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Hotspots of Infection: Spatial Analysis of Rat Populations and Leptospira sp. in South Sulawesi

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ABSTRACT

Leptospirosis is a zoonotic disease caused by the bacterium Leptospira sp., primarily transmitted through the urine of infected rodents. The objective of this research is to analyze the spatial distribution of rat populations and to detect the presence of Leptospira spp within these populations in Pitue Village, South Sulawesi. A descriptive observational approach was used to determine rat density and detect Leptospira sp. in captured rodent kidney samples. A total of 200 live traps were set in residential areas, both indoors and outdoors, over three consecutive days using roasted coconut as bait. Polymerase Chain Reaction (PCR) testing was conducted on rat kidney samples at Hasanuddin University Medical Research Center (HUM-RC). Geospatial mapping using Quantum GIS (QGIS) was employed to visualize rat density and Leptospira sp. distribution. The study found a trap success rate of 18.5%, with 37 rats captured, exceeding the national standard of less than 1%. Suncus murinus (62%) was the most frequently trapped species, followed by Rattus tanezumi (16%), Rattus norvegicus (12%), and Rattus argentiventer (5.4%). PCR testing confirmed Leptospira sp. in three rat kidney samples. Spatial analysis revealed clustering of rat presence within a 60-meter buffer zone, indicating high-risk areas for leptospirosis transmission. By identifying areas with high rat density and the occurrence of Leptospira infection, the study seeks to evaluate the potential public health risks posed by leptospirosis, a zoonotic disease transmitted through environmental exposure to contaminated urine from infected rodents. Future research should explore predictive modeling and environmental factors influencing leptospirosis transmission.

Keywords: Rat Density, Leptospirosis, Polymerase Chain Reaction, Mapping

INTRODUCTION

Leptospirosis, also known as Weil's disease, is an acute infectious disease affecting both humans and animals, classified as a zoonotic disease. Various animals, including cattle, goats, sheep, horses, dogs, cats, birds, and insectivores, can act as reservoirs for *Leptospira sp*. However, rodents, particularly rats, are the primary sources of transmission due to their role as natural hosts and their high reproductive capacity. Leptospirosis remains a significant public health problem worldwide, particularly in tropical and subtropical regions. In subtropical areas, incidence rates range from 0.1 to 1 per 100,000 people annually, while in tropical regions, the rate is higher, between 10 to 100 per 100,000 people. The elevated prevalence in these regions is associated with environmental conditions conducive to *Leptospira* proliferation, such as poor sanitation and frequent flooding.

According to the Leptospirosis Burden Epidemiology Reference Group (LERG) of the World Health Organization, there are approximately 1.03 million leptospirosis cases annually, resulting in 58,900 deaths, with incidence rates in tropical areas being about ten times higher than in temperate zones. Indonesia ranks third globally in Leptospirosis prevalence after China and India. The national mortality rate due to leptospirosis in Indonesia ranges from 2.5% to 16.45%, with an average of 7.1%. Among patients aged 50 and above, the mortality rate reaches 56%.

Data from the 2022 Indonesian Health Profile indicate 1,419 reported leptospirosis cases across ten provinces, including DKI Jakarta, West Java, Central Java, DI Yogyakarta, East Java, Banten, North Kalimantan, South Sulawesi, Southeast Sulawesi, and East Kalimantan. A total of 139 deaths were recorded, resulting in a case fatality rate (CFR) of 9.8%. The highest incidences were in Central Java and East Java, contributing 35.4% and 28.3% of total cases, respectively [4]. In contrast, North Kalimantan showed a decline from 15 cases in 2021 to 3 cases in 2022. Meanwhile, in South Sulawesi, sporadic leptospirosis cases have been reported in multiple districts. In Enrekang and Pinrang districts, one case was recorded in 2019, followed by one case in Wajo in 2020. By 2022, Sidrap and Pangkep each reported a suspected case, and by March 2023, four cases emerged in Pangkep District.

Leptospirosis outbreaks often follow heavy rainfall, with Leptospira interrogans being the primary pathogenic species affecting humans and animals. Over 200 serological variants have been identified. Transmission occurs through direct contact with contaminated water, soil, or infected animal urine. The risk of outbreaks is heightened in low-lying and flood-prone areas, such as Pitue Village, where a positive leptospirosis case was reported in early 2023. The Ma'rang Health Center confirmed leptospirosis in a 44-year-old fisherman from Pitue Village. Subsequent laboratory tests on 17 trapped rats identified two positive samples, belonging to Rattus norvegicus and Suncus murinus.

The number of leptospirosis cases often increases during the rainy season, exacerbating transmission risks. Flooding facilitates the spread of Leptospira bacteria by contaminating water, soil, and vegetation, increasing human exposure. Studies indicate that individuals affected by flooding are 23 times more likely to contract leptospirosis than those in non-flooded areas. Moreover, flooding forces rats to migrate into human settlements, further raising infection risks.

Recent public health studies emphasize the role of Geographic Information Systems (GIS) and spatial analysis in epidemiological research. These tools, initially pioneered by Dr. John Snow in the 19th century for cholera mapping, are now widely used to analyze infectious disease transmission patterns. GIS enables a comprehensive assessment of spatial-temporal trends in leptospirosis outbreaks, integrating environmental, demographic, and socioeconomic factors. The application of GIS in disease surveillance has been demonstrated in various countries, including China, Hungary, Canada, the USA, Zambia, and Brazil, highlighting its effectiveness in identifying high-risk areas and improving disease control measures.

By utilizing GIS and spatial statistical methods, researchers can better understand the environmental determinants of leptospirosis, identify transmission hotspots, and inform targeted interventions. The continuous integration of spatial epidemiology with public health strategies enhances disease surveillance, facilitates early outbreak detection, and strengthens multidisciplinary collaboration among human and animal health experts. Given the spatial-climatic relationship inherent to leptospirosis epidemiology, it is crucial to implement advanced surveillance models to address the complexities of disease transmission in urban and rural settings.

METHODS

This study employs a descriptive observational approach to assess rat density and the presence of *Leptospira sp.* in the kidneys of rats in Pitue Village, Ma'rang District, Pangkajene and Islands. The research population comprises all rats found in Pitue Village, with samples collected using a non-probability sampling method, specifically, accidental sampling. The samples consist of all rats captured using live traps set for three consecutive days, baited with roasted coconut.

Traps were deployed at 4 p.m. and retrieved at 7 a.m. WITA, with a total of 200 traps placed both indoors and outdoors. Captured rats were identified before leptospirosis testing, which was conducted using the Polymerase Chain Reaction (PCR) method at the Hasanuddin University Medical Research Center (HUM-RC) laboratory. PCR testing followed a simple random sampling technique to ensure representative samples were analyzed, taking into account the environmental uniformity across different locations.

Data analysis was conducted using descriptive statistical methods. The results of PCR testing were presented in figures, tables, and narratives. Additionally, spatial analysis was performed using the Centroid technique within the Quantum GIS (QGIS) application. Coordinates for each trap location were recorded using Google Earth, allowing for geospatial mapping of rat density and the distribution of Leptospira sp. within Pitue Village. The spatial data were analyzed to identify high-risk areas and potential hotspots for leptospirosis transmission.

Ethics Statement

This research has obtained permission from the Research Ethics Committee of the Faculty of Public Health, Hasanuddin University (No: 971/I/N4.14.1/TP.01.02/2024).

RESULTS

Rat density can be measured using the *Success Trap* method. The calculation is done by dividing the number of rats caught by the number of traps installed and multiplying by one hundred percent.

$$SuccesTrap = \frac{\text{The number of rats caught}}{\text{The number of traps installed}} \times 100\%$$
$$= \frac{37}{200} \times 100\%$$
$$= 18{,}5\%$$

The results of the above calculations indicate that the density of rats in Pitue Village, Ma'rang District, is high. This is based on the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning Environmental Health Quality Standards for Disease Carrying Animals, the quality standard value for *success traps* is <1%.

Table 1. Types of Rats Caught in Pitue Village, Ma'rang District, Pangkep

Species	Gender		Total
	Male	Female	
Suncus murinus	15	8	23
Rattus tanezumi	5	1	6
Rattus norvegicus	5	1	6
Rattus argentiventer	2	0	2
Total	27	10	37
Source: Primary Data, 2024			

Based on Table 1, the results of the identification of rats caught in Pitue Village, Ma'rang District, Pangkep Year 2024, it was found that the most common type of rat was *Suncus murinus* as many as 23 rats (62%). The next type of rat is *Rattus tanezumi, with* as many as 6 rats (16%), and *Rattus norvegicus* as many as 6 rats (16%). The least type of rat is *Rattus argentiventer* as many as 2 rats (5.4%).

Table 2. Result of Conventional PCR Examination on Rat Kidney Samples

Inspection Result	Sample Quantity
Positive	3
Negative	34
Total	37
Source: Primary Data, 2024	

Based on Table 2 above, it can be seen that the kidney samples examined were 37 samples and the results showed 34 negative rat samples containing *Leptospira sp* bacteria and there were 3 positive samples containing *Leptospira sp* bacteria.

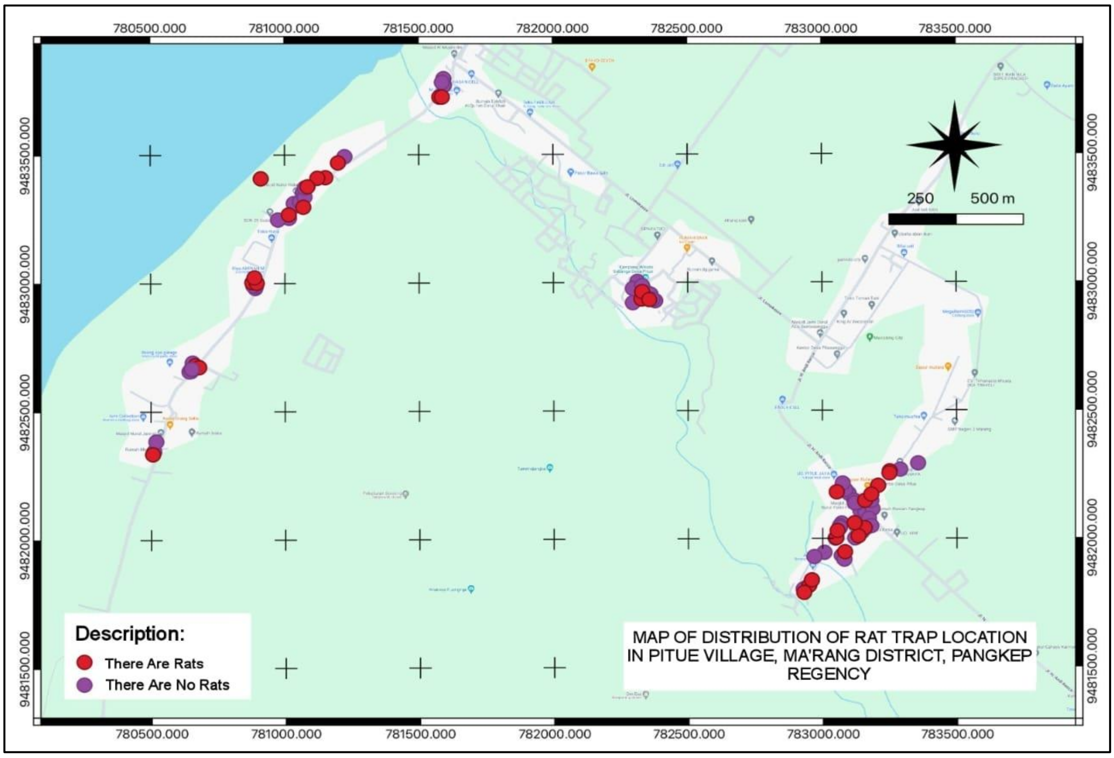

Figure 1. Map of Rat Trap Distribution Location in Pitue Village, Ma'rang Sub-district in 2024

Figure 1 shows the location of rat trap installations in Pitue Village. A map of the location of the distribution of mouse traps set in Pitue Village was created using the Quantum GIS 3.22 application. Based on the figure, traps containing rats are marked with red dots and there are 37 red dots out of 200 traps installed. Traps that did not contain rats were marked with purple dots. Areas that have more than 1 dot indicate the density of rats in that area.

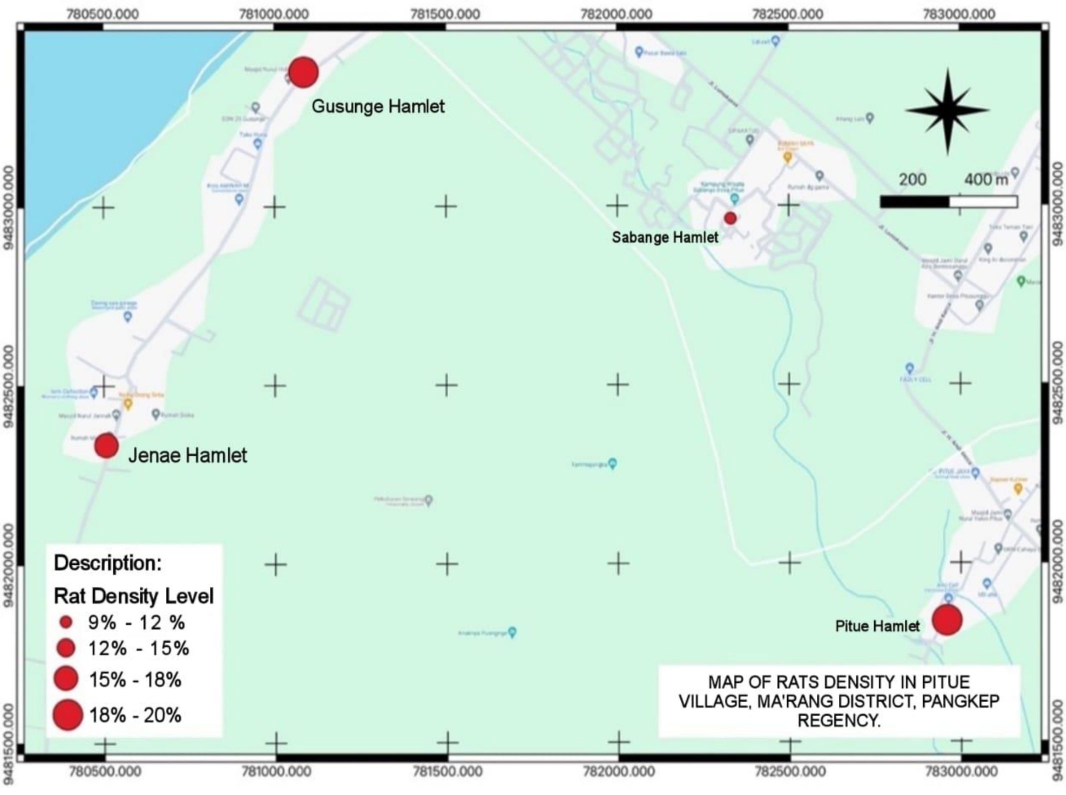

Figure 2. Map of Rat Density Level in Pitue Village, Mar'rang Sub-district in 2024

Figure 2 is an overview map of rat density in Pitue Village, Ma'rang District, Pangkajene and Islands. Mapping is done using centroid points in the QGIS application 3.22 to see the density of rats in an area. Rat density in Pitue Village is categorized based on the size of the red centroid points in each hamlet. Pitue Hamlet and Gusunge Hamlet have the highest rat density levels, reaching 20%. In Jenae Hamlet, the rat density level reached 17% and in Sabange Hamlet, it reached 12%. The four hamlets show a high level of rat density based on the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning Environmental Health Quality Standards for Disease Carrying Animals; the quality standard value for *success traps* is <1%.

a. b. c. d.

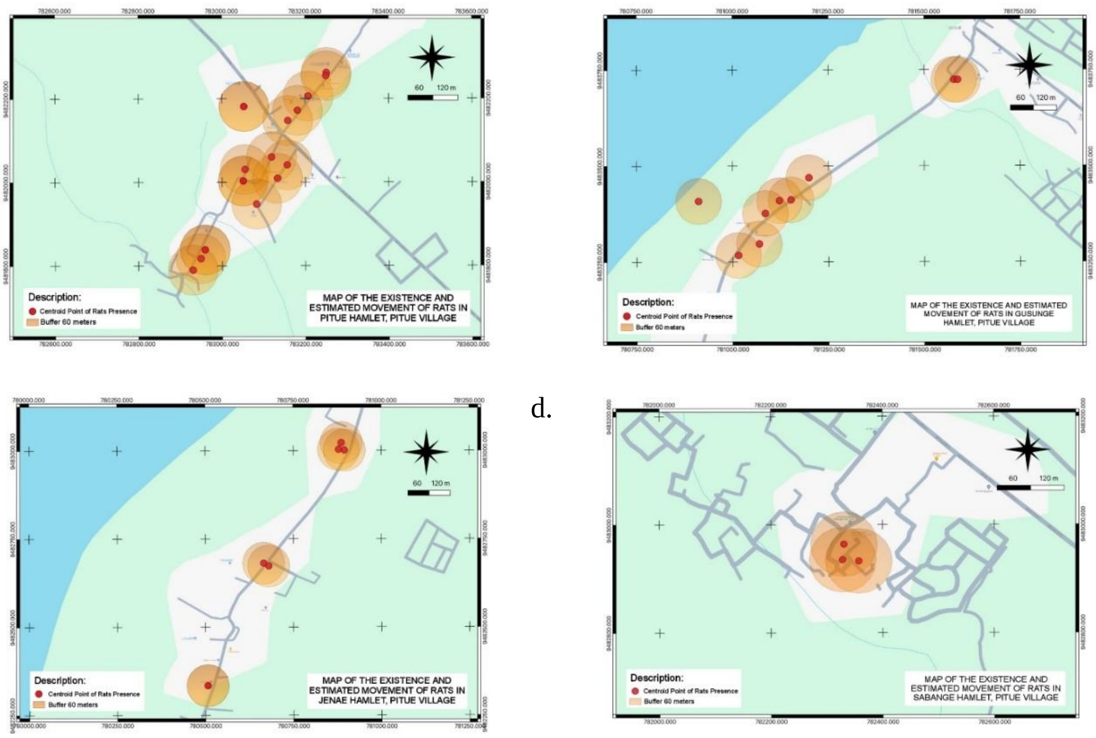

Figure 3. Map of the presence and movement of captured rats in a) Pitue Hamlet, b) Gusunge Hamlet, c) Jenae Hamlet, d) Sabange Hamlet

Based on Figure 3, it can be seen that the estimated presence and movement of rats caught in each hamlet. Red dots are marked as the location of the presence of rats. In Figure A, there are 18 points marked in red as the location of the presence of rats in Pitue Hamlet. Figure b: There are 9 points of red color as the location of the presence of rats in Gusunge Hamlet. In Jenae Hamlet (Figure c), there are 7 red dots, and in Figure d, there are 3 red dots in Sabange Hamlet the location of the presence of rats. Areas that have more than 1 point indicate the density of rats in the area. The buffer area is marked with an orange circle as the maximum distance of rat movement, which is 60 meters.

DISCUSSION

In a field study conducted in Pitue Village, South Sulawesi, a total of 200 traps were strategically deployed across residential areas, with each household equipped with two traps positioned both indoors and outdoors over three days. This systematic trapping effort yielded a capture success rate of 18.5%, resulting in the collection of 37 rats. Notably, this capture rate far exceeds the acceptable threshold of less than 1% as stipulated in the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023 concerning environmental health standards for disease vector and reservoir control. These findings indicate a substantial rat population density in the area, highlighting a potentially elevated risk of zoonotic disease transmission and underscoring the urgency for targeted public health interventions. This alarming statistic not only underscores the severity of the rodent infestation but also raises concerns about the potential risks for zoonotic disease transmission and the urgent need for improved pest control measures in the area.

The success of rat trapping is influenced by several critical factors, including the type of trap, the bait used, the trap's location, and the impact of human activity. In this study, researchers employed a robust, single-capture metal trap measuring 15x15x30 cm, engineered to close automatically when a rat enters to retrieve the bait. 9,10

Roasted coconut was selected as the bait due to its durability, non-perishable nature, and strong, attractive aroma—characteristics that align with World Health Organization standards. This choice not only ensures the bait remains effective over time but also highlights the importance of using locally available materials that enhance the lure for target species, thereby optimizing the overall efficiency of the trapping process.

The placement of traps plays a crucial role in capturing rats effectively. In this investigation, traps were strategically positioned in areas suspected to be common rat pathways, such as near kitchens or on rooftops, where signs of rat activity are most apparent. This strategy capitalizes on the natural thigmotaxis behavior of rats, which involves using familiar routes repeatedly for foraging, nesting, and other activities. Additionally, the timing of trap placement was carefully considered; traps were installed at 4:00 p.m. and retrieved the following morning between 6:00 and 9:00 a.m. to avoid interference from human activity. This scheduling not only minimizes disturbances but also provides valuable insights into the daily movement patterns of rats, which is essential for designing effective long-term pest management strategies.

Species identification of the captured rodents revealed a diverse community: 23 individuals (62%) were Suncus murinus (commonly known as the house shrew), 6 (16%) were Rattus tanezumi, 6 (12%) were Rattus norvegicus, and 2 (5.4%) were Rattus argentiventer. Suncus murinus, a species from the Soricidae family, is widely distributed and often found in proximity to human dwellings, earning it the nickname "house shrew." Rattus tanezumi, frequently observed on rooftops, thrives in residential environments due to its close association with human food sources. This diverse species composition not only reflects the adaptability of different rodents to urban settings but also suggests varying roles in disease transmission, necessitating tailored control strategies for each species.

Rattus norvegicus is typically associated with darker, damper environments, such as sewers, narrow passageways, and waterways, where its high metabolism and active behavior are well-suited to survival. In contrast, Rattus argentiventer is predominantly found in agricultural settings, including grasslands, rice fields, and irrigation systems, though it can occasionally infiltrate homes or storage areas. The distinct habitat preferences of these species indicate that a one-size-fits-all approach to rodent control may not be effective. Instead, pest management strategies should be adapted to target the specific environments where each species thrives, thereby reducing their impact on both public health and agricultural productivity.

Poor sanitation conditions significantly contribute to the spread of leptospirosis, a disease caused by Leptospira bacteria. This illness arises from a complex interaction between the pathogen, its rodent hosts, and the surrounding environment, with transmission occurring when the bacteria enter the human body through cuts or mucous membranes. In this study, laboratory tests on 37 rat kidney samples revealed that 3 samples were positive for Leptospira sp., underscoring the direct link between high rodent density and increased public health risks. These findings highlight the importance of enhancing environmental hygiene and waste management practices as a means to control both rodent populations and the spread of leptospirosis.

The outcomes of this research are consistent with the findings of Salim et al conducted in Pitue Village, Ma'rang District, Pangkajene Islands Regency. Their study aimed to detect Leptospira sp. in rat kidneys and found that 2 out of 17 rat samples tested positive, while additional tests on flood water samples showed no contamination. Notably, in Pangkajene and Islands Regency, rats carrying Leptospira are predominantly found in settlements characterized by stilt houses with poorly maintained lower structures. This parallel research reinforces the association between specific housing conditions and the prevalence of leptospira-positive rats, suggesting that targeted improvements in housing and sanitation infrastructure could play a vital role in mitigating the risk of leptospirosis in these communities.

To better comprehend the spatial distribution of rats, the research team employed Quantum GIS 3.22, a Geographic Information System (GIS) software, alongside Google Satellite Hybrid imagery. By mapping the GPS coordinates of trap locations, they created centroid points that indicated clusters of rat activity. Through buffer analysis, they determined that areas where these buffers intersected within a 60-meter radius were marked by high rat density, which is associated with a higher risk of Leptospira transmission. The spatial data for digital mapping was processed on QGIS 3.22, with Google Satellite Hybrid imagery providing a visual representation of the study area. This spatial analysis technique generated centroid points that reflect rat populations in relation to trap locations, identified via GPS. If multiple centroid points appeared within the same area, these areas were flagged for having potentially high rat densities.

In Pitue Village, buffer analysis of rat density revealed several overlapping points that indicate areas with a high risk of Leptospira presence. These areas, within a 60-meter radius of intersecting buffers, have an elevated population of rats, which are known carriers of zoonotic pathogens such as Leptospira bacteria. These bacteria pose a significant public health threat, as they can be transmitted from rats to humans, potentially causing severe illness and even death. Moreover, the presence of rats in residential spaces can also lead to chronic stress in individuals, affecting both their mental and physical well-being. This highlights the urgent need for enhanced rodent control measures and greater public awareness of the health risks associated with rodent infestations.

The Leptospira genus consists of various distinct serovars and genetic variants that thrive in different environmental conditions. In this context, Leptospira species can be classified using the rpoB gene, which exhibits a high level of variability. One study conducted in Boyolali District aimed to identify Leptospira serovars in the local rat population by analyzing kinship relationships based on rpoB gene polymorphism. The study involved a cross-sectional approach in Sindon and Jeron Villages, testing 104 rat kidney samples. The analysis confirmed the presence of positive Leptospira rpoB gene sequences in Rattus tanezumi, Rattus argentiventer, and Suncus murinus. Examining spatial distribution, the study found that rats with Leptospira sp. were concentrated within 30 to 150 meters of leptospirosis patients, thus linking rat populations to higher transmission risks in the human population. A separate study conducted with 135 traps over four days trapped 29 rats, including species such as Rattus norvegicus, Rattus tanezumi, Rattus argentiventer, and Rattus exulans. Despite an extensive Leptospirosis test on rat kidney samples, all results came back negative for Leptospira infection.

Observations focusing on environmental conditions were conducted at three university campuses—UIN, UNM, and Unhas, revealing critical insights into the role of environmental risk factors such as garbage accumulation, temperature, and humidity. At Unhas, 80% of observation points had garbage scattered around the dormitories, and 88.9% had optimal temperature conditions. Similarly, 46.7% of points at UIN had ideal humidity levels.

The study concludes that maintaining proper sanitation, temperature regulation, and humidity control in these areas could prevent rodent infestations and improve overall public health by decreasing the risk of leptospirosis. In slum settings, a study found a significant relationship between rat infestations, particularly by Rattus norvegicus, and the risk of Leptospira infection. These high infestation areas, commonly in poorly maintained household settings, show levels of disease transmission that are concerning. To counteract this, a predictive model was created using simple markers of rat infestations to calculate the likelihood of infection. This score-based system has been found effective in identifying homes at the greatest risk of exposure to Leptospira, highlighting the importance of such tools for community-based screening and targeted control efforts in high-high-transmission slum areas where leptospirosis is prevalent. Through early identification and preventive interventions, the spread of Leptospira and other rodent-borne diseases could be better managed, reducing public health burdens in these environments. A study on spatial analysis of rat presence in three student residential areas in Makassar City highlights the spatial distribution of rat populations as an indicator of potential environmental health risks. Although conducted in different areas and contexts-rural and urban show that rat density is influenced by environmental conditions, population density, and human activity patterns. These findings reinforce the importance of spatial approaches to rat population control and zoonotic disease prevention, both in rural and urban areas.

In the buffer analysis of rat density in Pitue Village, researchers discovered that several mapped points overlapped. Areas with two or more overlapping buffers within a 60-meter radius are considered high-risk zones for the presence of Leptospira bacteria, a finding directly linked to the dense rat populations in these locations. This high density of rats poses a significant public health threat, as rats are known carriers of various zoonotic pathogens, including Leptospira, which can cause serious illness and even death in humans. Moreover, the continuous presence of rats in residential areas can lead to chronic stress among inhabitants, negatively impacting both mental and physical well-being.

The Leptospira genus comprises multiple serovars and genetic variants that inhabit diverse environments. Due to the high polymorphism of the rpoB gene, it is an effective marker for classifying Leptospira species. A study was conducted to identify the specific Leptospira serovars present in the rat population and to map the spatial distribution of Leptospira-positive rats in Boyolali District. In April 2014, a cross-sectional study was carried out in Sindon Village (Ngemplak Subdistrict) and Jeron Village (Nogosari Subdistrict), where Polymerase Chain Reaction (PCR) tests were performed on 104 rat kidney samples. The spatial analysis revealed six positive rpoB gene samples from Rattus tanezumi, Rattus argentiventer, and Suncus murinus, with five of these samples showing the closest genetic similarity to Leptospira borgpetersenii serovar Sejroe. One isolate did not match closely with any known serovar in the cluster. Furthermore, the home range buffer analysis indicated that Leptospira-positive rats were found within distances of 30 to 150 meters from patients diagnosed with leptospirosis, underscoring the spatial connection between rat habitats and human infection risk. Similar to the SI-DINI application used for early detection and education on leprosy, utilizing technology to monitor rat density and the spread of leptospirosis can help increase community participation in environment-based disease prevention and control efforts.

In another investigation involving 135 traps set over four days, 29 rats were captured, representing various species such as Rattus norvegicus, Rattus tanezumi, Rattus argentiventer, and Rattus exulans. Although the kidney samples from these rats tested negative for leptospirosis, environmental observations at different dormitory locations, which include Alauddin Makassar Islamic State University (UIN), Makassar State University

(UNM), and Hasanuddin University (Unhas), revealed noteworthy findings. Garbage was scattered around 60% of observation points at UIN, 62.2% at UNM, and 80% at Unhas. Temperature measurements showed that 73% of points at Unhas, 82.2% at UNM, and 88.9% at UIN recorded optimal temperatures, while air humidity levels were optimal at 46.7% of points at UIN, 4.4% at UNM, and 26.7% at Unhas. The study concluded that the spatial presence of rats is significantly related to environmental risk factors such as waste accumulation, temperature, and humidity. Notably, Rattus norvegicus accounted for 69% of the captures, particularly prevalent in UIN lodgings where conditions such as scattered garbage, optimal temperature, and humidity favor their survival. The findings suggest that improving environmental management in these areas is critical to reducing rat infestations. These studies are interrelated in their efforts to prevent disease through increasing public awareness and knowledge. Both emphasize the importance of education as the first step in changing individual behavior towards health risks. Education about the dangers of zoonotic diseases caused by rats and pregnancy danger signs is key in building community awareness and preventive actions. This information-based approach also strengthens the role of public health interventions in encouraging active participation and appropriate decision-making to reduce morbidity in endemic areas.

A study conducted by Costa et al has relevance to a related topic on schistosomiasis, as both highlight the role of environmental factors and animal presence as indicators of zoonotic disease risk. Although the causative agents are different, leptospirosis and schistosomiasis are both closely related to human behavior, poor environmental sanitation conditions, and the presence of vectors or intermediate hosts. This shows that an ecological and integrated approach is very important in surveillance and control of environment-based diseases, especially in endemic areas such as Sulawesi.

Information on rat distribution and the potential spread of leptospirosis could be part of the data integrated in the health monitoring system, to improve the response and effectiveness of environmental health programs in various regions. Study on mapping rat density and the presence of Leptospira sp. in Pitue Village is relevant to the study conducted by P. Zulaeka et al on the effectiveness of management and monitoring of environmental health programs, as both emphasize the importance of monitoring systems based on accurate data to support health risk control.

A separate study focusing on slum households found a high prevalence of Rattus norvegicus infestation, which was significantly linked to an increased risk of Leptospira infection. Based on this association, researchers developed an easy-to-use prediction score derived from specific rat infestation markers. This scoring system effectively identified households with the highest infection risks and shows promise as a community-based screening tool. By stratifying risk in slum settings, this approach could guide targeted control measures and help mitigate high levels of leptospirosis transmission in vulnerable communities

CONCLUSIONS

The rat density in Pitue Village reached 18.5%, far exceeding the <1% threshold set by the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023, indicating a high-risk condition. The dominant species found was Suncus murinus (62%), while Rattus argentiventer was the least common (5.4%). PCR tests on rat kidneys confirmed the presence of Leptospira bacteria in several samples. Spatial and buffer analyses revealed overlapping zones within a 60-meter radius, identifying specific high-risk areas for leptospirosis linked to dense rat populations. These results highlight the urgent need for community action to maintain environmental hygiene and implement effective rat control to reduce disease transmission risks.

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Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: Syamsuar Manyullei. Methodology, Writing – original draft, Writing – review & editing, Supervision: Basir. Methodology, Formal analysis, Data curation, Writing: Deary Yosephine Sembiring, Rudi Hendro Purtanto. Investigation, Data curation, Visualization: Amir Su'udi. Review & Editing: Owildan Wisudawan B

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