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MORALITY BEFORE KNOWLEDGE

Identification of rodent species confirmed as the cause of leptospirosis disease with ecosystem distribution and environmental factors

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ABSTRACT
Background: Leptospirosis outbreaks have been reported in various parts of the world, classifying it as a re-emerging infectious disease. Rats act as the main reservoir for Leptospira spp. bacteria. The Indonesian Ministry of Health reported 1,170 cases of leptospirosis with 106 deaths Case Fatality Rate (CFR 9.1%) in 2020, obtained from 8 provinces. Additionally, in 2021, there was a decrease in cases by 734, but with an increased CFR of 11.4%, with the largest contributors being Central Java and East Java. Objective: To determine the most dominant rodent species confirmed to cause leptospirosis and the distribution of ecosystems and environmental factors that are the dominant causes of leptospirosis. **Methods:** This paper is a narrative literature review study. Articles were searched through online databases such as Google Scholar and PubMed using keywords leptospirosis, rats, ecosystem, and environmental factors, published within the last 5 years. **Findings:** The identification results showed that *Bandicota indica* was the most dominant rodent species infected with leptospirosis. This type of rat is a commensal species. Leptospirosis cases occurred in non-forest ecosystems near settlements and coastal areas near settlements. The dominant environmental factors associated with leptospirosis incidence were poor sanitation conditions, indiscriminate waste disposal behavior, and stagnant water. **Conclusion:** The identification results indicate that *Bandicota indica* is the most dominant rodent species infected with leptospirosis, being a commensal rat species in non-forest ecosystems near settlements and coastal areas near settlements. The dominant environmental factors associated with leptospirosis incidence include poor sanitation conditions, indiscriminate waste disposal behavior, and stagnant water. **Novelty/Originality of this Study:** The study's findings confirmed that non-forest and coastal ecosystems near settlements are significant reservoirs for Leptospira bacteria. Additionally, it highlighted the critical role of poor sanitation, indiscriminate waste disposal, and stagnant water as environmental factors contributing to the transmission of leptospirosis.

KEYWORDS: ecosystem; environmental factors; leptospirosis; rodent identification.

1. Introduction

Leptospirosis is a disease caused by bacteria that affect people and animal, its spread in the urine (pee) of infected animal. Leptospirosis occur wordwide but is most common in tropical and subtropical areas with hight rainfall. The disease is foundmainly wherever humans come into contact with the urine of infected. Leptospirosis is a global zoonotic disease estimated to cause around 1 million cases and 60,000 deaths annually. Caused by infection with bacteria from the genus *Leptospira*, leptospirosis presents a variety of symptomology ranging from asymptomatic to mild febrile illness to severe acute infection

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resulting in organ failure and death. Additionally, as many as 30% of leptospirosis cases result in long-term health impacts. There are many serovars and strains of *Leptospira,* with those that are pathogenic being of primary concern (Karpagam & Ganesh, 2020).

Leptospirosis is a zoonotic infectious disease that can lead to outbreaks if preventive measures are not promptly taken. This disease is caused by Leptospira bacteria, which can infect both humans and animals. Typically, leptospirosis cases are often associated with events such as floods, high tides in coastal areas, swampy regions, or peatland. Leptospirosis is widespread in tropical climate countries, such as Indonesia. The warm tropical environment with neutral pH in water and soil, high humidity, and abundant rainfall creates conditions highly conducive to the sustainability of Leptospira bacteria. This risk is further heightened if environmental conditions deteriorate, as it would support the development and survival of these bacteria. Leptospirosis often emerges in tropical regions after floods, typhoons, or other disasters, and the incidence of the disease is higher in tropical climates compared to subtropical and cold climates. Not only is there an increase in reported cases during these events, but there is also rapid and explosive disease spread upon reaching previously unaffected areas (Widjajanti, 2020).

Leptospirosis outbreaks have been reported in various parts of the world, including India, Indonesia, Malaysia, Sri Lanka, Thailand, Europe, Africa, North and South America. This occurrence classifies leptospirosis as a re-emerging infectious disease (Handayani et al., 2019). Leptospirosis is a disease that can affect and be transmitted between animals and humans (zoonosis) caused by infection from spiral-shaped bacteria of the genus Leptospira. Transmission of leptospirosis in humans occurs through direct contact with animals infected with Leptospira or indirectly through contact with water puddles contaminated with the urine of infected animals. The bacteria enter the body of animals or humans through the skin, open wounds, or mucous membranes due to contact with the organs, blood, and urine of infected reservoir animals (Supranelfy et al., 2019).

In 2020, the Indonesian Ministry of Health reported 1,170 cases of leptospirosis with 106 deaths Case Fatality Rate (CFR 9.1%) from 8 provinces. The provinces reporting leptospirosis cases were DKI Jakarta, West Java, Central Java, DI Yogyakarta, East Java, Maluku, South Sulawesi, and North Kalimantan. Additionally, in 2021, there was a decrease in cases by 734, but with an increased CFR of 11.4%, with the largest contributors being Central Java and East Java (Rachmawati et al., 2023). There were several environmental risk factors for the incidence of leptospirosis in Indonesia, namely the presense of standing water around the house, the poor maintained condition of ditches, the existence of trash bins that did not meet the requirements.

As part of improving the prevention and control of leptospirosis in Indonesia, the Ministry of Health, Ministry of Agriculture, and Ministry of Environment and Forestry are establishing a pilot program for rodent sentinel surveillance in 10 districts and starting integrated surveillance for leptospirosis involving the human, animal and wildlife sectors in certain districts. As part of the initiative, WHO, in collaboration with GLEAN, is supporting a series of virtual meetings on leptospirosis surveillance through a one health approach.

"To prevent and control leptospirosis effectively, multisectoral collaborative coordination involving a multidisciplinary team is needed, known as the One Health approach," said Hastuti, Director of Health Surveillance and Quarantine at the Ministry of Health, at the meeting. Integrated prevention and control of leptospirosis through this approach must involve various sectors involving humans, animals, wildlife and the environment to reduce risk factors and enable early detection and appropriate response fast. This is reflected in the composition of meeting participants: officers from the human, animal and wildlife sectors; doctors and laboratory technicians.

The gold standard for leptospirosis diagnosis in humans and animals is a serological assay called the microscopic agglutination test (MAT). MAT requires an accurate knowledge of locally circulating serovars with regular surveillance to maintain a complete panel of antigens for relevant serological tests. Some countries have a large number of circulating serovars making serological assays unfeasible and expensive, and testing is often limited to a small panel of reference isolates. In addition, interpretation of results can be subjective requiring expert knowledge given known cross-reactivity patterns between serovars, and delayed or absent immune responses with antibodies taking up to two weeks to reach detectable levels post-symptom onset. The classical methods for identifying *Leptospira* are visualization by dark field microscopy and culture. However, dark field microscopy requires at least 10 *Leptopspira*/ml for visualization with a reasonable chance for false negative diagnosis. Culture methods are laborious as *Leptospira* are fastidious bacteria that are often difficult to cultivate and it can take up to 13 weeks to grow in very specific culture conditions. Furthermore, the Cross-Agglutinin Absorption Test (CAAT) that determines serovar is difficult, only performed by a limited number of laboratories around the world and, it cannot be used to distinguish pathogenic and saprophytic *Leptospira* (Wilkinson et al., 2021).

Rats act as the main reservoir for *Leptospira spp*. bacteria. Various species of pathogenic Leptospira bacteria have been detected in the kidneys and urine of rats. Antibodies against various serovars of Leptospira have also been found in rat serum. Despite being a habitat for pathogenic Leptospira, rats can survive without showing significant clinical symptoms, unlike other mammals such as dogs or cows (Joharina et al., 2019). Leptospirosis has been present in Indonesia since 1936, with approximately 170 *Leptospira serovars* identified. The distribution areas include Central Java, DI Yogyakarta, West Java, North Sumatra, Riau, Jambi, South Sumatra, Bengkulu, and East Kalimantan. Rats with natural habitats that rarely come into contact with human activities have a low risk of transmitting leptospirosis or acting as reservoirs. *Rattus norvegicus, Rattus tanezumi*, and Mus musculus are three rodent species distributed almost worldwide and associated with Leptospira sp. Infection (Khariri, 2019).

Leptospirosis transmission is closely related to environmental factors, including abiotic and biotic factors. Abiotic environmental factors include rainfall index, air temperature, water temperature, air humidity, light intensity, water pH, and soil pH. Biotic environmental factors include vegetation and success in rat capture. Environmental factors are based on the characteristics of the residential environment, flood-prone areas, altitude, high rainfall, soil texture, vegetation density, and temperature and humidity. Densely populated settlements make it difficult to control environmental cleanliness. A dirty environment is a suitable habitat for rats and can increase the risk factor for Leptospira bacteria in rats. Meanwhile, the wider the flood-prone area and the presence of rats infected with Leptospira bacteria, the easier it will spread. Low altitudes also make it difficult for water to flow, resulting in puddles and becoming a medium for rats to urinate. Meanwhile, high rainfall causes puddles and floods, increasing the risk of spreading rat urine containing Leptospira bacteria. Soft soil also easily forms puddles. while denser vegetation such as forests, bushes, and rice fields provide more habitat for the definitive host of leptospirosis, namely rats. Finally, the optimal temperature for Leptospira bacteria to grow is 28-30°C (Muthiadin et al., 2022).

According to Samekto, several factors have been proven to influence the occurrence of leptospirosis, including the presence of rats inside and around houses. Leptospira bacterial infections occur due to the environmental conditions in residential areas where rats are commonly found. Rats act as reservoirs for diseases such as leptospirosis, and the habit of not wearing footwear contributes to this updating data on geographic distribution, climate change, and confirmation of disease reservoirs is crucial to understanding the types and numbers of species, their potential, and their roles in vector-borne disease transmission and reservoirs. Higher annual mean temperatures enchage the growth and activity of *Leptospira spp*, and at the same time lengthen the infectious season and expand the geographical distribution of the bacteria (Muthiadin et al.,2022). Data on rats as disease reservoirs can be used as a basis for controlling zoonotic diseases in Indonesia, such as leptospirosis (Khariri, 2019). This study aims to identify the most dominant rat species confirmed to cause leptospirosis and the distribution (ecosystem and environmental factors) that are the dominant causes of leptospirosis in rats, which are the main reservoirs of leptospirosis.

2. Methods

The method employed in this study is a literature review. Literature review can be and informative and useful synthesis of topic. It can identify what in know (and unknow) in the subject area and help formulate questions that need further research. The strengths of the literature review method oinclude its ability to summarize and synthesis previous research. Systematic literature reviews have advantages compared to other methods. Among them are meta-analysis, systematic, narrative reviews which allow us to produce more effective research.

The information sources (databases) used for searching references on this topic include Google Scholar and PubMed. Keywords used for the search are "leptospirosis," "rats," "ecosystem," and "environmental factors." These keywords were used to search for journals in both Indonesian and English languages. Journal searches were conducted online within the last five years. The selection of literature articles for review used inclusion criteria, including both national and international journals within the time frame of 2019 to 2023. The complete screening process is presented in the following prisma flowchart (Figure 1).

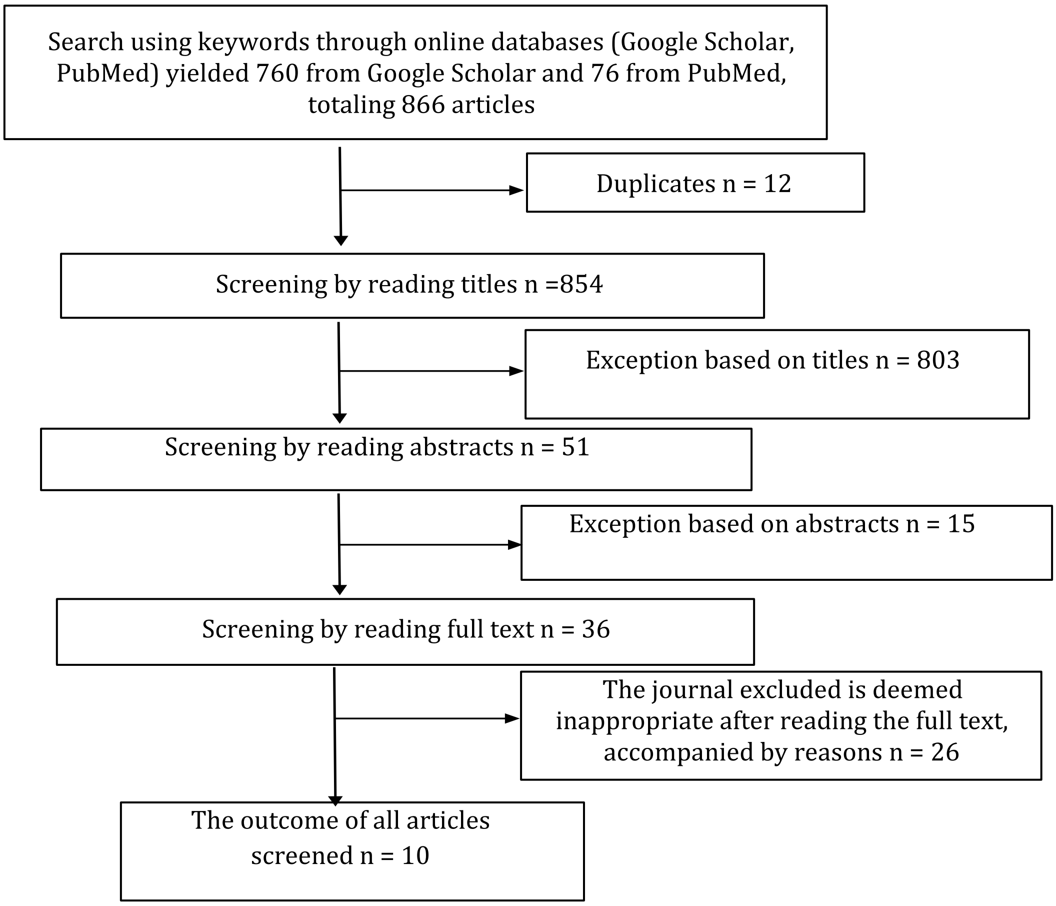

Fig.1. Prisma flowchart

3. Results and Discussion

Based on the literature review data from 2019-2023 by Solichah's study, *Bandicota indica* was found to be positive for leptospira in the research location, indicating that this species acts as a reservoir for *leptospira*. The findings of Leonardo et al. suggest that cases of leptospirosis in ecosystems near settlements can be attributed to several factors. One of them is that ecosystems near settlements, especially those with poor sanitation, become preferred habitats for rats. In endemic areas, poor environmental factors around homes can increase the availability of food, shelter, and breeding grounds for rats as reservoirs of leptospirosis. The overall findings of the literature review are summarized in the following matrix Table 1.

Table 1. Summary article matrix previous research

No	Article titles	Authors (Year)	Research design	Results/ Conclusions
1	Identification of captured rat species and detection of leptospira bacteria: Study at the Gapura Surya Nusantara Passenger Terminal, Tanjung Perak Port, Surabaya	Utama et al. (2023)	Quantitative. Descriptive cross-sectional	Mice are the main reservoir in the transmission of leptospirosis. In this study, mice were captured using traps baited with salted fish. The results showed that the most dominant species captured was *Rattus norvegicus*, and predominantly male. PCR results indicated that all were male *Rattus norvegicus*. This species should be noted as a potential transmitter of leptospirosis in the Tanjung Perak Port area, Surabaya
2	Identification of leptospira bacteria presence in endemic leptospirosis areas (A study in Dukuh Kalitengah, Wedi Subdistrict, Klaten Regency)	Sutiningsih et al. (2023)	Quantitative. Survey with cross-sectional design	Rat capture was conducted for 6 consecutive days using various baits such as tofu meatballs, roasted coconut, smoked fish, and meatballs. The captured rats were anesthetized, identified, and underwent kidney examination through surgery. Leptospirosis testing was performed on 23 kidney samples from various captured rats (*M. musculus*: 4 individuals, *R. tanezumi*: 7 individuals, *R. norvegicus*: 6 individuals, *S. murinus*: 11 individuals), with the final result showing only 2 individuals positive for leptospirosis, both belonging to the species *Rattus tanezumi* (28.5%) or 2 out of 7 *R. tanezumi* species tested positive for leptospirosis
3	Leptospirosis examination in rats in Ciwidey District, Bandung Regency, West Java	Gunawan et al. (2022)	Quantitative. Descriptive with cross-sectional design	This study aims to detect the presence of leptospira bacteria in rats in the Ciwidey district. Trap installations yielded 46 rats, predominantly of the Rattus tiomanicus species and predominantly male. PCR examination results showed that 11 R. Tiomanicus rats contained leptospira DNA. Leptospirosis tends to be higher during the rainy season, with environmental factors such as flood risk and the presence of stagnant water playing a crucial role in leptospirosis incidence.
4	Leptospira in rats and water bodies and transmission history of patients in newly identified leptospirosis	Sholichah et al. (2021)	Quantitative. Observational with cross-sectional design	This research was conducted in the location of leptospirosis transmission cases in Gilangharjo Village, Pandak Subdistrict, Bantul Regency. The trap installations resulted in the dominance of Rattus tanezumi species with 25 individuals, followed by *Bandicota indica* species. However, leptospirosis

	cases in Bantul District			examination using PCR showed 3 positive leptospira from *Bandicota indica* species only, all of which were female. One positive leptospirosis individual was captured in the patient's house, and two were captured within a radius of 4 – 47 meters from the patient's house. The leptospirosis patients had activities in the fields and at home, had untreated wounds, and had a history of contact with rats.
5	Detection of leptospira bacteria in rats in Ciomas Sub-District, Bogor District, West Java using real time pcr method.	Gunawan et al. (2021)	Quantitative. Analytical descriptive with cross-sectional design	This research was conducted in 3 villages, 75 houses in the Ciomas subdistrict with a total of 150 traps set. The most dominant rat species captured was Rattus tanezumi with 48 captures, followed by *Bandicota indica* with 19 captures, and Rattus norvegicus with 18 captures. However, rats positive for leptospirosis were predominantly of the Bandicota indica species (57.9%). Leptospirosis transmission occurs easily in densely populated areas with high rat populations and poor sanitation. Scattered garbage becomes a cause for rats to enter houses and transmit leptospirosis.
6	Leptospirosis in rats in Minahasa Regency, North Sulawesi	Lobo et al. (2020)	Quantitative. Descriptive survey	Based on the MAT and PCR test results, the dominant rats identified as leptospirosis reservoirs are *Rattus tanezumi* species, found mostly in Non-Forest Ecosystem Near Settlements (NFENS). Transmission among rats occurs in ecosystems close to settlements. Environmental conditions conducive to leptospirosis transmission include poor sanitation, indiscriminate waste disposal, and the presence of food storage areas. Leptospirosis transmission is also closely related to heavy rainfall and agricultural work.
7	Low prevalence of leptospira carriage in rodents in leptospirosis endemic Northeastern Thailand	Krairojananan et al. (2020)	Quantitative. Descriptive survey	The prevalence of leptospirosis in this study is only 3.6% (18 out of 495 rats examined). Leptospira infection is more commonly found in low rat population species such as Bandicota indica compared to high rat population species like Rattus rattus. Two species of leptospira bacteria were found in *Bandicota indica* species. High populations of *Rattus rattus* may not necessarily be the main cause of leptospirosis; rather, the potential for leptospirosis arises from low rat population species such as *Bandicota indica*.
8	Analysis of environmental	Supranelfy et al.	Quantitative. Analytical	This study is a specific vector research. From the 3 districts studied, 44 samples

	factors on distribution of rats which confirmed as reservoir in three districts in South Sumatera Province	(2019)	descriptive with cross-sectional design	tested positive for leptospirosis out of 308 samples examined. The rat species most commonly found positive for leptospirosis is *Rattus tanezumi*, with PCR results showing 18 samples positive for leptospirosis. There is a potential for transmission in forests because leptospirosis-positive forest rat species were found. The ecosystems where positive leptospirosis cases were predominantly found are non-forest ecosystems near settlements and coastal areas near settlements. Environmental conditions conducive to leptospirosis transmission include poor sanitation, indiscriminate waste disposal, and the presence of food storage areas.
9	Prevalence of leptospira infection in rodents from Bangladesh	Krijger et al. (2019)	Quantitative. Descriptive survey	The prevalence of leptospirosis in this study is 13.1% (61 out of 465 captured rats infected with pathogenic leptospira). Based on both PCR and MAT examinations, the confirmation of Bandicota indica species indicates leptospirosis infection among all species, and *B. bengalensis* and *R. exulans* (as peridomestic rats) show higher infection rates compared to M. musculus and R. rattus as domestic rats. This implies that rats farther from household environments have a higher potential to transmit leptospirosis compared to rats closer to household environments. It's possible that environments farther from households have more contaminants that promote the growth of leptospirosis bacteria.
10	The role of rats as leptospira reservoirs in three ecosystems in Bantul Regency, Yogyakarta	Joharina et al. (2019)	Quantitative. Descriptive survey	Bantul has become an endemic area reporting leptospirosis incidents every year. The research was conducted on 3 ecosystems: forest, non-forest, and coastal. The highest average capture of rat species was *Rattus tanezumi*. However, detection of leptospira bacteria was most commonly found in Rattus norvegicus, which was found in non-forest and coastal ecosystems. Based on ecosystems, the coastal area has the highest percentage of pathogenic leptospira with the main habitat being mangrove forests and the main species being *Rattus tiomanicus*.

3.1 Identification of rat species confirmed as the cause of leptospirosis disease

From the review of 10 journal articles, data were obtained showing that the dominant rat species causing leptospirosis, as confirmed by PCR examination of rat kidney specimens, Bandicota indica is the dominant cause of leptospirosis in articles (4, 5, 7, 9), while Rattus tanezumi is the dominant cause of leptospirosis in articles (2, 6, 8). Finally, Rattus norvegicus: The dominant cause of leptospirosis in articles (1 and 10). These three types of rats are commensal species that are accustomed to interacting in environments close to human activities. The non-forest ecosystem consists of several habitats, namely houses/settlements, yards, rice fields and gardens. The home/settlement habitat in the research results is the habitat with the highest relative density. This is a common thing because commensal mice have long adapted and become natural inhabitants of environments where human life exists. However, the habitat with a higher percentage of pathogenic leptospira infections is not the home habitat but the rice field habitat (in the case of yards, it is still considered the home environment). These results also support previous studies that agricultural areas are the main risk factor in Bantul Regency.

Meanwhile, PCR testing is a laboratory-scale/molecular examination conducted to detect the presence of DNA or RNA of viruses or bacteria. The presence of DNA and RNA is detected through amplification techniques. This aids in diagnosing the cause of a disease (Handayani et al., 2019). In research or programs on leptospirosis in rats, rat identification is conducted before entering the PCR examination process. Rat identification is the process of observing and measuring qualitative and quantitative characteristics of rat morphology. Qualitative morphological characteristics include color, body shape, hair texture, leg shape, tail shape, and other features. Quantitative characteristics involve measuring body weight, head and body length, tail length, hindfoot length, ear length, number of teats, and so on. The purpose of identification is, of course, to determine the rat species associated with location and control techniques, the locations of trapping were in six ecosystems: forests near and far from settlements, non-forest locations near and far from settlements, and coastal areas near and far from settlements.

The three dominant rat species causing leptospirosis are divided into two based on their habitat distribution: domestic rats and peridomestic rats. Species classified as domestic rats include *Rattus tanezumi*, while peridomestic rats include *Bandicota indica* and Rattus norvegicus. Domestic and peridomestic rats are also known as commensal rodents, meaning they have adapted well to human activities and rely on human habitation for survival. The rats captured and tested positive for *Leptospira bacteri*a are commensal rat species whose presence is close to human settlements or households. Species such as *Rattus tanezumi, Rattus norvegicus, Mus musculus,* and *Bandicota indica* are classified as commensal rats. *Rattus argentiventer*, which inhabits rice fields, *Rattus exulans*, found in gardens, and *Rattus tiomanicus*, which resides in trees, are considered peridomestic rats. Peridomestic rats primarily live outside homes and their surroundings, but they are occasionally found inside homes. *Rattus norvegicus* also falls into the category of peridomestic rats. These findings are consistent with Sholichah et al.'s research, which found that PCR-positive results came from *Bandicota indica, Rattus norvegicus*, and *Rattus tanezumi* species (Sholichah et al., 2021).

Types of mice caught in the study It consists of 3 species, namely Rattus tanezumi, Rattus norvegicus and Mus musculus. Apart from 3 This species includes Suncus murinus caught. This type of rat is group of domestic mice that live activities These mice look for food, shelter, nest and breeding at home. Leptospira infection in mice can influenced by species. Rattus tanezumi can be a source of Leptospira infection and can spread to humans and the environment which was exposed by Rattus tanezumi yang Its habitat can be found in residential areas population. The presence of a rat reservoir was detected Leptospira positivity is one factor risk of leptospirosis. Leptospira bacteria were detected in this study lodged in the renal tubules of rats and excreted together with urine. Bacteria It is transmitted directly through urine and fluids the body of an infected or in contact animal not directly through water or land contaminated by Leptospira bacteria. 12 Rats can remove Leptospira bacteria continuously through urine throughout his life so it can be a source of infection leptospirosis, especially in humans. Leptospira can contaminate water and food with the risk of causing infection and disease in humans article (2).

Field rats *Rattus argentiventer*, garden rats *Rattus exulans*, and tree rats *Rattus tiomanicus* have been detected as leptospirosis transmission species. This aligns with Khariri's study in Central Java Province, which found leptospira bacteria in the bodies of these three peridomestic rat species (Khariri, 2019). However, the percentage of leptospira bacteria presence through PCR examination for these three rat species is lower, and the dominance of positive leptospira PCR results is still found mostly in *Rattus tanezumi* (house rat) and *Rattus norvegicus* (sewer rat). This data also corresponds with Kesuma A.P. et al.'s research, which states that *Rattus tanezumi* and *Rattus norvegicus* species are the main reservoirs of leptospirosis in several regions experiencing increased cases such as Semarang, Klaten, Bantul, and Tangerang (Kesuma et al., 2020). Meanwhile, Mohanrao's study on leptospirosis in Gujarat, India, mentions that four rat species, namely *Rattus norvegicus, Rattus tanezumi, Bandicota indica*, and *Bandicota bengalensis*, are vectors of leptospirosis and transmit infections in rural and urban areas (Rao, 2020).

To date, there are a few studies on the confirmation of rats infected with leptospirosis in all ecosystems in Indonesia. Consequently, leptospirosis becomes a neglected disease, the diagnosis and management of leptospirosis cases are relatively unknown to health workers, and epidemiological research, laboratory facilities, and infrastructure for leptospirosis detection are still very limited, especially outside of Java Island. Some studies revealed that the main inhibiting factors for leptospirosis monitoring are the availability of resources, awareness of good communication, lack of partner/researcher collaboration, incomplete data infrastructure, limited availability of the *Rapid Diagnostic Test* (RDT), *Microscopic Agglutination Test* (MAT), and *Polymerase Chain reaction* (PCR) in hospitals and health centers, unavailability of standard operating procedures (SOP) for leptospirosis surveillance systems, lack of evaluation standards, and insufficient activation of surveillance at community levels article (8).

3.2 The dominant ecosystems confirmed for cases of leptospirosis

Based on the review, data show that non-forest ecosystems near settlements (articles 6, 8, 10) and coastal ecosystems near settlements (articles 8, 10) are the locations where cases of leptospirosis are most commonly found. The occurrence of leptospirosis in ecosystems near settlements can be attributed to several factors. One of them is that ecosystems near settlements, especially those with poor sanitation, become favored habitats for rats to live. Unmanaged waste, usually containing food scraps, attracts rats to inhabit residential environments. Poor sanitation environments can trigger rats to urinate in their surroundings. Water, soil, and rivers around residential environments become contaminated with leptospira bacteria. Moreover, slums and overcrowded settlements also trigger the spread of leptospirosis, often having poor wastewater and waste disposal systems, making it easy to pollute rivers and small waterways in residential areas. These water flows become nesting and foraging grounds for rats.

These findings align with Khariri's research stating that the ecosystems where the most cases of leptospirosis in dominant rats are found are Non-Forest Near Settlement (NFNS) and Coastal Near Settlement (CNS) ecosystems. In urban areas, socioeconomically disadvantaged communities often reside in high-density housing with conditions that facilitate the spread of leptospirosis by increasing the contact with environmental sources of the disease. These conditions include reduced rates of governmental sanitation interventions, trash accumulation, poor infrastructure, and contact with sewer water. Positive examination results from samples with habitats near settlements located in densely populated areas can accelerate the spread of Leptospira bacteria even further (Khariri, 2019). Although most leptospirosis findings in rats are in urban or rural areas around human settlements, according to Ardanto et al.'s research, humans can be infected with leptospirosis in other humid areas such as forest ecosystems. Studies in Thailand, Laos, and Cambodia show that leptospirosis is also found in rats captured in locations far from human settlements, including forests (Ardanto et al., 2018).

Article (10) explain that Leptospira bacteria were detected in kidney specimens using the PCR method from a total of 196 mice obtained during the study. Most mice are obtained from ecosystems near settlements and all are commensal mice. Rattus tanezumi is the dominant species in all three ecosystems, but the highest percentage of pathogenic leptospira infection is found in R. norvegicus. Coastal ecosystems contain the highest number of mice infected with pathogenic leptospira, with the main habitat being mangrove forests. Based on these results, mice have a high potential for transmitting leptospirosis.

3.3 Environmental conditions supporting leptospirosis transmission

The presence of standing water can result in the incidence of leptospirosis. This is due to contamination through the urine of infected animals. So, if the standing water is not contaminated by the urine of rats infected with leptospira bacteria, then it may not cause leptospirosis2 . A previous study conducted in the city of Semarang showed that people who had standing water around the house had 3.273 times higher risk of contracting leptospirosis compared to respondents who did not have standing water around the house8 . This was reinforced by the presence of leptospirosis bacteria in 38 positive water samples or around 61.29% taken from the houses of case and control respondents. Environmental conditions that influence the transmission of leptospirosis include poor sanitation (articles 5, 6, 8), indiscriminate waste disposal behavior (articles 6 and 8), the presence of stagnant water including heavy rainfall (articles 3 and 6), and the presence of food storage at the patient's home (articles 6, 8).

Poor sanitation conditions are synonymous with situations where basic sanitation facilities such as access to clean toilets and contaminated drinking water are lacking, and densely populated environments also contribute to poor sanitation due to the difficulty in maintaining cleanliness in such areas. Based on Ragil A. et al.'s research, the transmission of leptospirosis occurs due to poor environmental sanitation. In endemic areas, poor environmental conditions around homes can increase the availability of food, shelter, and breeding sites for rats as leptospirosis reservoirs. Other physical environmental factors include the presence of stagnant water and habits of washing/bathing in rivers. According to preliminary studies, the physical environmental characteristics show that 94% of respondents have a distance of less than 2 meters between their homes and drainage ditches, and 67% of homes have scattered garbage. The presence of garbage around the home becomes a favored place for rats, Although rural areas may be at higher risk, leptospires in urban environments may be more virulent In addition, urban leptospirosis is often associated with epidemics and is possibly underrepresented in this review because outbreak reports were excluded. It has also been noted that the increasing pressures on wildlife agglomerations at the peri-urban interface might lead to increased risk of leptospirosis in urban areas in the future (Andriani & Sukendra, 2020).

Indiscriminate waste disposal behavior also poses a risk for leptospirosis transmission, as scattered garbage invites rats into residential environments. With rats entering densely populated and poorly sanitized residential areas, the risk of leptospirosis increases. This is consistent with research conducted by Ginting et al., which states that open garbage in front or behind houses is associated with leptospirosis incidence. Poor waste collection points are a risk factor for leptospirosis incidence because the intermediate vectors of leptospira bacteria, especially rats, are highly attracted to places with garbage piles (Ginting, 2022). However, this is not consistent with the findings of Ragil Andriani et al., which state that the presence of garbage is not directly related to the risk factors for leptospirosis incidence (Andriani & Sukendra, 2020).

The presence of stagnant water, including heavy rainfall, is an environmental factor that supports leptospirosis transmission. Water becomes an effective medium for disease transmission (waterborne diseases). Rats roaming around settlements where there are stagnant waters from heavy rains causing floods, from overflowing rivers, or due to road construction errors can become habitats for leptospirosis from rat urine. This aligns with Ragil Andriani et al.'s research, which states that there is a significant relationship between the presence of stagnant water and leptospirosis incidence. Water is a breeding ground for Leptospira sp. bacteria, which can survive for months in open areas such as muddy soil, rice fields, livestock areas, and in freshwater, for example, ponds (Andriani & Sukendra, 2020).

The presence of food storage inside the homes of leptospirosis patients is also synonymous with the presence of rats potentially affected by leptospirosis. Consistent with

Afra's research, which states that there is a relationship between food storage and the disposal of food scraps with the presence of rats. It is advisable to store food items and meals in closed containers and always clean the kitchen from scattered food scraps (Nur, 2022).

4. Conclusions

This highlights the potential role of species and gender in the spread of these bacteria. Increased surveillance and control measures are needed to address the issue of rats and the spread of Leptospira bacteria. The *Bandicota indica* species, particularly the males exposed to Leptospira bacteria, requires special attention.

Bandicota indica is rats can also be found in swamp area, grasslands and garden oaround the house is the dominant species of rat most frequently confirmed positive for Leptospira bacteria. This type of rat is a peridomestic species, primarily living outside homes and their surroundings, but sometimes found inside homes close to human habitation. The most dominant ecosystem where positive leptospirosis cases are found is in non-forest ecosystems near settlements and coastal ecosystems near settlements. The dominant environmental factors associated with leptospirosis incidence are poor sanitation conditions, indiscriminate waste disposal behavior including disposing of food waste, and the presence of stagnant water.

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Author Contribution

S.K. and R.J. conceived the study, carried out all research activities, analyzed the data, wrote the manuscript, and were responsible for the final content. The authors approved the final version and agreed to be accountable for all aspects of the work.

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