ECONOMICS OF THE 2021-2022 LUMPY SKIN DISEASE (LSD) OUTBREAK IN MALAYSIA: INSIGHTS FROM THE GLOBAL BURDEN OF ANIMAL DISEASES (GBADs) FRAMEWORK

NABILAH, A.T[1,2], SITI NORSYAKIRAH, H.[2], MOHAMAD FAIZUL SHAHRIL, M.R.[2], SYAMIRA SYAZUANA, Z.[4], MARK, B.[3], AND NORHARIANI, M.N.[1*]

1 Department of Veterinary Preclinical Sciences, Faculty of Veterinary Medicine, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia
2 Department of Veterinary Services, Wisma Tani, Blok Podium 4G1, Federal Government Administration Centre, 62624 Putrajaya, Malaysia
3 Department of Agribusiness and Bioresource Economic, Faculty of Agriculture, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia
4 Department of Veterinary Clinical Sciences, Faculty of Veterinary Medicine, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
**Corresponding author*: norhariani@upm.edu.my

ABSTRACT. Lumpy skin disease (LSD) is a viral disease that mainly affects cattle and buffalo. It has been first detected in South Africa since 1944 and first appeared in Southeast Asia in 2020. In Malaysia, the first case were found in May 2021 in Perak, with infection in dairy cattle and later spreading across Peninsular Malaysia. LSD has caused a significant socio-economic impact on affected country, especially affecting small-scale farming and trade due to treatment costs and productivity losses. This study focuses on the prevalence, mitigation and risk factors of LSD based on a biocost-LSD framework at farm, state, and national levels. The analysis covered the period from the first case in May 2021 to May 2022 and also assesses biweekly trends. The data relies solely from official reports by the Department of Veterinary Services (DVS), comprising of surveillance data collected from 504 animal farms, including one farm with gaur. The results showed a national prevalence rate of 3%. The case fatality rate was 5.12%, and the mortality rate was 0.15%. Kelantan and Terengganu had the highest number of farms with LSD, while Selangor reported the most cattle deaths. Biweekly trends showed that from May to August, LSD spread more quickly. This increase was linked to animal movement during the Aidiladha and Aidilfitri festivals and changes during the monsoon season. Key risk factors identified include farm management practices, especially among small-scale beef cattle farmers with fewer than 30 animals. This study helps build a basic understanding of how LSD spreads in Malaysia and supports generating national animal disease dataset for better systematic approaches in mitigation strategies of future transboundary diseases.

Keywords: Lumpy skin disease (LSD), socio-economic, risk factors, prevalence, biological output

INTRODUCTION

Lumpy Skin Disease (LSD) is a contagious viral disease caused by the Lumpy Skin Disease Virus (LSDV), a member of the genus *Capripoxvirus* within the family *Poxviridae*. The disease primarily affects large ruminants, particularly cattle and domestic water buffalo, resulting in significant health and economic challenges (Ratyotha *et al.*, 2022). Since its first outbreak in 1929 in Zambia, LSD has spread across Africa and later to parts of Europe and Asia. By 2020, Southeast Asia saw its first cases in Vietnam and Myanmar, with the disease spreading to Thailand, Laos, and Malaysia by 2021. According to Ratyotha *et al.* (2022), LSD is a newly emerging disease in Southeast Asia, necessitating further research into the economic impacts and distribution patterns of the disease in the region.

The rapid spread of LSD into Malaysia was preceded by precautionary measures taken by the Department of Veterinary Services (DVS) as early as 2019, following the disease's appearance in Bangladesh. These steps included distributing information about LSD to DVS staff and restricting the importation of live cattle after the disease was detected in Thailand. DVS also implemented clinical surveillance on local ruminant farms and disseminated information for example infographic leaflets and pamphlets, as well as conducting forum series. through official digital channels such as Facebook, Instagram, radios and official meetings (DVS, 2022). Despite these efforts, the first confirmed LSD case in Malaysia occurred on 10 May 2021, in Perak involving a dairy farm, where the virus was confirmed via Polymerase Chain Reaction (PCR) testing conducted by the Veterinary Research Institute (VRI). LSD clinical signs had been previously observed in cattle quarantined in northern Peninsular Malaysia (Khoo *et al.*, 2022). Following the outbreak, DVS implemented aggressive control measures, including infected LSD farm movement restrictions, culling infected cattle, heightened surveillance, and farm biosecurity efforts (Muhid *et al.*, 2021). These measures aimed to curb further spread, however, the disease continued to affect multiple states, culminating in an official report to the World Organization for Animal Health (WOAH) on 21 June 2021. It was reported that LSD appeared in Malaysia following the outbreak in Thailand (Arjkumpa *et al.*, 2022).

LSD's impact on the ruminant industry extends beyond livestock animal health, affecting the socio-economic well-being of small-scale farmers. Research has shown that LSD leads to reduced milk yield, quality loss, decreased fertility, poor-quality hides, and higher morbidity, among other factors (Sprygin *et al.*, 2019; Calistri *et al.*, 2018). Comparative studies in Ethiopia and Kenya revealed both direct and indirect economic losses at the farm level, providing the financial burden faced by affected farmers (Farah Gumbe, 2018; Kiplagat *et al.*, 2020). In Malaysia, food security is a national priority. With a growing population, there is an increasing need for both white and red meat, particularly in the beef industry. However, the sustainability of beef production is challenged by the lack of a large cattle population (Mark *et al.*, 2021). According to the Ministry of Agriculture and Food Security (MAFS), beef and milk production are essential protein sources, yet the ruminant livestock industry, largely composed of small-scale farms (92%), remains underdeveloped, with a self-sufficiency level of only 18.9% for beef and 61% for milk (DVS, 2022). The presence of LSD in Malaysia further complicates efforts to stabilize and expand this livestock production industry.

Several Southeast Asian countries, such as Thailand and Vietnam, have published studies on the prevalence of LSD and the associated risk factors. Thailand, for instance, reported a prevalence rate of 27%, the highest in the region. In contrast, Malaysia has yet to publish comprehensive data on LSD, leaving a critical gap in basic understanding of the disease's spread and risk factors within the country. This study seeks to address this gap by investigating the prevalence of LSD in Peninsular Malaysia and identifying risk factors related to the outbreak that occurred between May 2021 and May 2022. The objective of this study is to determine the spread of LSD in Peninsular Malaysia, including a biweekly analysis of cases by state and cattle category (beef and dairy). Additionally, the study aims to identify basic risk factors contributing to the spread of LSD, thus providing vital data for future control measures and mitigate the economic impact on the livestock industry. Despite the disease's significant implications, little has been published on the gaps in risk factor investigations, making this study timely and essential for addressing the challenges posed by LSD in Malaysia.

MATERIALS AND METHOD

Ethical approval

The official authorization to conduct this study and obtain formal data on the LSD outbreak was granted on 27 November 2023 by the Research Division of the DVS.

Study area

The study was conducted in 11 states of Peninsular Malaysia (Perlis, Kedah, Penang, Perak, Selangor, Negeri Sembilan, Melaka, Johor, Pahang, Terengganu, and Kelantan) which was affected by LSD from 2021 to 2022. (DVS, 2022). The comprehensive distribution of cattle population and LSD cases in Peninsular Malaysia is as shown in Figure 1a (DVS Malaysia, 2022).

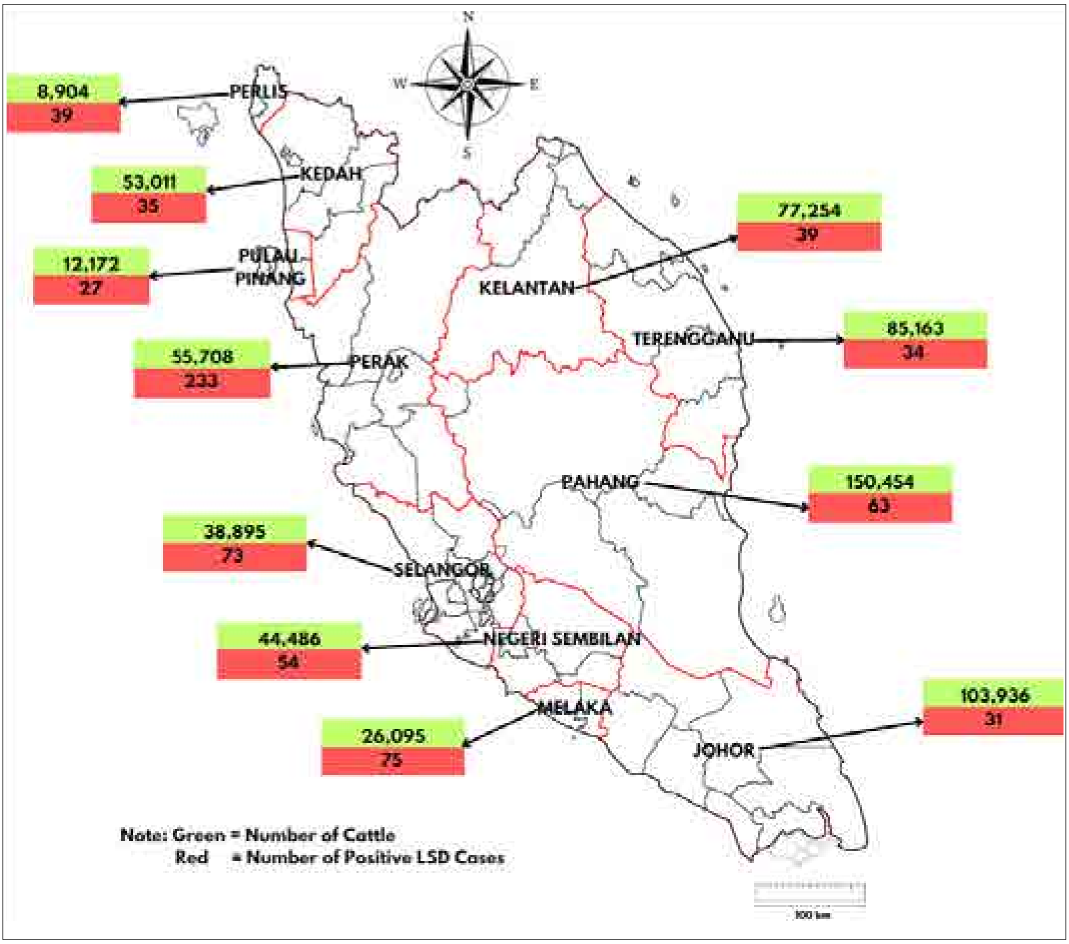


Figure 1a. The number of cattle affected with LSD in various states across Peninsular Malaysia.

Study design

The official LSD outbreak data was analyzed using the Global Burden of Animal Diseases (GBADs) framework by Rushton (2009) and Rushton *et al.*, (2018) to determine the spread and risk factors in this study (Figure 1b). It clarifies the dimensions of LSD spread by identifying areas that are more likely to experience visible and invisible loss impact from the disease. Additionally, it highlights key factors that contribute to the spread, such as poor biosecurity, climate conditions, or cattle category and also impact from mitigation actions during an outbreak. The framework aids in predicting future outbreaks and targeting interventions, allowing for more precise control of the disease at different stages and under various risk conditions.

The data on the LSD outbreak in Malaysia was obtained from the Animal Disease Control and Veterinary Biosecurity Division of the DVS Malaysia. Through this data, a total of 504 large ruminants (N=504) farms were surveyed. LSD surveillance was carried out both actively and passively throughout the country by the state DVS during the LSD outbreak from 2021 to 2022. This data was collected using the Epidemic Surveillance Form (Epis 01) used by DVS to carry out annual surveillance activities. Reports for each surveillance from state DVS were submitted to the Epidemiology and Surveillance Section of DVS Malaysia through Epis 01. Epis 01 consists of data on the farm identification (ID) of LSD-infected farms, their location (state, district), farm management system, cattle population, type and breed of animals, number of cattle showing LSD symptoms, their movement history, and the type of samples taken.

Any actions taken during the inspection activities were reported using the Epis 06 form. Epis 06 includes data on the number of LSD-infected cattle treated, the number of cattle deaths due to LSD, the number of cattle culled, the number of cattle slaughtered, the number of disinfection activities carried out, the number of samples taken, and information about awareness campaigns. Additionally, data on LSD-infected cattle culled at ruminant abattoirs were obtained from the Regulatory Division to support the work. This

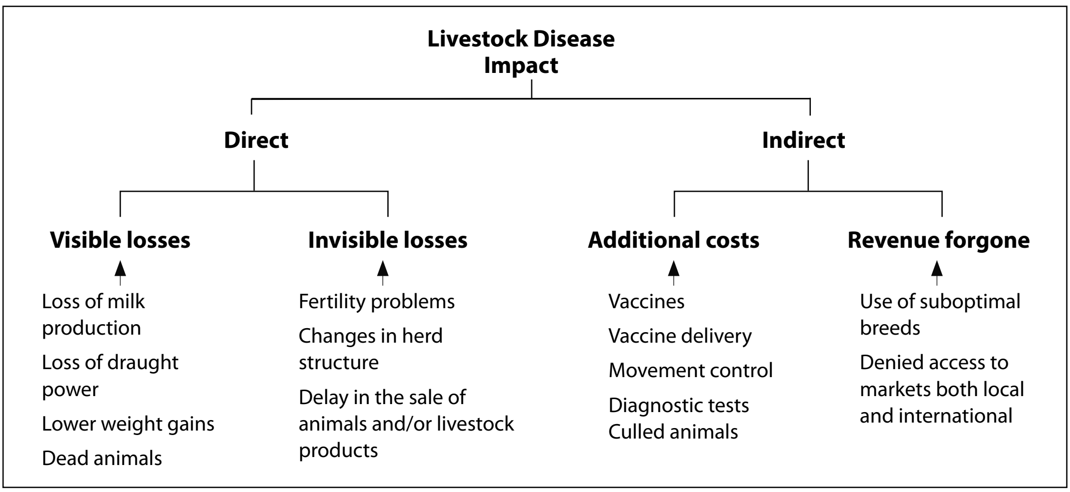


Figure 1b. The impact of livestock disease in GBADs (Rushton,2009; Rushton *et al.*, 2018)

explains how the animal disease reporting system is implemented in Malaysia. The comparison was measured based on two categories of cattle; (i) dairy and (ii) beef cattle. In addition, out of 504 farm surveillance cases, only one case involved the gaur and was included in the entire study. The assessment is evaluated according to the affected states, cattle categories and biweekly trends at the farm, industry and national level to provide a comprehensive overview associated with LSD occurrence in Malaysia.

Data editing

Official LSD outbreaks from DVS were checked and merged between the Epis 01 and Epis 06 reports. Basically, Epis 01 is used to report LSD cases detected with or without laboratory confirmation, while Epis 06 is used to report any control and prevention measures implemented during LSD management at the farm and state level. The data merging was done using Microsoft Excel 365 (Microsoft, USA). From the data, continuous and categorical variables were generated for descriptive analysis using IBM SPSS Statistics Version 29 (IBM Corporation, Armonk, New York).

RESULTS

A. Direct loss

i) Biological output at national level

Prevalence rate

The LSD outbreak revealed that Kelantan had the highest prevalence rate at 9.4% (N=39/414) in the respective cattle farms. Terengganu followed closely behind with a rate of 8.7% (N=34/392). Although Perak recorded a high number of confirmed cases of LSD in 233 cattle, the LSD prevalence rate was only 3.9% due to the large population at the farm level at the time of LSD farm surveillance. Pahang exhibited the lowest prevalence of LSD at 0.9%, despite having a substantial cattle population of 6,819, with only 63 confirmed LSD cases identified during surveillance (Figure 2a). The study found that the overall prevalence due to LSD in Peninsular Malaysia was 3% (Appendix A).

Mortality rate and fatality case rate

As shown in Figure 2b, Selangor had the highest number of cattle deaths due to LSD infection, with 28 out of 97 cattle that showed clinical signs died

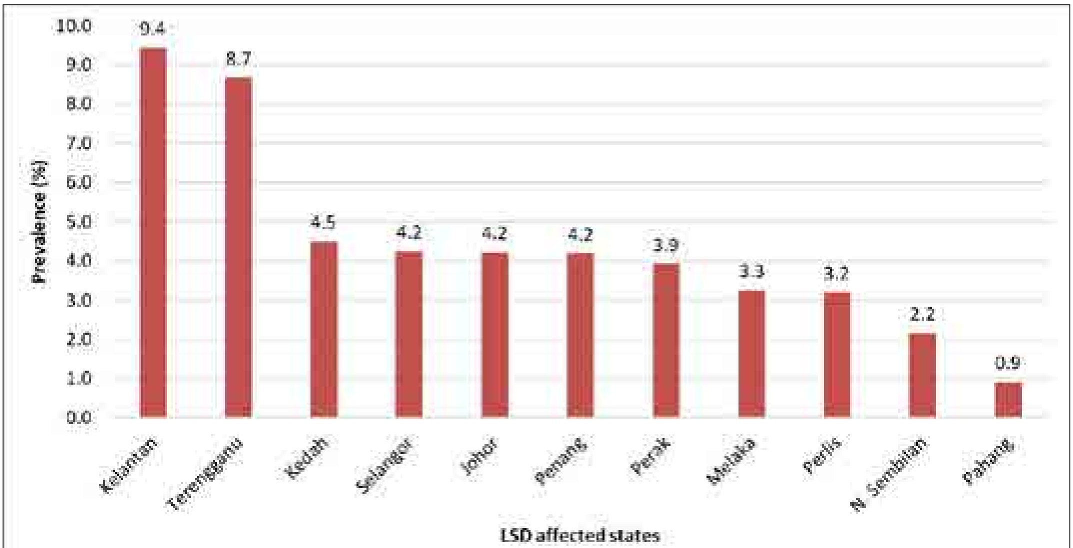


Figure 2a. LSD prevalence status of 11 states in Peninsular Malaysia from Year 2021 to Year 2022

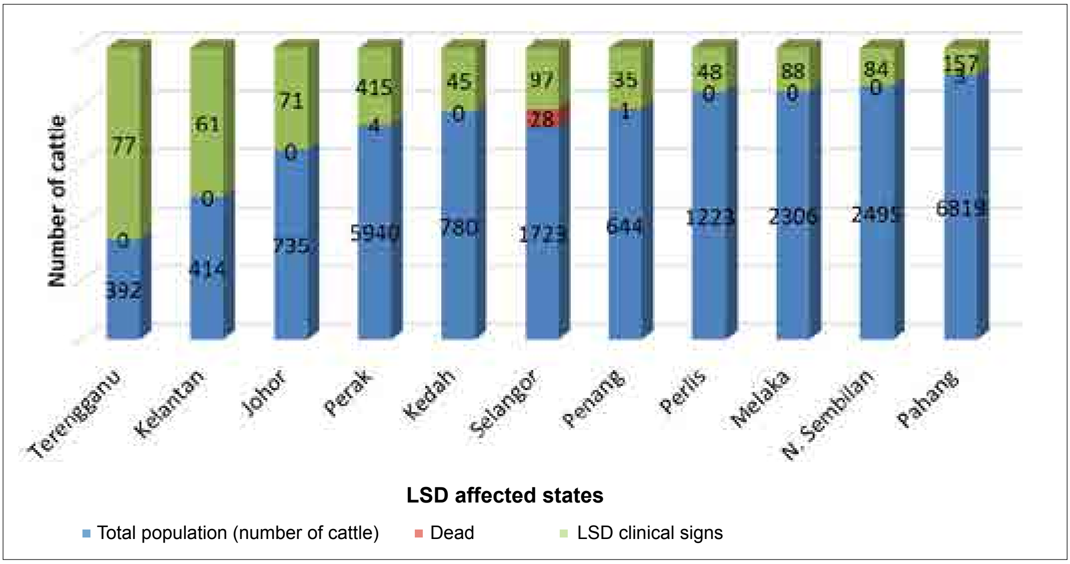


Figure 2b. Summary of mortality and case fatality rate for 504 cattle farms in Peninsular Malaysia.

from the disease. The number of cattle deaths was statistically low in all other states, with most not reporting any cattle deaths. Only Perak, Penang, and Pahang reported fewer than four cattle deaths at the farm level. Interestingly, despite having the highest number of cattle showing LSD clinical signs (N=415), Perak reported a low number of deaths due to LSD. Overall, the case fatality and mortality rate in Malaysia was 5.12% and 0.15% respectively as presented in Appendix A.

Bi-weekly trends in LSD cases and culling measures

The trend occurrence of LSD can be seen in Figure 3a and 3b, prevalence (%) (herd-biweekly) reflects the proportion of affected cattle within the herd during each biweekly period. Notable peaks occurred during W1Mei (13.8%), W2Jun (6.0%), W2Aug (10.7%), and W1Jan02 (50.0%). These fluctuations indicate varying levels of disease spread. Simultaneously, the number of positive LSD farms reveals how many farms were impacted by the disease during each biweekly interval. While there is some correlation with prevalence, it doesn't strictly follow the same pattern. For instance, in June, there was a significant increase in positive LSD farms despite a moderate prevalence rate. Moreover, the number of LSD cattle culled at DVS abattoir provides insights into the severity of the outbreak. Peaks in culling align with higher prevalence periods (as shown in W2Jun, and W1Sep). Overall, a total of 670 cattle heads were culled.

Figure 3c illustrates the surge in reported LSD cases during weeks W2Mei, W1Jun, and W2Jun. Perak consistently reported high incidence of LSD during these periods. In Week W2Jun, there was a substantial spike in cases across multiple states, including Perak, Kelantan and Perlis. Perak maintained the highest number of cases, followed by Melaka and Selangor. During W1Mei, Perak experienced its first occurrence of LSD, while W2Mei saw first LSD cases in Kedah, Melaka, and Terengganu. In week one of June, almost all states were affected by LSD, with Perak still reporting the highest number of cases. Negeri Sembilan began experiencing LSD cases in W1Jul, two months after the initial occurrence in Peninsular Malaysia. The spike in cases occurred again during W1Sep and W2Sept, with Perak, Melaka, and Selangor being the most affected. Subsequently, the number of LSD cases gradually decreased, and in 2022, only three cases were reported: one from Negeri Sembilan (W1Jan02), one from Selangor (W2Feb02), and the last reported case from Perlis (W2Mei02).

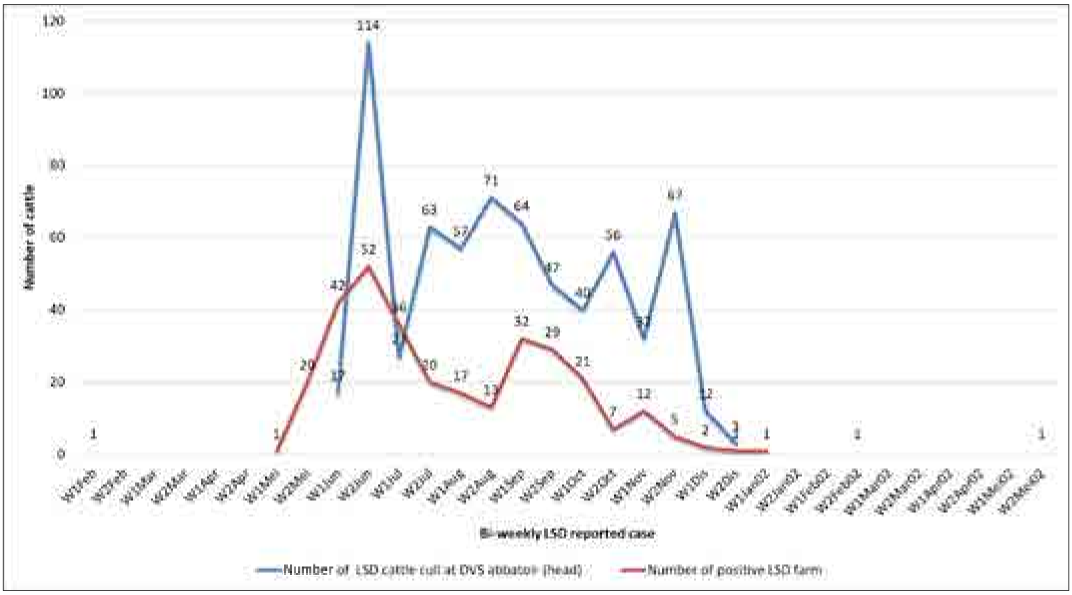


Figure 3a. Number of cattle culled and affected farms associated with LSD in one year LSD outbreak.

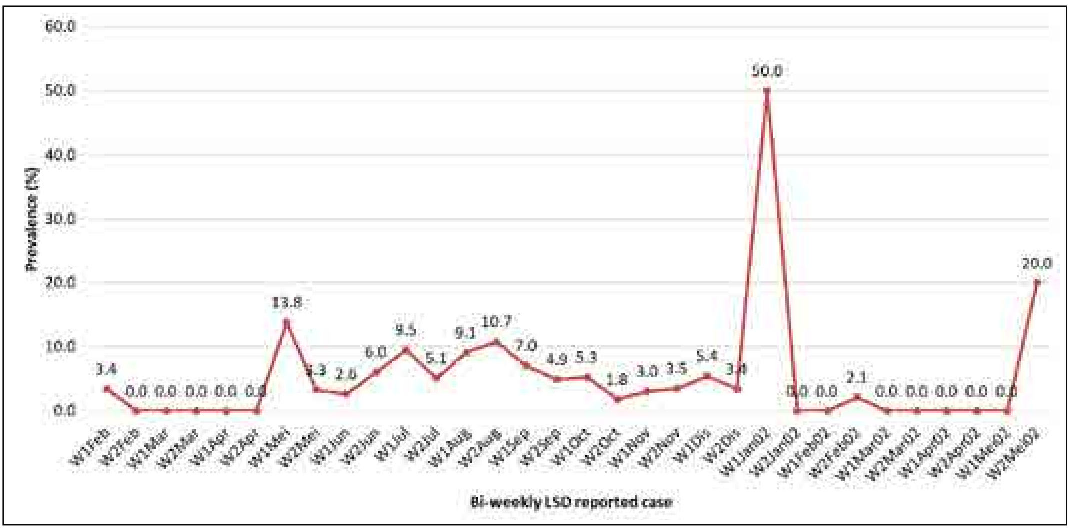
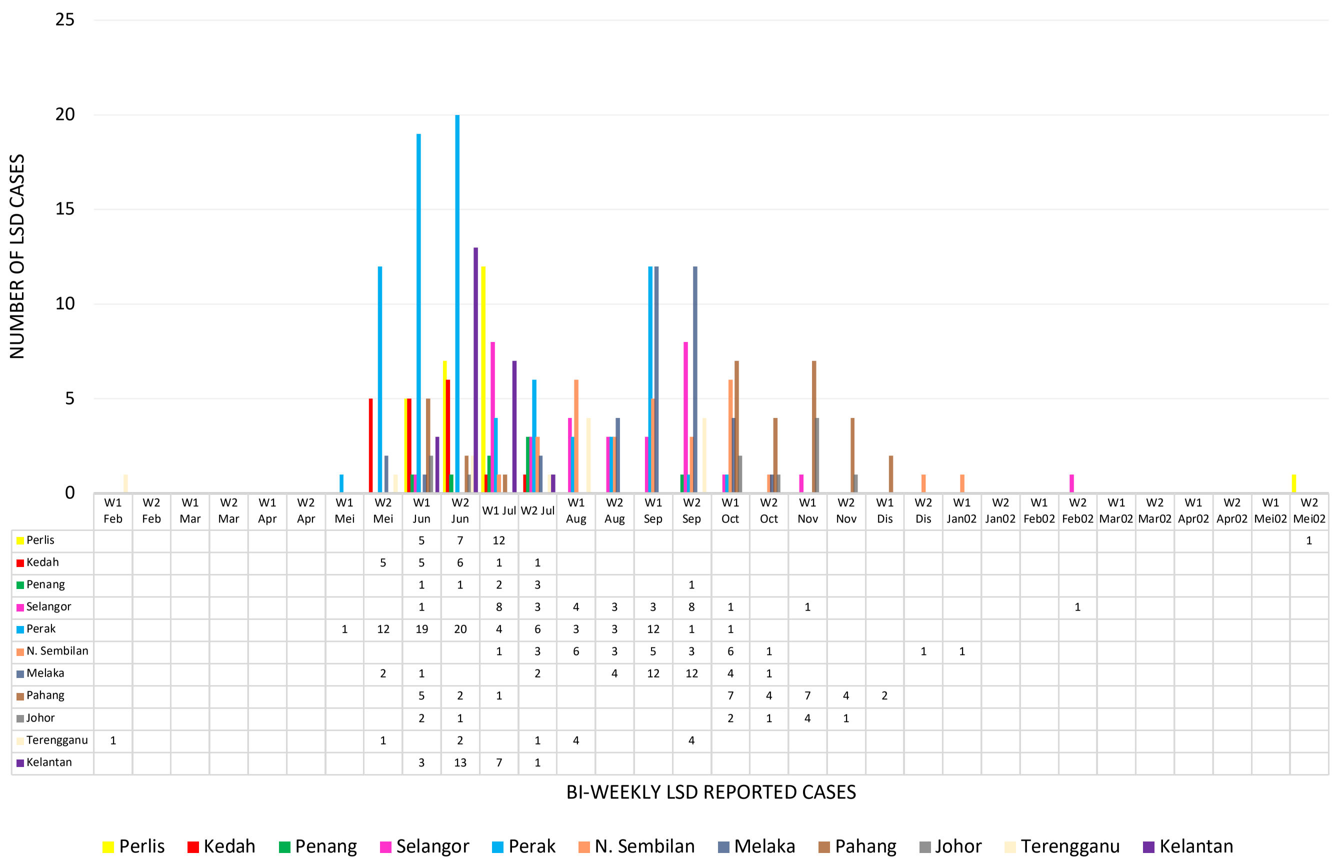


Figure 3b. Overall trend of LSD outbreak in Peninsular Malaysia from 2021 to 2022.



	W1 Feb	W2 Feb	W1 Mar	W2 Mar	W1 Apr	W2 Apr	W1 Mei	W2 Mei	W1 Jun	W2 Jun	W1 Jul	W2 Jul	W1 Aug	W2 Aug	W1 Sep	W2 Sep
Perlis									5	7	12					
Kedah								5	5	6	1	1				
Penang									1	1	2	3				1
Selangor									1		8	3	4	3	3	8
Perak							1	12	19	20	4	6	3	3	12	1
N. Sembilan											1	3	6	3	5	3
Melaka								2	1			2		4	12	12
Pahang									5	2	1					
Johor									2	1						
Terengganu	1							1		2		1	4			4
Kelantan									3	13	7	1				

	W1 Oct	W2 Oct	W1 Nov	W2 Nov	W1 Dis	W2 Dis	W1 Jan02	W2 Jan02	W1 Feb02	W2 Feb02	W1 Mar02	W2 Mar02	W1 Apr02	W2 Apr02	W1 Mei02	W2 Mei02
Perlis																1
Kedah																
Penang																
Selangor	1		1							1						
Perak	1															
N. Sembilan	6	1				1	1									
Melaka	4	1														
Pahang	7	4	7	4	2											
Johor	2	1	4	1												
Terengganu																
Kelantan																

Figure 3c. Biweekly trends in LSD incidence across 11 states in Peninsular Malaysia.

ii) Biological output at industry level

Mortality

The average number of cattle deaths due to LSD was 2 from beef farm and 1 from dairy farm with a maximum of 10 deaths reported in beef farms.

The comparative descriptive direct loss analysis between the categories of beef and dairy cattle, as presented in Appendix B, shows that the average treatment for LSD-infected cattle per farm was 2 for beef (ranging from 1 to 50) and 1 for dairy (ranging from 1 to 11). The maximum number of LSD-infected cattle culled was 28 for beef with an average of 2, while for dairy, the average was 1 with a maximum of 10 cattle culled. Beef farms had the highest number of quarantine orders, with an average of 5 cattle ordered to be quarantined per farm (ranging from 1 to 682). Both beef and dairy cattle prominently showed LSD clinical signs per farm with an average of 2. However, the minimum number of cattle showing symptoms was 1-50 in beef and 1-11 in dairy per farm. Sanitation was conducted by farms with an average of 2 (ranging from 1 to 3) for both dairy and beef. Sampling was the same for beef and dairy cattle with 2 samples taken with maximum number of sampling at 682 for beef cattle, while the maximum number of samples taken for dairy cattle was 11.

As depicted in Figure 4, beef cattle have higher rate of deaths by LSD at 86% (30), while dairy cattle have lower rate of death by 14% (5). The most significant occurrence of LSD infection in Peninsular Malaysia was in the beef category, with a prevalence of 3% (confirmed positive beef cattle/total beef cattle = 632/18405) compared to dairy cattle.

iii) Biological output at farm level

Descriptive analysis on farm demography and structure

An analysis of the LSD outbreak data from May 2021 to May 2022, obtained from the DVS through Epis 01 and Epis 06 surveillance forms, revealed that out of 504 cattle farms under LSD surveillance during the outbreak, 314 (62%) cattle farms were confirmed positive for LSD through laboratory tests. Meanwhile, 56 cattle

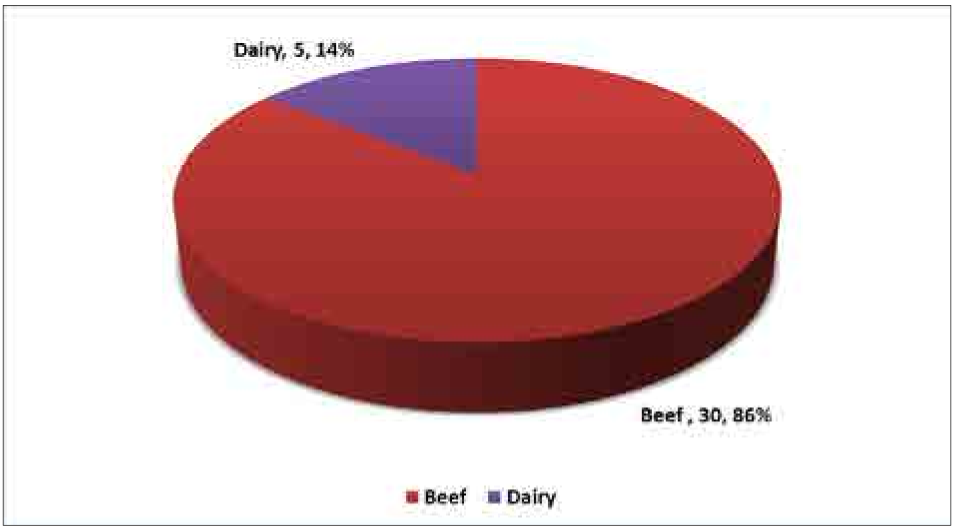


Figure 4. Number of cattle deaths due to LSD based on cattle category during LSD surveillance from 2021 to 2022.

Table 1. Descriptive summary of cattle farm structure and LSD risk during LSD surveillance in Year 2021 to Year 2022 for overall cattle farm N=504, Positive cattle farm N=314 and Negative cattle farm N=134

Variables	Levels / categories	N 504	Counts (n)	Percent (%)	N 314	Counts (n)	Percent (%)	N 134	Counts (n)	Percent (%)
Farm status	Negative		134	26.6						
	Positive		314	62.3						
	Suspected		56	11.1						
Farm management	Extensive		105	20.8		44	8.7		49	9.7
	Semi Extensive		153	30.3		117	23.2		24	4.8
	Integration		28	5.6		23	4.6		5	1
	Intensive		206	40.9		121	24		53	10.5
	No data		12	2.4		9	1.8		3	0.6
Farm size	Small scale (<30 cattle per farm)		321	63.7		182	36.1		97	19.2
	Semi-commercial (30-50 cattle per farm)		69	13.7		51	10.1		13	2.6
	Commercial (>50 cattle per farm)		108	21.4		76	15.1		24	4.8
	No data		6	1.2		5	0.1		-	-
Cattle breed	Indigenous beef (Kedah-Kelantan)		103	20.4		115	22.8		56	11.1
	Exotic beef (beef cross)		330	65.5		148	29.4		61	12
	Indigenous dairy (local Indian Dairy)		5	1.0		5	0.1		-	-
	Exotic Dairy (dairy crossbreed)		49	9.7		36	7.1		11	2.2
	Bos Gaurus Hubackki		1	0.2		1	0.2		-	-
	No data		16	3.2		9	1.8		-	-
Cattle category	Beef cattle		456	90.4		277	54.9		124	24.6
	Dairy cattle		47	9.3		36	7.1		10	46.9
	Gaur		1	0.2		1	0.2		-	-
Movement history	No		84	16.7		55	10.9		27	5.4
	Yes		36	7.1		17	3.4		17	3.4
	No data		384	76.2		242	48		90	17.9

farms were under suspicion (quo suspected), and 134 cattle farms were found to be negative (Table 1). It revealed that farms employing integration and semi-extensive management systems face a similar risk of infection, with rates of 24% and 23.2% respectively. It can be seen that small scale cattle farms (<30 cattle per farm) are the most affected, representing 36.1% of the cases with 182 cattle farms. They are followed by commercial farms (>50 cattle per farm) at 15.1%, and semi-commercial farms at 10.1%. The majority of cattle affected by LSD where beef cattle with beef crossbreed followed by indigenous breeds, while dairy cattle made up only 7.1% of the cases. Moreover, the analysis revealed that the movement history of the cattle was not a relevant factor in assessing the risk of LSD. This conclusion was drawn despite the fact that half of the reports did not include complete information on the cattle's movement history. In the analysis of LSD, reports from 11 DVS states indicated that 76% of surveillance notes did not include information about animal movement history.

However, Chi-Square test reveals all p-values associated with the LSD cases were remarkably small (<0.000), which indicates a significant relationship between LSD cases to the farm management system, farm size, cattle category and breed of cattle. These results suggest that different farm management systems significantly influence LSD occurrence. Additionally, farm size played an important role in influencing the disease. Furthermore, different cattle breeds exhibit varying susceptibility to LSD. Lastly, the cattle category likely influences LSD occurrence, while movement history significantly affects the prevalence of the disease (Appendix C).

B. Indirect loss

i) Biological output at national level

The initial phase of LSD mitigation measures involved 504 cattle farms, as shown in Figure 5. These measures included culling infected cattle, quarantining infected cattle, and providing supportive treatment for suspected or confirmed cases. Although there is no specific treatment for LSD, supportive care is given to improve cattle health, reduce pain, and promote animal welfare. A comparative analysis of initial control measures across Malaysia indicates varying levels of engagement by state. Perak leads with robust involvement in all control measures. Selangor,

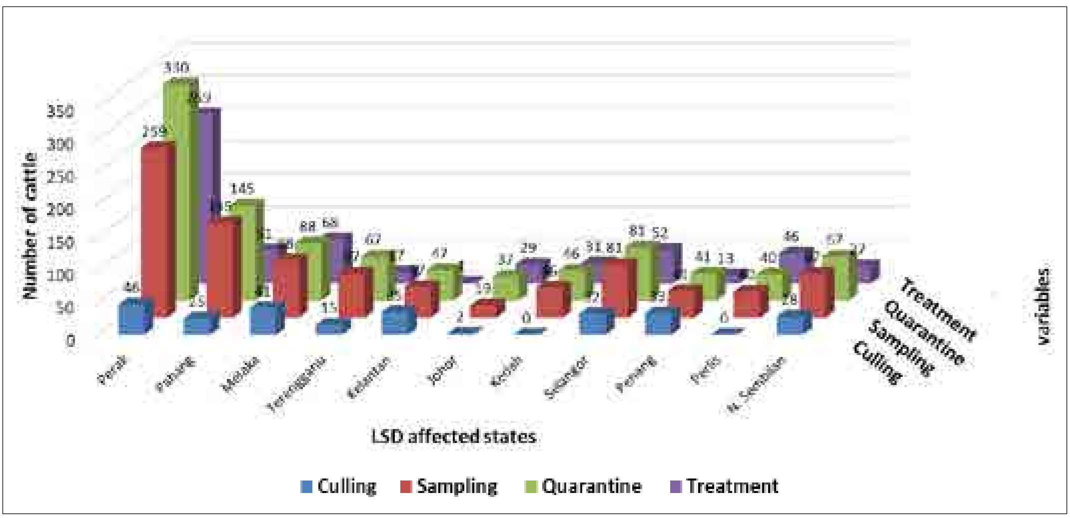


Figure 5. Comparison of the LSD mitigations applied during LSD surveillance from 2021 to 2022 outbreak in 11 states for 504 cattle farms in continuous variables.

Melaka and Pahang showed moderate to high engagement, while Terengganu and Negeri Sembilan demonstrated moderate involvement. In contrast, Penang and Kelantan exhibit limited interventions, with minimal activity. Johor and Perlis have the lowest engagement levels, indicating limited efforts in culling, sampling, quarantine, and treatment.

The summary of the descriptive analysis on LSD mitigation measures across various states, as presented in Appendix D, shows that Selangor had the highest average number of cattle receiving supportive treatment for LSD (mean = 7, 1-40), followed by Johor (mean = 4, 1-7). Other states, including Perak (1-3), Penang (1-5), and Pahang (1-17), had a mean value of 3. For culling orders, Penang had the highest mean with 8 cattle culled per farm (1-20), with Perak following closely with a mean of 5 (1-28). No culling orders were reported in Kedah and Perlis. The death rate of LSD-infected cattle was very low in Peninsular Malaysia, with no deaths recorded in some farms and a maximum of only 2 deaths per farm recorded in Perak (1-3) and Selangor (1-10), with 1 each for Penang and Pahang. Most farms recorded an average of 1 to 3 sanitation activities, with a maximum of 3 reported in most states. The mean number of samples taken per farm ranged from 1 to 4, with a maximum of 50 samples taken from a single farm. Pahang had the highest number of LSD cattle quarantined, with 682 cattle quarantined and a state mean of 17, followed by Selangor with a mean of 8 (1-100). However, the mean number of LSD clinical signs observed directly on the farm was 2 to 3 for all states. Johor, Perak, and Penang had a mean of 3 (10-50), while other states had a mean of 2 (4-17).

Table 2 presents the immediate actions taken by the DVS during the LSD outbreak. The first immediate response was LSD sampling. The data indicates that mixed LSD samples, which include blood, swabs, and LSD nodule scrapings, were taken from 58.1% of the 504 cattle farms surveyed. LSD nodules made up two-thirds of the samples taken from the cattle farms, accounting for 18.8% of the total cattle farm population. Serum sampling was the least common, contributing to only 0.2% of the total farms.

The second response was the imposition of movement restrictions. These restrictions were enforced on 54.2% (273) of the cattle farms to prevent the disease from spreading. However, for 31.1% (157) of the farms, there was no information available about such restrictions. At the same time, the DVS implemented awareness campaigns in 89.3% (450) of the cattle farms.

Table 2. Descriptive summary of mitigation measures during LSD outbreak for N= 504 cattle farms, Positive cattle farm N=314 and Negative cattle farm N=134 from 2021 to 2022

		OVERALL			LSD POSITIVE			LSD NEGATIVE		
Variables	**Levels / categories**	**N 504**	**Counts (n)**	**Percent (%)**	**N 314**	**Counts (n)**	**Percent (%)**	**N 134**	**Counts (n)**	**Percent (%)**
Type of sampling	Blood		35	7.0		20	3.9		15	2.9
	Swab		8	1.6		7	1.4		2	0.4
	LSD nodules		95	18.8		93	18.5		2	0.4
	Mix samples		293	58.1		187	37.1		106	21.0
	Serum		1	0.2		1	0.2		-	-
	No data		72	14.3		6	1.2		10	2.0
Movement restrictions	No		74	14.7		46	9.1		25	5.0
	Yes		273	54.2		177	35.1		56	11.1
	No data		157	31.1		91	18.1		53	10.5
Awareness campaign	No		54	10.7		28	5.6		23	4.6
	Yes		450	89.3		286	56.7		111	22.0

ii) Biological output at industry level

The majority of the mitigation activities (treatment, culling, sampling, and quarantine) measures, were predominantly implemented in beef cattle farms (Figure 6a). This aligns with the higher prevalence of LSD in beef cattle. Additionally, sanitation activities were particularly emphasized in beef cattle compared to dairy cattle farms (Figure 6b).

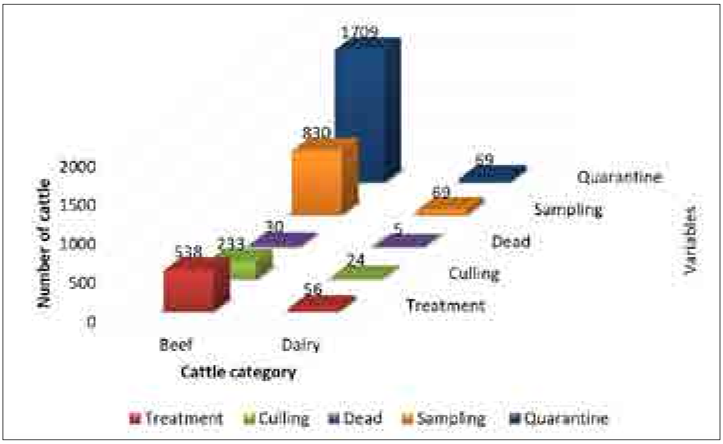


Figure 6a. Comparison of the continuous variables based on cattle category during LSD surveillance for 504 cattle farms.

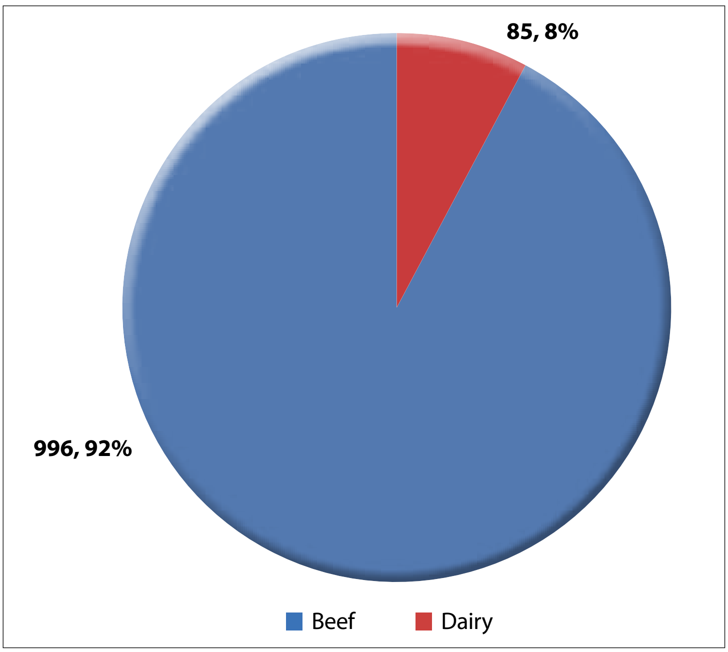


Figure 6b. Number of farm sanitation during LSD surveillance.

iii) Biological output at farm level

LSD control and prevention measures

Table 3 provide a descriptive summary on several variables during LSD surveillance on 504 farms. During the LSD outbreak, farms had an average of 47 cattle, ranging from 1 to 3440. On average, 4 cattle were quarantined per farm. Supportive treatment was provided to 2 cattle per farm on average, and there were 2 cattle deaths per farm. Each farm was sanitized an average of 2 times, and 2 samples were taken per farm, with a maximum of 50 samples during surveillance. These findings highlight the extensive measures taken to control and prevent LSD spread.

DISCUSSION

From May 2021 to May 2022, Malaysia experienced an outbreak of LSD, with a prevalence of 3% across 11/16 states (13 states and 3 federal territories). The prevalence was determined based on the number of animals exhibiting clinical signs of LSD confirmed by laboratory tests, relative to the total animal population surveyed in each state during the outbreak. Interestingly, the results did not correlate with the size of the animal population in each state. For example, Perlis, despite having the smallest cattle population in Malaysia, reported a prevalence of 3.2%. The detection of LSD in cattle is significantly influenced by the farm management system. For instance, Pahang, despite having the largest cattle population in Malaysia, presents unique challenges. The integration of cattle into oil palm plantations complicates the detection of clinical signs of LSD. Consequently, this results in a lower prevalence rate, even though the total number of cattle surveyed in Pahang surpasses that of other states. In a separate study, Wilhelm *et al.* (2023) reported a 19% prevalence rate for LSD in Malaysia, following Thailand and Cambodia, with rates of 37% and 22.4% respectively (Wilhelm &

Table 3. Descriptive summary of continuous variables during LSD surveillance for N=504 farms in 2021 to 2022.

Variables (Per Farm)	Mean	Std. Deviation	Median	Minimum	Maximum	Total
Total cattle population	47	171	16	1	3440	23471
Number of cattle with LSD clinical signs	2	4	1	1	50	1179
Number of cattle treated	2	4	1	1	50	594
Number of cattle deaths	2	2	1	1	10	36
Number of cattle quarantined	4	35	1	1	682	1778
Number of cattle culled	1	3	1	0	28	257
Number of farm sanitation	2	1	3	1	3	1084
Number of samplings	2	3	1	0	50	900

Ward, 2023). However, Wilhelm's investigation spanned from October 2020 to October 2021. The first detection of LSD in Malaysia was confirmed through PCR testing of skin nodules and whole blood from dairy cattle, revealing the presence of LSD virus nucleic acids (Khoo *et al.*, 2022). The first report to the WOAH from Malaysia was made on 10 May 2021, which aligns with the timeline reported by Wilhelm in his study article (Wilhelm & Ward, 2023).

Moreover, the by-weekly reported in highest prevalence of LSD at the farm level exceeded 50%, aligning with a similar study conducted in Ethiopia, where a 55% prevalence was observed of 330 cattle farms (Gari *et al.*, 2010). Despite the differences in the studies conducted by Kiplagat *et al*. (2020) and Arjkumpa *et al*. (2024). the prevalence at the farm level was found to be 25% in Kenya and 33% in Thailand. However, the morbidity case prevalence rate was higher in both countries, with the highest being 37% in Southeast Thailand and 7% in Kenya, as reported in 2020 (Arjkumpa *et al.*, 2024; Kiplagat *et al.*, 2020). The variation in results can be attributed to factors such as the duration of the study, the area of study, and the density of the sample size.

Interestingly, the number of infected farms initially increased steadily until the first case, after which it significantly declined over two months, starting from the first week of July. However, there was a subsequent rise in positive cases among affected cattle in the first week of September. Despite some fluctuations, the prevalence continued to decrease, with a slight increase observed in the first week of November 2021, ultimately stabilizing by May 2022. The unstable cases or fluctuations from the first outbreak (Week 1 of May) until the second week of August were influenced by the festive seasons of Hari Raya Aidilfitri on 13 May 2021 and Aidiladha on 20 July 2021. During these festive periods, there was heightened movement of cattle due to increased demand for beef consumption and live cattle for qurban (sacrificial purposes). Simultaneously, a significant importation of live cattle occurred from neighboring countries a month prior, with undetectable clinical signs due to the incubation period. Additionally, the shift from the first inter-monsoonal period (March to May) to the southwest monsoon (May to August) altered the environment from summer months and the start of seasonal rain, creating favorable conditions for vector breeding (Pathania *et al.*, 2022; Tan, 2018). These changes facilitated the enhanced transmission of lumpy skin disease (LSD).

Relatively, LSD exhibits high morbidity but lower mortality (Calistri *et al.*, 2020). This observation aligns with this study, where the morbidity rate and mortality rate were low at 3% and 0.15%, respectively. In contrast, a study in Thailand found a a high morbidity rate of 40.5% and a mortality rate of only 1.2% (Arjkumpa *et al.*, 2022). Wilhelm (2023) conducted a study on six Southeast Asia (SEA) countries affected by LSD, revealing morbidity and mortality rates of 20.9% and 2.7%, respectively (Wilhelm & Ward, 2023). Additionally, Kazakhstan reported a mortality rate of 1% (Issimov *et al.*, 2020), and Jordan reported 2% (Abutarbush *et al.*, 2015). However, it's important to note that immune response influences both morbidity and mortality rates (Akther *et al.*, 2023; Rushton J, 2009). In SEA countries, including Malaysia, LSD poses a relatively new threat to cattle populations. As no LSD vaccine has been introduced in these regions, the mortality rate is slightly higher compared to countries with prior experience in managing the disease.

In this study, the case fatality rate was comparatively low when compared to studies conducted in other countries. For instance, India reported a fatality rate of 20.24%, Ethiopia 11.58%, and Jordan 7.5% (Abutarbush *et al.*, 2015; Ayelet *et al.*, 2013; Limon *et al.*, 2020; Manjunatha Reddy *et al.*, 2023). No fatality rate was reported in cattle in the Nigerian study, while fatality rates of 34% in sheep and 33% in goats were recorded (Limon *et al.*, 2020). India also highlighted that a lack of vaccination contributed to a higher fatality rate in their findings (Manjunatha Reddy *et al.*, 2023). Meanwhile, Ethiopia revealed that crossbreed cattle had a higher fatality rate compared to indigenous cattle (Ayelet *et al.*, 2013). From this study, fatality rates were inclusive of all ages and breed categories due to limited information on ages and the mixed-breed composition of cattle farms in the data.

It was observed that 63.7% of the cattle farms surveyed were dominated by small-scale farmers, which reflected the overall trend in Malaysia, where the cattle industry was mainly driven by small-scale beef cattle farming (DVS, 2021). Basically, small scale farmers predominantly practices traditional, nature-based farming, often with limited grazing areas in Malaysia (DVS, 2021). This context creates an environment ripe for increased cattle infection. Our findings resonate with a report by Gari (2010), which highlights the high-risk occurrence of LSD associated with communal grazing and watering management. This connection likely arises from environmental contamination and direct or indirect fomite transmission during free-range activities (Tuppurainen *et al.*, 2020).

Movement history includes the replacement of animals in farm and farm practice behavior during certain times of an outbreak, which is a potential risk factor for LSD. According to the study by Kiplagat *et al*. (2020), introducing new animals to a farm significantly increases the chances of LSD infection, a finding that aligns with studies from Ethiopia and Europe (Tuppurainen, 2017; Gari *et al.*, 2011). This increases the risk to animals in the incubation period who are not yet showing LSD clinical signs. Further information need to be collected to explain further on the movement effect on LSD infection. However, analysis revealed minimal activity in the movement history, with only 7% of the 504 surveyed cattle farms showing any movement during the surveillance period.

Based on descriptive analysis conducted, it appears that beef cattle are significantly more affected (54.9%) compared to dairy cattle (7.1%). Among beef cattle, crossbreeds showed 29.4% prevalence, followed by indigenous beef cattle at 22.8%. Similarly, crossbreed dairy cattle exhibit an 7.1% prevalence, while indigenous dairy cattle, specifically referring to Mafriwal cattle in Malaysia, are also affected. Some studies have also shown that crossbreed cattle are more susceptible compared to the indigenous cattle (Gari *et al.*, 2011; Kiplagat *et al.*, 2020).

In Malaysia, cattle farming reveals a fascinating blend of breeds. The majority of beef cattle are mixed combining local breeds from Kedah-Kelantan cattle (KK cattle) with exotic breed cattle imported from Australia or other countries for breeding purposes. Additionally, artificial insemination practices involve pairing hybrid breeds with local ones. For instance, the KK cattle are often crossed with Friesian Sahiwal, resulting in what is conversationally known as Mafriwal (Malaysia-Friesian-Sahiwal) and other giant hybrid cattle in Malaysia familiarly called 'sado' cattle. However, retrieved information through expert opinion showed that KK cattle (indigenous breed) experienced more severe infections than their crossbred counterparts. This observation is consistent with a similar study conducted in Bangladesh, where it was reported that the incidence of LSD was significantly higher in indigenous cattle compared to crossbred cattle (Sadia Pory *et al.*, 2021). However, the discrepancy between the results from the statistical descriptive analysis and the expert opinion was not significant. This could be attributed to the fact that only one expert, representing their own farm's experience with the disease, was involved in this study. In contrast, the descriptive analysis encompassed 504 farms, indicating a high number of mixed breed beef cattle in the study area during LSD surveillance associated with the LSD outbreak. Notably, even a farm in Pahang, which was involved in gaur farming, was affected by the disease. The occurrence is not surprising, considering that other wild ruminants, including gaur (*Bos gaurus*) (Andriy Rozstalnyy *et al.*, 2020) giraffe, and springbok, have also been reported to be infected (Ratyotha *et al.*, 2022).

The FAO has specified preferred sample types for LSD virus detection in their diagnostic protocol. These include skin lesions, scabs, saliva and nasal swabs, EDTA blood for PCR, and serum samples (Tuppurainen, 2017). In the analysis, all categories of samples were included during farm surveillance. However, mixed samples were prominent in the report, accounting for 58.1% of the collected samples. Some reports clearly specified the sample types, with LSD nodules being the second most commonly collected during surveillance, while other reports did not state the type of samples collected. Blood, swabs, nodules, and serum were preferred for diagnosing LSDV due to their distinct clinical signs, with confirmation by Polymerase chain reaction (PCR) analysis. However, postmortem sampling in the field is not commonly practiced because mild LSD cases typically do not exhibit internal organ lesions. In severe cases, diagnosis relies on external samples, as obvious LSD lesions are observed to further confirmed test (Tuppurainen, 2017).

The DVS implemented a movement restriction for 28 days on farms infected with LSD. This aligns with the LSD incubation period, which various reports indicated to be between 6 to 26 days (Calistri *et al.*, 2018), and up to 35 days according to Ratyotha *et al.* (2022). To prevent high transmission to unaffected areas, animal movement was strictly prohibited. The cattle isolated at the restricted farms were tested on a scheduled basis to assess the LSD infection and consideration on extending the isolation period. As mentioned by the European Food Safety Authority (EFSA), controlling the movement of cattle for at least 3-4 weeks ensures the reduction or elimination of the virus circulation at the infected farm (Calistri *et al.*, 2020). In India, there is a practice to stop cattle trade within a 10 km radius from the infection area. This measure ensures that no animal movement affects the disease-free area and the local market. Additionally, cattle suspected of having LSD nodular lesions, along with fever, are isolated within the farm.

The awareness campaign played a crucial role in educating the farmers about LSD, a disease that was new to Malaysia. During active surveillance for LSD, field officers from DVS simultaneously conducted an awareness campaign about LSD among cattle farmers. This initiative resulted in an 89.3% awareness rate among farms surveyed. The WOAH recommends early awareness targeting farmers and, local government staff (DVS and MAQIS). The goal is to ensure that they are aware of the disease and promptly report any suspicion of LSD to the veterinary authorities (Calistri *et al.*, 2018; Tuppurainen, 2017). A national awareness program is also recommended through social media, Television, and radio programs to the public/consumers, as done by India (Biswas *et al.*, 2020). In addition, awareness is not only about the knowledge of LSD itself but also about the relevant control measures to be taken if LSD is detected or in an outbreak situation. This helps the public understand, become aware, and prepare for any control measures taken by the government. The awareness program needs to be conducted continuously to enhance awareness among industry players and government staff.

CONCLUSION

In Peninsular Malaysia, LSD shows a prevalence of 3%, with higher infection rates in beef cattle compared to dairy cattle. This prevalence is the lowest among Southeast Asian countries and is associated with a low mortality rate but higher fatality rates. This might be due to the absence of LSD vaccine, as no outbreaks had been detected before, leading to a substantial increase in fatality numbers. The study indicates that initial LSD cases began in the central states of Peninsular Malaysia, spreading to the north (Kedah) and east (Terengganu). Further research is needed to understand the trend, as the current study's limitations may be due to animal movements and potential vector transmission. Key risk factors identified include disease movement history, herd population, management systems, and animal types and breeds. The use of LSD vaccination significantly reduced the number of cases, with only three cases detected by May 2022, compared to 700 cases in 2021. Therefore, raising disease awareness, applying strategic prevention, and enhancing farm biosecurity are crucial measures against LSD.

REFERENCES

1. Abutarbush, S. M., Ababneh, M. M., Al Zoubi, I. G., Al Sheyab, O. M., Al Zoubi, M. G., Alekish, M. O., & Al Gharabat, R. J. (2015). Lumpy Skin Disease in Jordan: Disease Emergence, Clinical Signs, Complications and Preliminary-associated Economic Losses. *Transboundary and Emerging Diseases*, 62(5), 549–554. Retrived from https://doi.org/10.1111/tbed.12177.
2. Akther, M., Akter, S. H., Sarker, S., Aleri, J. W., Annandale, H., Abraham, S., & Uddin, J. M. (2023). Global Burden of Lumpy Skin Disease, Outbreaks, and Future Challenges. *In Viruses* (Vol. 15, Issue 9), 2-29. Multidisciplinary Digital Publishing Institute (MDPI). Retrived from https://doi.org/10.3390/v15091861.
3. Andriy Rozstalnyy, Akiko Kamata, Damian Tago, & Pittiglio Claudia. (2020). Introduction and spread of lumpy skin disease in South, East and Southeast Asia. In Introduction and spread of lumpy skin disease in South, East and Southeast Asia. *FAO*. Retrived from https://doi.org/10.4060/cb1892en.
4. Ayelet,G.,Abate,Y.,Sisay,T.,Nigussie,H.,Gelaye,E., Jemberie,S., & Asare,K. (2013). Lumpy skin disease: Preliminary vaccine efficacy assessment and overview on outbreak impact in dairy cattle at Debre Zeit, central. Ethiopia. *Antiviral Research*. 10.1016/j.antiviral. 2013.02.008, 2(98), 261-265.
5. Arjkumpa, O., Suwannaboon, M., Boonrod, M., Punyawan, I., Liangchaisiri, S., Laobannue, P., Lapchareonwong, C., Sansri, C., Kuatako, N., Panyasomboonying, P., Uttarak, P., Buamithup, N., Sansamur, C., & Punyapornwithaya, V. (2022). The First Lumpy Skin Disease Outbreak in Thailand (2021): Epidemiological Features and Spatio-Temporal Analysis. *Frontiers in Veterinary Science*, 8, 3-14. Retrived from https://doi.org/10.3389/fvets.2021.799065.
6. Arjkumpa, O., Wachoom, W., Puyati, B., Jindajang, S., Suwannaboon, M., Premashthira, S., Prarakamawongsa, T., Dejyong, T., Sansamur, C.,Salvador,R.,Jainonthee,C.,&Punyapornwithaya, V. (2024a). Analysis of factors associated with the first lumpy skin disease outbreaks in naïve cattle herds in different regions of Thailand. *Frontiers in Veterinary Science*, 11(February), 2-9. Retrived from https://doi.org/10.3389/fvets.2024.1338713.
7. Biswas, D., Saha, S. S., Biswas, S., & Sayeed, Md. A. (2020). Outbreak of Lumpy Skin Disease of Cattle in the South-West Part of Bangladesh and its Clinical Management. *Veterinary Sciences: Research and Reviews*, 6(2), 1-5. Retrived from https://doi.org/10.17582/journal.vsrr/2020.6.100.108.
8. Calistri, P., De Clercq, K., Gubbins, S., Klement, E., Stegeman, A., Cortiñas Abrahantes, J., Marojevic, D., Antoniou, S. E., & Broglia, A. (2020b). Lumpy skin disease epidemiological report IV: data collection and analysis. *EFSA Journal*, 18(2), 1-4. Retrived from https://doi.org/10.2903/j.efsa.2020.6010.

9. Calistri, P., DeClercq, K., De Vleeschauwer, A., Gubbins, S., Klement, E., Stegeman, A., Cortiñas Abrahantes, J., Antoniou, S. E., Broglia, A., & Gogin, A. (2018). Lumpy skin disease: scientific and technical assistance on control and surveillance activities. *EFSA Journal*, 16(10), 2-43. Retrived from https://doi.org/10.2903/j.efsa.2018.5452.
10. Khoo., C.K., Dahlan., R., Mat Desa., Z., Syarina, P.N.A., Mohd. Salim., S.S.H., Barker., Z., Abu Hassan., M.H., Hassan., R. and Mohd Saeid, F.H. (2022). Molecular Detection and Antibiogram of Bacillus cereus Isolated from Dairy Goat with Mastitis in Malaysia. *International Journal of Infectious Diseases*, 116, S63–S64. Retrived from https://doi.org/10.1016/j.ijid.2021.12.149.
11. DVS. (2021). Pelan Strategik & Tindakan Pembangunan Industri Pedaging Negara 2021-2025. *Pelan Strategik and Tindakan Pembangunan; Industri Pedaging Negara* 2021-2025, 1–52.
12. DVS. (2022a). An update on the LSD situation and its control in Malaysia. *World Organisation for Animal Health*, December. Retreived from https://rr-asia.woah.org/app/uploads/2023/12/1-8-malaysia_lsd_situation-country_presentation.pdf.
13. *DVS Malaysia*. (2022). Perangkaan Ternakan Livestock Statistics. Retrieved from https://www.dvs.gov.my/dvs/resources/user_1/2022/bpspv/perangkaan 2021.2022/1)*_buku_perangkaan_ternakan_2021_2022_keseluruhan.pdf*
14. Eeva Tuppurainen. (2017). A Field Manual for Veterinarians Manual Lumpy Skin Disease. 1–60.
15. Gari, G., Bonnet, P., Roger, F., & Waret-Szkuta, A. (2011). Epidemiological aspects and financial impact of lumpy skin disease in Ethiopia. *Preventive Veterinary Medicine*, 102(4), 274–283. Retrived from https://doi.org/10.1016/j.prevetmed.2011.07.003.
16. Gari, G., Waret-Szkuta, A., Grosbois, V., Jacquiet, P., & Roger, F. (2010). Risk factors associated with observed clinical lumpy skin disease in Ethiopia. *Epidemiology and Infection*, 138(11), 1657–1666. Retrived from https://doi.org/10.1017/S0950268810000506.
17. Kiplagat, S. K., Kitala, P. M., Onono, J. O., Beard, P. M., & Lyons, N. A. (2020). Risk Factors for Outbreaks of Lumpy Skin Disease and the Economic Impact in Cattle Farms of Nakuru County, Kenya. *Frontiers in Veterinary Science*, 7. Retrieved from https://doi.org/10.3389/fvets.2020.00259.
18. Limon, G., Gamawa, A. A., Ahmed, A. I., Lyons, N. A., & Beard, P. M. (2020a). Epidemiological Characteristics and Economic Impact of Lumpy Skin Disease, Sheeppox and Goatpox Among Subsistence Farmers in Northeast Nigeria. *Frontiers in Veterinary Science*, 7. Retrived from https://doi.org/10.3389/fvets.2020.00008.
19. Buda, M. and Mohamed, Z. (2021)..Impact of different importation policies scenarios on beef industry in Peninsular Malaysia.(24-35). Retrived from 10.18196/agraris.v7i1.10540
20. Muhid, D. A., Senawi, D. J., Abdullah, D. S. D., Nik Husin, D. N. H., Amad Bugis, D. S., Shamsuddin, D. M. S., Muhammad Sabri, D. M. S., & Basir, D. A. H. (2021). *Protokol Veterinar Malaysia* No. Dokumentasi: PVM 2(11):1/2021 Lumpy Skin Disease (LSD).
21. Pathania, A., Mishra, A., & Malik, Y. S. (2022). Lumpy Skin Disease: Emerging Concern for Livestock Owners: A Review. Bhartiya Krishi Anusandhan Patrika,37(3), 241-244. Retrieved from https://doi.org/10.18805/bkap594.
22. Ratyotha, K., Prakobwong, S., & Piratae, S. (2022). Lumpy skin disease: A newly emerging disease in Southeast Asia. *Veterinary World*, 15(12), 2764–2771. Retrieved from https://doi.org/10.14202/vetworld.2022.2764-2771.
23. Rushton. (2009). Economic analysis and policy making: Examples from around the world. *The Economics of Animal Health and Production*, 263-295.
24. Rushton, J., Bruce, M., Bellet, C., Torgerson, P., Shaw, A., Marsh, T., Stone, M., Pinto, J., Mesenhowski, S., and Wood, P. (2018). *Initiation of Global Burden of Animal Diseases Programme*. Lancet, Vol 392, 538-540..
25. Sadia Pory, F., Mahmud Lasker, R., Nazrul Islam, M., & Saiful Islam Siddiqui, M. (2021). Prevalence of Lumpy Skin Disease at District Veterinary Hospital in Sylhet District of Bangladesh. *International Journal of Research and Innovation in Applied Science*. www.rsisinternational.org, VI(X), 2454-6196.

26. Sprygin, A., Pestova, Y., Wallace, D. B., Tuppurainen, E., & Kononov, A. V. (2019). Transmission of lumpy skin disease virus: A short review. *Virus Research* (Vol. 269). Elsevier B.V. Retrieved from https://doi.org/10.1016/j.virusres.2019.05.015.
27. Tan, K.C. (2018). Trends of rainfall regime in Peninsular Malaysia during northeast and southwest monsoons. *Journal of Physics* 995(2018)012122. Retrieved from 10.1088/1742-6596/995/1/012122.
28. Wilhelm, L., and Ward, M. P. (2023). The Spread of Lumpy Skin Disease Virus across Southeast Asia: Insights from Surveillance. *Transboundary and Emerging Diseases*, 1–9. Retrieved from https://doi.org/10.1155/2023/3972359.

ACKNOWLEDGEMENT

The authors would like to thank the Director General of the Department of Veterinary Services, and the Epidemiology and Surveillance Section for providing the data for this study.

APPENDICES

Appendix A: Summary of prevalence status due to LSD in Peninsular Malaysia in one year period of LSD outbreak from Year 2021 to Year 2022

States/overall	Surveyed cattle population	Number of cattle having LSD signs	Number of cattle confirmed case (laboratory test)	Death cattle	Prevalence (%)
Terengganu	392	77	34	0	8.7
Kelantan	414	61	39	0	9.4
Johor	735	71	31	0	4.2
Perak	5940	415	233	4	3.9
Kedah	780	45	35	0	4.5
Selangor	1723	97	73	28	4.2
Penang	644	35	27	1	4.2
Perlis	1223	48	39	0	3.2
Melaka	2306	88	75	0	3.3
N. Sembilan	2495	84	54	0	2.2
Pahang	6819	157	63	3	0.9
Overall	23,471	1178	703	36	3.0

Case fatality rate (%)	5.12
Mortality rate (%)	0.15

Appendix B: Descriptive summary of continuous variables based on cattle farm surveillance (N=503*) by cattle categories during LSD outbreak

Continuous Variables	Descriptive Summary	Cattle categories	
		Beef Farm (N=456)	Dairy Farm (N=47)
Treatment	Mean	2	1
	Standard Deviation (SD)	5	2
	Median	1	1
	Minimum	1	1
	Maximum	50	11
Culling	Mean	2	1
	Standard Deviation (SD)	3	2
	Median	1	1
	Minimum	1	0
	Maximum	28	10
Dead	Mean	2	1
	Standard Deviation (SD)	5	1
	Median	1	1
	Minimum	1	1
	Maximum	10	2
Sanitation	Mean	2	2
	Standard Deviation (SD)	1	1
	Median	3	1
	Minimum	1	1
	Maximum	3	3
Sampling	Mean	2	2
	Standard Deviation (SD)	3	2
	Median	1	1
	Min	1	1
	Max	682	11
Quarantine	Mean	5	2
	Standard Deviation (SD)	36	2
	Median	1	1
	Minimum	1	1
	Maximum	682	11
Cattle with LSD clinical signs	Mean	2	2
	Standard Deviation (SD)	4	2
	Median	1	1
	Minimum	1	1
	Maximum	50	11

Note: *exclude one Gaur Farm

Appendix C: Chi-Square tests

Test Statistics

	Movement History	Herd Population	Management System	Type of Animal	Breed
Chi-Square	277.191[a]	214.994[b]	222.331[c]	360.471[b]	353.006[d]
df	2	3	5	3	6
Asymp. Sig.	.000	.000	.000	.000	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 104.7.
b. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 78.5.
c. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 52.3.
d. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 44.9.

Appendix D: Descriptive summary of continuous variables based on cattle farm surveillance (N=504) by states during LSD outbreak

Continuous Variables	Descriptive Summary	States										
		Terengganu (N=43)	Kelantan (N=38)	Johor (N=26)	Perak (N=125)	Kedah (N=25)	Selangor (N=48)	Penang (N=11)	Perlis (N=31)	Melaka (N=48)	N. Sembilan (N=41)	Pahang (N=68)
Treatment	Mean	1	1	4	3	2	7	3	2	2	2	3
	SD	1	0	2	5	2	14	2	1	1	2	4
	Median	1	1	4	1	2	2	2	1	1	1	1
	Minimum	1	1	1	1	1	1	1	1	1	1	1
	Maximum	3	1	7	50	4	40	5	4	6	8	17
Culling	Mean	2	3	2	5	0	2	8	0	3	1	1
	SD	1	6	0	9	0	2	8	0	3	1	1
	Median	2	1	2	2	0	2	6	0	1	1	0
	Minimum	1	1	2	1	0	1	1	0	1	0	0
	Maximum	4	21	2	28	0	10	20	0	11	3	1
Dead	Mean	0	0	0	2	0	2	1	0	0	0	1
	SD	0	0	0	1	0	2	0	0	0	0	0
	Median	0	0	0	2	0	1	1	0	0	0	1
	Minimum	0	0	0	1	0	1	0	0	0	0	1
	Maximum	0	0	0	3	0	10	1	0	0	0	1
Sanitation	Mean	2	3	3	2	2	3	2	3	1	3	2
	SD	1	1	1	1	1	1	1	0	0	1	1
	Median	3	3	3	1	3	3	1	3	1	3	1
	Minimum	1	1	1	1	1	1	1	3	1	1	1
	Maximum	3	3	3	3	3	3	3	3	1	3	3

Continuous Variables	Descriptive Summary	States										
		Terengganu (N=43)	Kelantan (N=38)	Johor (N=26)	Perak (N=125)	Kedah (N=25)	Selangor (N=48)	Penang (N=11)	Perlis (N=31)	Melaka (N=48)	N. Sembilan (N=41)	Pahang (N=68)
Sampling	Mean	2	1	2	3	2	2	4	2	2	2	2
	SD	1	1	3	6	1	2	6	1	2	2	3
	Median	1	1	1	1	1	1	2	1	1	1	1
	Minimum	1	1	1	1	1	1	1	1	1	2	1
	Maximum	6	3	10	50	4	10	20	4	12	9	17
Quarantine	Mean	3	2	3	3	2	8	4	2	2	2	17
	SD	5	1	2	6	1	25	3	1	2	4	97
	Median	1	1	2	1	1	2	3	1	1	1	2
	Minimum	1	1	1	1	1	1	1	1	1	2	1
	Maximum	29	9	7	50	4	100	10	4	11	22	682
Cattle with LSD clinical signs	Mean	2	2	3	3	2	2	3	2	2	2	2
	SD	1	1	2	6	1	2	3	1	2	2	3
	Median	1	1	2	2	1	1	2	1	1	1	1
	Minimum	1	1	1	1	1	1	1	1	1	1	1
	Maximum	6	9	10	50	4	10	10	4	11	9	17

Note: SD = Standard Deviation