzed during this study are included in this published article. Additional data are available from the corresponding author upon reasonable request.

Acknowledgments

The authors would like to express my sincere gratitude to my research supervisor for their invaluable guidance, expertise, and continuous support throughout the course of this study. Special appreciation is also extended to the Bukittinggi Veterinary Center, the Department of Animal Husbandry and Animal Health of West Sumatra Province, and the Department of Public Health of West Sumatra Province for their valuable insights, data access, and collaborative contributions.

Authors' contributions

Kartika Amira was responsible for the overall design and execution of the research, data collection, analysis, and preparation of the draft of the manuscript. Heru Susetya and Ida Tjahajati assisted in the conceptualization of the research. Kartika Amira, Heru Susetya, and Ida Tjahajati revised the manuscript after corrections from the reviewer. All authors have read and approved the final version of the manuscript before publication in the present journal.

Competing interests
There is no conflict of interest in this study.

Ethical considerations

All the authors have read and approved the final manuscript. All authors checked the originality of data and sentences via plagiarism checkers.

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