ACTA VETERINARIA INDONESIANA
P-ISSN 2337-3202, E-ISSN 2337-4373

*Research* Vol. 13, No. 1: 77–86, Maret 2025

# Diversity of Mites in Captured Rats and the Role of Rickettsiosis in Semarang City and Demak Regency

**Indah Mulyani[1], Ristiyanto Ristiyanto[3*], Dita Pratiwi Kusuma Wardani[1,a], Muhammad Luthfi Almanfaluthi[2], Farida Handayani[4]**

[1]Study Program of Medical Laboratory Technology, Faculty of Health Sciences, University of Muhammadiyah Purwokerto
[2]Study Program of Medical Education, Faculty of Medicine, University of Muhammadiyah Purwokerto
[3]Public Health Research Center, National Research and Innovation Agency (BRIN)
[4]Eijkmen Center for Molecular Biology Research, National Research and Innovation Agency (BRIN)
*Correspondence author: rist009@brin.go.id
Received: 20 May 2024, Approved: 28 October 2024

## ABSTRACT

Rats can spread rickettsiosis by ectoparasite bites or direct contact. Ectoparasites, residing on the host's exterior or body surface, serve as parasitic vectors for rickettsial diseases. Mites are ectoparasites commonly found in mice. This study aimed to assess the ecological index of mite ectoparasites in rats captured in Semarang City and Demak Regency from June to August 2023. This study employed a descriptive observational design utilizing a rodent survey conducted through an accidental sampling technique. A total of 2,116 individuals were identified, comprising the mite species *Laelaps nutalli*, *Laelaps turkestanicus*, *Eulaelaps stabularis*, *Echinolaelaps echidninus*, *Dermanyssus gallinae*, and *Ornithonyssus bacoti*. Semarang and Demak exhibited average diversity index values of 1.00 and 0.78, respectively, categorizing them as medium and high. Rat populations and mite abundance significantly influence environmental health, which includes human health. Monitoring the prevalence of *Laelaps nutalli* mites is essential because of their potential to transmit murine typhus.
**Keywords**: Ectoparasites, Infestation, Diversity, Ricketssiosis, Mites

## ABSTRAK

Ricketssiosis ditularkan oleh tikus baik secara kontak langsung maupun gigitan ektoparasit. Ektoparasit merupakan parasit vector penularan penyakit rickettsia yang hidupnya pada permukaan tubuh atau di bagian luar inangnya. Tungau merupakan salah satu ektoparasit yang sering ditemukan pada tikus. Penelitian ini bertujuan untuk mengetahui indeks ekologi ektoparasit tungau pada tikus yang tertangkap di Kota Semarang dan Kabupaten Demak pada bulan Juni – Agustus 2023. Penelitian ini bersifat observasional deskriptif dengan metode yang digunakan survey rodent dengan teknik yaitu teknik accidental sampling. Jumlah tikus yang tertangkap sebanyak 218 ekor dengan jenis *Rattus Norvegicus, Rattus Norvegicus javanus, Rattus Tanezumi, Rattus Argentiventer, Suncus murinus, Mus Musculus*. Hasil spesies tungau yang ditemukan yaitu *Laelaps nutalli, Laelaps turkestanicus, Eulaelaps stabularis, Echinolaelaps echidninus, Dermanyssus gallinae, Ornithonyssus bacoti* dengan total 2.116 individu. Rata-rata nilai indeks keanekaragaman adalah 1,00 (Semarang) dan 0,78 (Demak) termasuk kategori sedang dan tinggi. Banyaknya tikus yang tertangkap dan banyaknya tungau memengaruhi kesehatan lingkungan, terutama manusia. Kelimpahan tungau *Laelaps nutalli* perlu diwaspadai karena sebagai salah satu yang berpeluang menularkan *murine typhus*.
**Kata kunci:** Ektoparasit, Infestasi, Keanekaragaman, Ricketssiosis, Tungau

 

# INTRODUCTION

Rickettsiosis is an infectious disease caused by obligate intracellular bacteria (Chen et al. 2022). *Murine typhus* and *scrub typhus* are most commonly found in the Asia-Pacific region. *Murine typhus* is caused by *Rickettsia typhi* with clinical manifestations of acute fever accompanied by pneumonia, respiratory failure, central nervous system disorders, and death (Chang et al. 2019). *Scrub typhus* is characterized by fever accompanied by headache, chills, arthralgia, and myalgia (Richards 2020).

Rickettsiosis is caused by organisms belonging to the family Rickettsiaceae, which includes the genera Rickettsia and Orienta. Rickettsia is categorized into two groups: the spotted fever group (SFG) and the typhus group (TG). The *Rickettsia akari* serves as a vector for Rickettsiae, whereas the *Trombiculid* mite is the sole vector of *Orientia* spp. to humans (Abdad et al. 2018). *Trombiculid* mites in China serve as vectors for the pathogens *Orientia tsutsugamushi*, *Bartonella* spp., and *Rickettsia* spp. (Huang et al. 2017).

Rats serve as a reservoir for the transmission of rickettsiosis via both direct contact and bites from ectoparasites (Maibang et al. 2023). Rats belong to the Rodensia Order, which shares a close relationship with humans (Haidar et al. 2022; Husna & Chandra 2021; Manyullei et al. 2022). The most prevalent ectoparasites in rats include fleas, lice, ticks, and mites (Lokida *et al*., 2020).

The Indonesia Research Partnership on Infectious Disease (INA-RESPOND) reported that rickettsiosis cases from 2013 to 2016 ranked third among the most common infections, accounting for 103 subjects (10.3%), following dengue fever and typhoid fever (Gasem et al. 2020). There were six cases of murine typhus in Semarang (9%) out of 67 hospitalized patients and three cases (4%) out of 70 outpatients (Widiastuti et al. 2020). There have been no reported cases of rickettsiosis in Demak Regency. Limited laboratory facilities for diagnosing the cause of this disease result in underreporting, and it is considered a neglected disease in Indonesia (Pramestuti et al. 2022).

The ectoparasite diversity index for female *Rattus tanezumi* in the enzootic area of Mount Merapi's slopes is 1.75, which is higher than the index for male rats at 1.48. In garden habitats, the diversity index value of female rats is also higher than that of male rats (Ristiyanto et al. 2016). Various environmental factors, such as disease, predation, climate, altitude, habitat type, food sources, and human exploitation of habitats, shape the distribution and diversity of rats (Hidayat & Mairawita 2021).

This study identified and analyzed mite infestations and diversity in the rat population in Semarang City and Demak Regency to prevent and control ectoparasites that cause rickettsiosis, as well as serve as a reference for further research.

## MATERIALS AND METHOD

This observational study employed a rodent survey design conducted between June and August 2023. The study population included all rats and mites present at the survey site. The sample included all rats and mites that were successfully captured. This study employed a randomization technique through random sampling.

The research was conducted in Semarang City, specifically in Sawah Besar Subdistrict, Siwalan Subdistrict (Gayamsari District), and Muktiharjo Kidul Subdistrict (Tlogosari District); and in Demak Regency, in Tridonorejo and Gebang Subdistricts (Bonang District), Central Java.

### *Rat Capture and Identification*

Rat trapping was conducted over a period of two to four consecutive days using 676 single live traps, each measuring 15x15x30 cm. In each house, two traps were set up inside and outside the house with burnt coconut bait. The traps were set between 3:30 and 5:30 p.m. WIB and were collected the following day between 6:00 and 9:00 a.m. WIB. Traps containing rats were documented by recording the date, month, year, location (roof, kitchen, garden, type of tree), and the location code of the capture area. The trap was placed in a strong cloth bag measuring 30 x 40 cm, ensuring that ectoparasites that escaped from the body remained secured within the bag. Rats were identified using a Javanese rat identification book (Yuliadi et al. 2016).

### *Collection of Ectoparasites*

The rat dislocation procedure was conducted following the approval from the Health Ethics Commission of the National Research and Innovation Agency (BRIN), reference number 049/KE.03/SK/05/2023. Weak or deceased rats were then combed on a tray. Ectoparasites that fell into the tray were collected with tweezers. Ectoparasites located on the ears, nose, and base of the tail were removed using a needle or tweezers. Subsequently, all ectoparasites were placed in a tube with 70% alcohol and assigned an identity (location code and number) (Yuliadi et al. 2016).

### *Preparation and Identification of Mites*

Mite samples were immersed in a 10% KOH solution for 24 hours, as described by Ristiyanto et al. (2016). Following immersion, the samples were rinsed with distilled water and subsequently immersed in an acetic acid solution for four hours. The sample was cleaned with distilled water, followed by the application of a few drops of 60%, 70%, and 90% alcohol for 20 minutes. This was followed by the application of xylol for 30 minutes and clove oil for 15 minutes. The mite sample was positioned on a glass slide with its legs directed backward and its head oriented downward. Subsequently, the solution was meticulously dripped while gradually pressing the specimen to the bottom of the object glass using a fine needle, followed by the application of a cover glass. The mite preparations were observed under a stereo microscope and a binocular microscope at 40 x 10 magnification. Mite identification was carried out using a rodent infectious disease book (Ristiyanto et al. 2014).

*Data Analysis*

The findings from the observations and identifications were provided in the form of tables and visuals, with each type defined in terms of the observed features. The trap success, infestation value, and Shannon-Wienner (H') diversity index were calculated (Sriwahjuningsih et al. 2022).

## RESULTS

According to Table 1, the highest trap success rate was in Muktiharjo Subdistrict, Semarang City (24.48%), while the lowest was in Tridonorejo Subdistrict, Demak Regency (8.6%). Rat density in these areas was high, with trap success rates of ≥7% inside and ≥2% outdoors (Sholichah et al. 2020).

Based on Table 2, the highest mite infestation was found in *Rattus norvegicus* (94.83%) and the lowest in *Mus musculus* in Semarang City. Meanwhile, *R. norvegicus javanus* had the highest mite infestation in Demak Regency (92.30%), while *Suncus murinus* and *R. argentiventer* had the lowest, with only one *R. argentiventer* and three *S. murinus* rats captured.

Six species of mites were identified in the captured rats: *Laelaps nutalli*, *Laelaps turkestanicus*, *Eulaelaps stabularis*, *Echinolaelaps echidninus*, *Dermanyssus gallinae*, and *Ornithonyssus bacoti*, totaling 2,116 mites.

According to Table 3, *R. tanezumi* exhibited the highest diversity index in both locations. In contrast, the lowest index was recorded for *M. musculus* (0.50) in Semarang City and *R. norvegicus* (0.62) in Demak Regency. *The Shannon-Wiener H' diversity index can be classified as low for values less than 1, while values between 1 and 3 are considered moderate.* The data analysis results indicate that the average diversity index in Semarang City was moderate (1.00), while in Demak Regency, the average was low (0.78).

Table 1. Trap success of rat catching in Semarang City and Demak Regency

| Location | Trap success |
|---|---|
| Sawah Besar Subdistrict, Gayamsari District, Semarang City | 6.56% |
| Siwalan Subdistrict, Gayamsari District, Semarang City | 18.66% |
| Muktiharjo Kidul Subdistrict, Tlogosari District, Semarang City | 24.48% |
| Tridonorejo Subdistrict, Bonang District, Demak Regency | 8.66% |
| Gebang Subdistrict, Bonang District, Demak Regency | 11% |

Table 2. Mite infestation in rats captured in Semarang City and Demak Regency

| Types of rat | Number of mites infested rats | | Number of rats captured | | Infested with mites | |
|---|---|---|---|---|---|---|
| | A | B | A | B | A | B |
| **Rodentia** | | | | | | |
| *R. norvegicus* | 55 | 9 | 58 | 10 | 94.83% | 90% |
| *R. tanezumi* | 30 | 34 | 42 | 43 | 71.43% | 79.10% |
| *R. norvegicus javanus* | 11 | 12 | 22 | 13 | 50% | 92.30% |
| *R. argentiventer* | - | 1 | - | 1 | - | 100% |
| **Eulipotyphla** | | | | | | |
| *S. murinus* | 6 | 3 | 13 | 3 | 46.15% | 100% |
| *M. musculus* | 1 | - | 9 | - | 11.11% | - |

Note: Semarang City (A), Demak Regency (B)

Table 3. Diversity index of mites found on rats captured in Semarang City and Demak Regency

| Types of Rat | Number of Mites | | | | | | | | | | | | Diversity Index | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ln | | Lt | | Es | | Ee | | Dg | | Ob | | | |
| | A | B | A | B | A | B | A | B | A | B | A | B | A | B |
| **Rodentia** | | | | | | | | | | | | | | |
| *R. norvegicus* | 499 | 451 | 21 | 58 | 43 | 6 | 74 | 6 | 55 | 2 | 93 | 18 | 1.20 | 0.62 |
| *R. tanezumi* | 28 | 121 | 3 | 2 | 4 | 29 | 21 | 61 | 8 | 0 | 2 | 11 | 1.40 | 1.14 |
| *R. norvegicus javanus* | 118 | 156 | 0 | 42 | 8 | 114 | 13 | 0 | 0 | 0 | 19 | 0 | 0.83 | 0.71 |
| *R. argentiventer* | - | 1 | - | 0 | - | 0 | - | 1 | - | 0 | - | 1 | - | 0.73 |
| **Eulipotyphla** | | | | | | | | | | | | | | |
| *S. murinus* | 7 | 5 | 1 | 0 | 0 | 0 | 4 | 4 | 1 | 0 | 0 | 0 | 1.09 | 0.69 |
| *M. musculus* | 4 | - | 0 | - | 0 | - | 1 | - | 0 | - | 0 | - | 0.50 | - |

Note: Semarang City (A), Demak Regency (B), *Laelaps nutalli* (Ln), *Laelaps turkestanicus* (Lt), *Eulaelaps stabularis* (Es), *Echinolaelaps echidninus* (Ee), *Dermanyssus gallinae* (Dg), *Ornithonyssus bacoti* (Ob)

## DISCUSSION

This study aligns with the findings of Husni et al., indicating that the rat density in the settlements surrounding the Gayamsari market was 15.1%, demonstrating a relatively high rat density in the area. The habitat of rats significantly affects their population and the accessibility of food and water resources (Husni et al. 2023). Furthermore, a study by Ronny et al indicated that both trap failure and success are affected by various factors, including the effectiveness of pushing the trap door, the type of bait used, and the presence of human scent on the bait or trap, which serves as a primary deterrent for rats consuming the bait (Ronny et al. 2020).

The geographical conditions of Semarang City, characterized by high population density and the presence of gutters and waste, contribute to its highest trap success rate. In Demak Regency, the geographical conditions are characterized by numerous swamps and puddles, which facilitate rat breeding due to the ample food sources and the presence of waste in the surrounding settlements. The predominant rat species identified were *Rattus norvegicus* and *Rattus tanezumi*. These domestic rats typically inhabit homes and gutters, respectively, leading to their significant presence in this study.

In this study, female rats were captured more frequently, consistent with the findings of Raharjo and Wijayanti in the Cepogo District of Boyolali Regency, which reported the capture of 30 female rats due to their role as food providers for their young, particularly during the breastfeeding period. Male rats serve as protectors of their nests or territories, defending against potential predators. Consequently, female rats are more vulnerable to capture, as they are more likely to be found outside their shelters (Raharjo & Wijayanti 2021).

Rats usually prefer dirty and dark areas, including roofs, wall cavities, construction debris, and locations with available food sources (Ainun et al. 2021). Factors that influence the presence of rats include environmental factors such as food sources, water, nests, and humans (Husna & Chandra 2021). The high rat population is a risk factor for rickettsiosis disease (Wijayanti & Marbawati 2018).

Among the nine *M. musculus* captured, only one was free of mite infestation. The rat's minimal fur compared to other rats hinders mites' ability to attach and thrive on the surface of *M. musculus*. Both observation areas have an equal likelihood of rats being infested with ectoparasites.

Rats are susceptible to ectoparasite infestations due to their significant mobility in search of food, shelter, and nesting sites. Rats can naturally acquire ectoparasites, particularly when they come into contact with plants, soil, or moist environments like rice fields and swamps. *Rattus norvegicus* and *R. norvegicus javanus*, inhabiting wet, humid, and unsanitary environments, are highly susceptible to ectoparasite infestations. Rats can also acquire ectoparasites through direct contact and aggressive interactions while defending themselves (Dewi et al. 2020; Ristiyanto et al. 2016). The pattern of ectoparasite infestation is influenced by host behavior, age, and gender (Sepe et al. 2020).

This study revealed that the *R. tanezumi* mouse exhibited the highest level of ectoparasite infestation, following the *R. norvegicus*. *R. tanezumi*, commonly known as a house rat, is easily found on the roof of a house. The habitat of this rat is in direct contact with *M. musculus* (Stuart et al. 2015). *R. tanezumi* is a domestic rat commonly found in residential areas, associated with the food sources typically consumed by humans (Priyanto et al. 2020). This study's rat trapping occurred in residential areas, leading to the capture of numerous *R. tanezumi* rats.

The capture results indicate that the family Laelapidae contains the highest number of species identified. This study identified four species of the family Laelapidae: *L. nutalli*, *E. echidninus, L. turkestanicus*, and *E. stabularis*. *L. nutalli* represents the ectoparasite species with the highest individual count when compared to other ectoparasites identified in rats collected from Semarang City and Demak Regency. *L. nutalli* is a common mite that infests black rats, specifically members of the genus Rattus, including *R. norvegicus* and other rodent species. This mite may serve as a vector for the zoonotic bacteria *Coxiella burnetti*, which causes Q fever; *O. tsutsugamushi*, responsible for scrub typhus; and *Leptospira interrogans*, the causative agent of leptospirosis (Ainun et al. 2021).

*Laelapidae mites (Acari: Mesostigmata) are globally distributed and are among the most prevalent ectoparasites of rodents.* Ectoparasitic species of this family are commonly found on the body or in the nests of rodents. Previous studies have confirmed the role of *Mesostigma* mites in various pathogens, and recent research indicates that these mites serve as reservoirs and vectors for several pathogenic rickettsiae (Radzijevskaja et al. 2018). This research aligns with Thille et al. (2019), indicating that 84.6% of the ectoparasites found in rats are positive for mesostigma mites.

The *O. bacoti* species is also known as a mite that often becomes an ectoparasite in mice. *O. bacoti* may induce dermatitis and exacerbate typhus in humans. This mite has a cell structure that makes it easy to see under a microscope (Sari et al. 2020). *O. bacoti* is a mesostigmatid mite identified in multiple species of wild rodents across temperate and tropical regions. This mite induces pruritic dermatitis and hemorrhagic rickettsial disease with kidney syndrome while also transmitting various diseases to humans. In addition to the mesogtimatid suborder, mites from the Prostigmata, Astigmata, and Tetrastigmata groups can also lead to dermatitis (Clancy et al. 2022; Juhairiyah et al. 2021).

The mite *E. echidninus*, recognized for its extensive distribution, serves as the predominant ectoparasite in small mammals such as *R. tanezumi*, *R. norvegicus*, and *M. musculus*. This study's results indicate that, in addition to *L. nutalli*, *E. echidninus* also predominates and is frequently encountered in the majority of the captured rats. *E. echidninus* exhibits ovoviviparity and undergoes four distinct life cycle stages: larva, first nymph, second nymph, and adult. During the first nymph, second nymph, and adult stages, these organisms require nourishment from blood, tissue fluid, wound exudate, and various secretions, which may lead to skin damage, itching, rashes, and potentially systemic reactions in the host. *E. echidninus* serves as a vector for zoonoses, including *Rickettsia tsusugamushi*, R. Q fever, *R. mooseri*, *R. pox*, *Corynebacterium pseudotuberculosis*, and *Leptospira*. (Yuan et al. 2023)

This study identified the mite species *E. stabularis*, which is commonly associated with rodents but can also inhabit diverse microhabitats, including litter, soil, moss, and bird nests (Kaminskienė et al. 2017). This study also identified the species *D. gallinae*, commonly known as the red mite. This mite typically infests poultry within the obligate mesostigmata Order. *D. gallinae* flourishes in high-humidity environments; however, it is unable to sustain adequate humidity levels in dry conditions (Pritchard et al. 2015). *D. gallinae* spreads not only among poultry but also in carrier animals, including birds and rats. This mite is capable of biting mammals, including humans, potentially leading to papular pruritic dermatitis (Waap et al. 2019).

*L. nutalli* exhibits greater dominance compared to other mite species, as it infests various types of rats found in Semarang City and Demak Regency. The Laelaptidae family of mites, particularly the *L. nutalli* species, predominantly inhabits *R. norvegicus* and is cosmopolitan, indicating their widespread and abundant presence in various environments (Maibang et al. 2023). Laelapidae mites are linked to small rodents and are typically located on the surface of their bodies or within their nests, making their presence on rat a common occurrence (Kaminskienė et al. 2017). *Mesostigma*tid mites may serve as reservoirs and vectors for various rickettsiae (Radzijevskaja et al. 2018).

The diversity index of Semarang City was in the moderate category, and Demak Regency was classified as low. The community diversity index value is determined by the types and quantities of individuals present in each category. A higher diversity index is observed when the number of species is substantial, and the individuals of each type are nearly evenly distributed (Susilo et al. 2018). This study identified six species of mites present in both locations, with one species being predominant. The number of mites identified in Demak Regency was higher. The average diversity index was low due to an uneven distribution


Figure 1. Locations of Rat Captures in Semarang City and Demak Regency. Note: (a) Muktiharjo Kidul Subdistrict; (b) Sawah Besar Subdistrict; (c) Siwalan Subdistrict; (d) Demak Regency.

of mite species, leading to the dominance of specific species.

When there are no dominant species, and the numbers are evenly distributed in a community, the diversity will be higher (Hudiwaku et al. 2022). Sufficient food and weather conditions are also closely related to the life of the host and affect the diversity of ectoparasites (Maibang et al. 2023).

The involvement of rats in the transmission of rickettsiosis in Semarang City and Demak Regency poses significant health risks to both humans and animals, potentially leading to fatalities, thereby necessitating considerable attention (Sepe et al. 2020). Mites inflict significant discomfort on both humans and animals through their biting and blood-sucking behavior. Mites can induce allergies, including

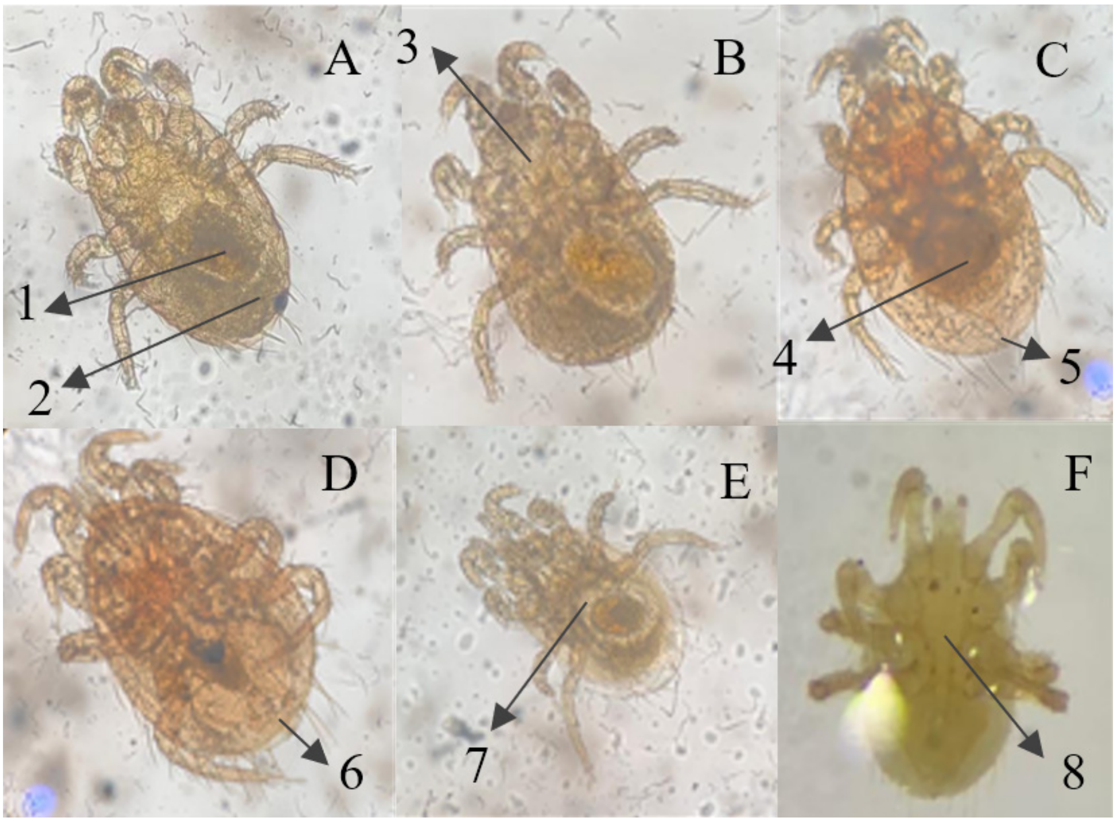


Figure 2. Mite identification results on several rats caught in Semarang City and Demak Regency. (A) *Laelaps nutalli,* separate anal plate with; (1) Ventral genitor plate, anterior edge; (2) Blunt anal plate with flat end sides with sides forming an angle, small body measuring 0.5-1 mm in length; (B) *Laelaps turkestanicus,* same shape as *L. nutalli* but (3) the surface of the body is more tapered or pointed; (C) *Eulaelaps stabularis,* (4) ventral genital plate with many setae, (5) transverse anal plate wider than elongated, triangular; (D) *Echinolaelaps echidninus*, (6) separate anal plate with ventral genital plate, anterior edge of anal plate rounded, concave and ventral genital plate right at that concave, body 1-2 mm long; (E) *Dermanyssus gallinae,* (7) dorsal body surface with single plate, the peritema channel is somewhat sinuous and extends anteriorly and tapers in front of the second hock; (F) *Ornithonyssus bacoti,* (8) the dorsal plate narrows posteriorly, the seta row in the center of the dorsal plate is longer than the distance between each base of the seta.

severe hypersensitivity reactions (Juhairiyah et al. 2021). Semarang City and Demak Regency may experience rickettsiosis due to the high infestation of rats by mites. Several species of mites can spread rickettsiosis. The current diversity index, which was in the moderate category, may increase if the community remains inattentive and fails to implement preventive measures.

Rickettsia infection represents a significant and frequently neglected source of fever among hospitalized patients in Indonesia (Lokida et al. 2020). At present, there is no vaccine available to prevent SFG and typhus group rickettsiosis; therefore, vector control remains the primary solution. Vector control techniques significantly influenced the incidence of murine typhus cases in the United States during the 1940s, effectively decreasing the prevalence of the disease (Blanton 2019). Rat control should be conducted in four stages: monitoring, sanitation, trapping, and the application of chemicals (insecticides) (Wijayanti & Marbawati 2018).

*Rattus norvegicus*, *R. norvegicus javanus*, *R. tanezumi*, *R. argentiventer*, *Suncus murinus*, and *Mus musculus* were identified in Semarang City and Demak Regency. Semarang is the city with the highest trap success rate. Six species of mites were identified, including *Laelaps nutalli, Echinulaelaps Echidninus, Eulaelaps stabularis, L. turkestanicus, Dermanissus gallinae,* and *Ornithonyssus bacoti*. Semarang exhibited a moderate diversity index value, whereas Demak displayed a low value. The number of rats captured and the identification of mites influence environmental health, particularly concerning human well-being. Monitoring the abundance of mesostigmatid mites is essential, as they can serve as both a reservoir and vector for various rickettsiae.

## ACKNOWLEDGEMENT

Gratitude is expressed to the World Health Organization (WHO) and the National Research and Innovation Agency (BRIN) for their funding of the PESTORITA 2023 research. Appreciation is also extended to the Salatiga Regional Office of the National Research and Innovation Agency for facilitating the implementation of this research, as well as to the D4 Study Program in Medical Laboratory Technology, Faculty of Health Sciences, Muhammadiyah University of Purwokerto for providing the necessary facilities for this study.

*"The authors state no conflicts of interest with the parties involved in this study"*

## REFERENCES

Abdad MY, Abdallah R, Fournier P-E, Stenos J, Vasooa S. 2018. crossm A Concise Review of the Epidemiology and Diagnostics of. *J. Clin. Microbiol.* 1–10

Ainun NR, Mannyullei S, Amqam H. 2021. Identifikasi Ektoparasit Dan Endoparasit Pada Tikus Di Tempat Pembuangan Akhir (Tpa) Tamangapa Kota Makassar [Identification of Ectoparasites and Endoparasites in Rats at the Tamangapa Landfill Site in Makassar City]. *Hasanuddin J. Public Heal.* 2(1):32–41. In Indonesian Language.

Blanton LS. 2019. The Rickettsioses: A Practical Update. *Infect. Dis. Clin. North Am.* 33(1):213–29

Chang YC, Kuo KC, Sun W, Lin JN, Lai CH, Lee CH. 2019. Clinicoepidemiologic characteristics of scrub typhus and murine typhus: A multi-center study in southern Taiwan. *J. Microbiol. Immunol. Infect.* 52(5):769–78

Chen LK, Nelwan EJ, Pasaribu A. 2022. Revisiting the Overlooked Infection : Rickettsioses. . 54(4):647–52

Clancy BM, Theriault BR, Schoenberger JM, Bowers CJ, Mitchell CM, et al. 2022. Identification and Control of an *Ornithonyssus bacoti* Infestation in a Rodent Vivarium by Using Molecular Diagnostic Techniques. . 72(2):113–21

Dewi WM, Partaya P, Susanti S. 2020. Prevalensi Ektoparasit Pada Tikus Sebagai Upaya Pemetaan Risiko Zoonosis Di Kawasan Rob Kota Semarang [Prevalence of Ectoparasites in Rats as an Effort to Map Zoonosis Risks in the Coastal Flooding Area in Semarang City]. *J. Ekol. Kesehat.* 18(3):171–82. In Indonesian Language.

Gasem MH, Kosasih H, Tjitra E, Alisjahbana B, Karyana M, et al. 2020. An observational prospective cohort study of the epidemiology of hospitalized patients with acute febrile illness in Indonesia. *PLoS Negl. Trop. Dis.* 14(1):1–17

Haidar M, Rizwar R, Darmi D, Putra AH. 2022. Preferensi Tikus terhadap Beberapa Jenis Umpan yang Berbeda di Kawasan Pemukiman [Rats' Preference for Several Different Types of Bait in Residential Areas]. *BIOEDUSAINSJurnal Pendidik. Biol. dan Sains*. 5(1):137–42. In Indonesian Language.

Hidayat R, Mairawita. 2021. Ectoparasite Infestation On Rattus tiomanicus As a Disease Vector At Mount Sago, West Sumatra. *BEST J. (Biology, Educ. Sci. Technol.* 4(1):71–76

Huang Y, Zhao L, Zhang Z, Liu M, Xue Z, et al. 2017. Detection of a novel rickettsia from leptotrombidium scutellare mites (Acari: *Trombiculid*ae) From Shandong of China. *J. Med. Entomol.* 54(3):544–49

Hudiwaku S, Himawan T, Rizali A. 2022. View of Keanekaragaman, komposisi spesies, dan kunci identifikasi lalat buah (Diptera_ Tephritidae_ Dacinae) di Pulau Lombok.pdf [View of Diversity, species composition, and key to the identification of fruit flies (Diptera_ Tephritidae_ Dacinae) on the island of Lombok]. In Indonesian Language.

Husna N, Chandra E. 2021. Studi Ektoparasit Pada Tikus Di Pelabuhan Kuala Tungkal Tahun 2019 [Study of Ectoparasites in Rats at Kuala Tungkal Port in 2019]. *Ruwa Jurai J. Kesehat. Lingkung.* 14(2):92. In Indonesian Language.

Husni SH, Martini M, Suhartono S, Budiyono B, Raharjo M. 2023. Faktor Lingkungan Yang Berpengaruh Terhadap Keberadaan Tikus Serta Identifikasi Bakteri Leptospira sp. di Pemukiman Sekitar Pasar Kota Semarang Tahun 2022 [Environmental Factors Affecting the Presence of Rats and the Identification of Leptospira sp. Bacteria in Settlements Around Semarang City Market in 2022]. *J. Kesehat. Lingkung. Indones.* 22(2):134–41. In Indonesian Language.

Juhairiyah, Hairani B, Annida, Fakhrizal D. 2021. Keberadaan Ektoparasit Dan Endoparasit Pada Tikus Di Daerah Pesisir Pantai Desa Juku Eja [The Presence of Ectoparasites and Endoparasites in Rats in the Coastal Area of Juku Eja Village]. *J. Kesehat. Lingkung.* 1(1):307-. In Indonesian Language.

Kaminskienė E, Radzijevskaja J, Balčiauskas L, Gedminas V, Paulauskas A. 2017. Laelapidae mites (Acari: *Mesostigma*ta) infesting small rodents in the Curonian Spit, Lithuania. *Biologija*. 63(2):

Lokida D, Hadi U, Lau CY, Kosasih H, Liang CJ, et al. 2020. Underdiagnoses of Rickettsia in patients hospitalized with acute fever in Indonesia: Observational study results. *BMC Infect. Dis.* 20(1):1–12

Maibang WG, Martini M, Santoso L. 2023. Kepadatan Tikus dan Ektoparasit yang Tertangkap di Pasar Jatingaleh dan Pasar Kedung Mundu Kota Semarang [Density of Rats and Ectoparasites Caught in Jatingaleh Market and Kedung Mundu Market in Semarang City]. *J. Ris. Kesehat. Masy.* 3(1):40–48. In Indonesian Language.

Manyullei S, Nurlia, Handoko SA, Dasrilano S, Kasim S. 2022. Associated Factors to Rat Density: A Systematic Review. *World J. Adv. Healthc. Res.* 6(8):87–89

Pramestuti N, Widiastuti D, Lestari E, Sari IZR, Apriliana S. 2022. *Rickettsioses: Penyakit Tular Vektor Yang Terabaikan* [Rickettsioses: Neglected Vector-Borne Diseases]. In Indonesian Language.

Pritchard J, Kuster T, Sparagano O, Tomley F. 2015. Understanding the biology and control of the poultry red mite *Dermanyssus gallinae*: a review. *Avian Pathol.* 44(3):143–53

Priyanto D, Raharjo J, Rahmawati R. 2020. Domestikasi Tikus: Kajian Perilaku Tikus Dalam Mencari Sumber Pangan dan Membuat Sarang [Study of Rat Behavior in Searching for Food Sources and Making Nests]. *Balaba J. Litbang Pengendali. Penyakit Bersumber Binatang Banjarnegara*. 67–78. In Indonesian Language.

Radzijevskaja J, Kaminskiene E, Lipatova I, Mardosaite-Busaitiene D, Balčiauskas L, et al. 2018. Prevalence and diversity of Rickettsia species in ectoparasites collected from small rodents in Lithuania. *Parasites and Vectors*. 11(1):1–10

Raharjo J, Wijayanti T. 2021. Keragaman, Dominasi Tikus Silvatik, Kepadatan Pinjal dan Kewaspadaan Pes di Daerah Fokus Pes di Kecamatan Cepogo Kabupaten Boyolali [Diversity, Dominance of Silvatic Rats, Louse Density and Pest Awareness in the Focus Area of Cepogo District, Boyolali Regency]. *Balaba J. Litbang Pengendali. Penyakit Bersumber Binatang Banjarnegara*. 47–56. In Indonesian Language.

Richards AL. 2020. Scrub Typhus : Historic Perspective and Current Status of the Worldwide Presence of *Orientia* Species

Ristiyanto R, Handayani FD, Boewono DT, Heriyanto B. 2014. *Penyakit Tular Rodensia [Rodent Infectious Diseases]*. Salatiga: UGM PRESS. In Indonesian Language.

Ristiyanto R, Mulyono A, Agustina M, Yuliadi B, Muhidin M. 2016. Indeks keragaman ektoparasit in roof rat *R. tanezumi* (Temminck, 1844) and polynesian rat R. exulans (Peal, 1848) in plague area [Index of ectoparasite diversity in roof rat *R. tanezumi* (temminck, 1844) and polynesian rat r. Exulans (peal, 1848) in plague area]. *J. Vektora*. 1(2):73–84. In Indonesian Language.

Ronny, Khaer A, Muammar. 2020. Kemampuan Perangkap Tikus Dengan Variasi Umpan Dalam Pengendalian Tikus [The Ability to Trap Mice with Variations of Bait in Rat Control]. *J. Sulolipu Media Komun. Sivitas Akad. dan Masy. Vol.* 20(2):282–90. In Indonesian Language.

Sari MD, Setyaningrum E, Sutyarso, Rosa E. 2020. Identifikasi ektoparasit pada tikus (Rattus sp.) sebagai vektor penyakit Pes di areal pelabuhan panjang Kota Bandar Lampung [Identification of ectoparasites in rats (Rattus sp.) as vectors of Pes disease in the port area of Bandar Lampung]. *J. Med. Malahayati*. 4(April):120–28. In Indonesian Language.

Sepe M, Maryana N, Priyambodo S. 2020. The diversity of ectoparasites on some type of rats. *IOP Conf. Ser. Earth Environ. Sci.* 492(1):

Sholichah Z, Wijayanti T, Raharjo J, Widiastuti D, Ningsih DP, et al. 2020. Spot Survei Reservoir Leptospira di Daerah Dataran Rendah dan Dataran Tinggi [Spot Survey of Leptospira Reservoirs in Lowland and Highland Areas.]. *J. Litbang Media Inf. Penelitian, Pengemb. dan IPTEK*. 16(2):129–38. In Indonesian Language.

Sriwahjuningsih, Hernawan H, Fitri N. 2022. Indeks Ekologi Gastropoda Sebagai Bioindikator Pencemaran Air Di Ekowisata Situ Bagendit Kecamatan Banyuresmi Kabupaten Garut [Ecological Index of Gastropods as Bioindicators of Water Pollution in Situ Bagendit Ecotourism, Banyuresmi District, Garut Regency]. *J. Cahaya Mandalika, ISSN 2721-4796*. 3(1):33–43. In Indonesian Language.

Stuart AM, Singleton GR, Prescott C V. 2015. Population ecology of the Asian house rat (Rattus tanezumi) in complex lowland agroecosystems in the Philippines. *Wildl. Res.* 42(2):165–75

Susilo A, Martuti NKT, Setiati N. 2018. Keanekaragaman Jenis Ektoparasit pada Udang Windu di Tambak Desa Langgenharjo Kecamatan Margoyoso Kabupaten Pati [Diversity of Ectoparasite Types in Tiger Shrimp in Langgenharjo Village, Margoyoso District, Pati Regency]. *J. Life Sci.* 7(1):1–8. In Indonesian Language.

Thille KN, Rametta NF, Fitzpatrick DM, Springer CC, Tiwari K, et al. 2019. Ectoparasites of brown rats (Rattus norvegicus) in Grenada, West Indies. *Vet.*

*World*. 12(9):1390–94

Waap H, Nunes T, Mul MF, Gomes J, Bartley K. 2019. Survey on the prevalence of *Dermanyssus gallinae* in commercial laying farms in Portugal. *Avian Pathol.* 48(sup1):S2–9

Widiastuti D, Pramestuti N, Wijayanti SPM, Jastal. 2020. Detection of Rickettsial Infection Among Febrile Patients in Semarang City. . 24(Uphec 2019):18–20

Wijayanti T, Marbawati D. 2018. Keanekaragaman, Deteksi dan Peranan Tikus terhadap Penularan Toksoplasmosis di Kabupaten Banjarnegara [Diversity, Detection and Role of Rats in the Transmission of Toxoplasmosis in Banjarnegara Regency]. *Balaba J. Litbang Pengendali. Penyakit Bersumber Binatang Banjarnegara*. 169–80. In Indonesian Language.

Yuan B, He G, Dong W. 2023. The first complete mitochondrial genome of the genus Echinolaelaps reveals mitochondrial genome rearrangement type and evolution of Gamasida. *Parasitology*. 150(7):644–52

Yuliadi B, Muhidin, Indriyani S. 2016. *Tikus Jawa, Teknik Survei Di Bidang Kesehatan [Javanese Rat, Survey Techniques in the Health Sector].* In Indonesian Language.