Tropical Biomedicine 42(2): 100-122 (2025)
https://doi.org/10.47665/tb.42.2.003

RESEARCH ARTICLE

Rodent-borne zoonotic diseases in Southeast Asia: A narrative review

Ganasen, T.[1,2], Mohd-Azami, S.N.I.[1], Khoo, J.J.[3], Peng, T.L.[4], Johari, J.[1], Sahimin, N.[1,5], Ya'cob, Z.[1], AbuBakar, S.[1], Loong, S.K.[1*]

[1]Tropical Infectious Diseases Research & Education Centre, Higher Institution Centre of Excellence, Universiti Malaya, 50603 Kuala Lumpur, Malaysia
[2]Institute for Advanced Studies, Advanced Studies Complex, Universiti Malaya, 50603 Kuala Lumpur, Malaysia
[3]Department of Infection Biology and Microbiomes, Institute of Infection, Veterinary and Ecological Sciences, University of Liverpool, Liverpool, United Kingdom
[4]Department of Veterinary Paraclinical Study, Faculty of Veterinary Medicine, Universiti Malaysia Kelantan, City Campus, 16100 Pengkalan Chepa, Kota Bharu, Kelantan, Malaysia
[5]Department of Parasitology, Faculty of Medicine, Universiti Malaya, 50603 Kuala Lumpur, Malaysia
*Corresponding author: loongsk@um.edu.my

ARTICLE HISTORY

Received: 14 November 2024
Revised: 18 February 2025
Accepted: 19 February 2025
Published: 30 June 2025

ABSTRACT

Rodent-borne zoonotic diseases, including hantavirus pulmonary syndrome, leptospirosis, and rickettsiosis, significantly impact public health. However, there is a limited understanding of these diseases in Southeast Asia, a region emerging as a hotspot for zoonotic diseases. To address this, the authors reviewed the recent developments in prevalent rodent-borne diseases in Southeast Asia from 2000 to 2024. A comprehensive literature search was conducted in databases such as PubMed, Scopus, Web of Science, Google, and Google Scholar, using keywords like "rodent-borne diseases," "prevalence," "epidemiology," "humans," and "Southeast Asia". Leptospirosis is widespread in several Southeast Asian countries. Malaysia and Thailand have established effective national surveillance systems, tracking annual cases and fatalities. For viral diseases, such as haemorrhagic fever with renal syndrome, most countries lack a structured reporting system. Vector-borne rodent diseases deal with similar underreporting, with diseases like bartonellosis and borreliosis noted only anecdotally, even in relatively-resourced countries like Thailand and Malaysia. This underreporting is concerning, as the causative pathogens are often detected in rodent reservoirs and their arthropod vectors around these regions during biosurveillance studies. Invasive rodents have long infiltrated into human environments and thrive as successful commensal species, facilitating the transmission of zoonotic pathogens to humans. Therefore, robust surveillance systems, often essential in disease control are urgently needed across the Southeast Asian region. Further scientific research and biosurveillance studies are crucial in understanding the impact of these diseases on human health, rodent populations, and the environment.

Keywords: Chigger; flea; hygiene; tick; tropical.

INTRODUCTION

Southeast Asia (SEA) is emerging as a hotspot for zoonotic diseases due to several factors, including biodiversity richness, population growth, increased migration (travel), land encroachment, agricultural expansion, bushmeat trade, and climate change (Villarroel *et al*., 2023). Among mammals; rodents, bats, primates, and carnivores are the primary wildlife reservoirs, harbouring the majority of zoonotic viruses (Engel & Ziegler, 2020). Rodents and bats represent the largest wild mammal reservoirs for zoonotic emerging infectious diseases across SEA, East Asia, and Australasia. These mammals are 15 times more likely to inhabit human-modified environments (McFarlane *et al*., 2012). The rapid reproductive cycle of some rodent species further amplifies their role as competent reservoirs for zoonotic pathogens (Han *et al*., 2015). Rodent-borne diseases are classified based on their transmission routes. Direct transmission occurs via bites, contaminated food or water, and inhalation of aerosolized rodent excrement (Meerburg *et al*., 2009). Indirect transmission involves rodents hosting infected arthropod vectors such as ticks, fleas, lice, and mites, which then transmit the pathogens to humans (Ho *et al*., 2021).

Globally, rodent-associated diseases of primary concern are hantavirus pulmonary syndrome (HPS), tick-borne encephalitis, Lassa fever, leptospirosis, scrub typhus, tularaemia, lymphocytic choriomeningitis, rickettsial diseases, Lyme disease (LD), and rat bite fever (Meerburg *et al*., 2009; Low *et al*., 2020b). Some of these diseases, such as leptospirosis and scrub typhus, are endemic to the Southeast Asian region. In this region, rodents inhabiting human-modified landscapes, particularly agricultural areas, exhibit higher species richness of pathogens, including *Leptospira* spp., *Bartonella* spp., *Orientia* spp., and hantaviruses (Bordes *et al*., 2013). Consequently, infected rodents may carry higher pathogen loads, and the abundance of vector populations in these environments further promotes the disease transmission. Additionally, cultivated and frequently flooded lowland areas, such as rice fields, provide favourable conditions for pathogen transmission. To further complicate matters, several rodent-borne pathogens such as *Leptospira* spp., *Rickettsia* spp., and *Orientia* *tsutsugamushi* are significant drivers of acute febrile illness (AFI) in SEA (Wangrangsimakul *et al*., 2018; Wangdi *et al*., 2019; Althaus *et al*. 2020). For instance, in endemic areas of Malaysia, rickettsial infections account for 14% of AFI cases, but they often remain underdiagnosed or neglected (Yuhana *et al*., 2022). AFI, also known as acute undifferentiated febrile illness (AUFI) is typically characterised by a fever of $\geq$ 38°C occurring for less than two weeks (Tun *et al*., 2016; Wangdi *et al*., 2019). The incidence of AFI in regions where endemic tropical diseases are prevalent, complicates the differential diagnosis and accurate determination of aetiological agents (Bressan *et al*., 2023).

Despite the extensive distribution of rodents globally, particularly in SEA, there remains a significant lack of comprehensive studies on the epidemiology of endemic rodent-borne diseases. This has led to discrepancies in available data on the prevalence of these diseases in humans across the region. For example, many current reports on outbreaks are outdated and incomplete, and the full impact of these events on communities is poorly understood, creating a substantial knowledge gap. In light of this situation, this review aims to provide an overview of the epidemiology of key rodent-associated diseases in SEA, including leptospirosis, haemorrhagic fever with renal syndrome (HFRS), bartonellosis, borreliosis, scrub typhus, murine typhus, and spotted fever rickettsiosis (SFR). The review will focus on human cases and rodent reservoirs, drawing epidemiological data from available studies, and highlighting the existing knowledge gaps in the current literature.

METHODOLOGY

Literature Search

A comprehensive literature search was conducted using databases available in the public domain, such as PubMed, Scopus, and Web of Science, to compile this review article. In this review, the rodent-borne diseases were narrowed down to leptospirosis, HFRS, bartonellosis, borreliosis, scrub typhus, murine typhus, and SFR based on the frequencies and impact of these diseases in the Southeast Asian region. Articles on rodent-borne diseases in SEA from 2000 to 2024 were searched using keywords, such as "leptospirosis", "hantavirus", "bartonellosis", "borreliosis", "rickettsiosis", "scrub typhus", "murine typhus", "spotted fever rickettsiosis", "*Leptospira* spp.", "*Bartonella* spp.", "*Borrelia* spp.", "*Orientia* spp.", "*Rickettsia* spp.", "rodents", "humans", "epidemiology", "prevalence", "Malaysia", "Thailand", "Indonesia", "Philippines", "Vietnam", and "Southeast Asia". The selected articles were organized and reviewed based on the epidemiology of these diseases in humans and rodent reservoirs. Additionally, search engines including Google and Google Scholar were utilized to identify relevant and significant articles. Only articles in English were included in the present study.

Rodent-borne zoonotic diseases

Leptospirosis

Approximately 1.03 million leptospirosis cases are reported annually, resulting in at least 58 900 deaths worldwide. A higher prevalence of disease and fatalities is observed in tropical regions of South Asia, SEA, Latin America, and East Sub-Saharan Africa (Abela-Ridder *et al*., 2010; Costa *et al*., 2015). This neglected zoonotic disease is caused by a gram-negative spirochete bacterium from the order Spirochaetales, family *Leptospiraceae*, and genus *Leptospira* (Mohammed *et al*., 2011). In SEA, this endemic disease is prevalent across various countries. The highest incidence rates are estimated to occur in Thailand and the Lao People's Democratic Republic (PDR), surpassing the overall expected incidence of 2.34 cases per 100 000 population in SEA (Douchet *et al*., 2022). According to Sakundarno *et al*. (2014), the elevated incidence of leptospirosis in tropical and subtropical areas is often related to temperate or humid climates and significant rainfall patterns in these regions.

Frequent contact with rodents, occupational exposure, recreational activities, lack of awareness, and natural disasters such as flash floods are common risks associated with the transmission of leptospirosis (Brown *et al*., 2011; Shafie *et al*., 2021; Senaka, 2022; Philip & Ahmed, 2023). Humans are typically infected via open wounds, ingestion of contaminated food or water, and contact with soil tainted by infected rodent urine (Haake & Levett, 2015). The clinical manifestations of leptospirosis range from mild to severe and life-threatening. Typical symptoms include fever, myalgia, headache, abdominal pain, nausea, vomiting, and diarrhoea (Chacko *et al*., 2021). A severe form of the disease is characterised by multiple organ failure, pulmonary haemorrhage, meningitis, or Weil's syndrome, which presents with jaundice and acute renal failure (Haake & Levett, 2015; Pothuri *et al*., 2016; Cardoso *et al*., 2022). The diagnosis of leptospirosis is often challenging due to co-infections or the presence of non-specific clinical signs, such as fever, myalgia, and headache, overlapping with other tropical diseases during the acute phase of illness (Kumar *et al*., 2012; Wijesinghe *et al*., 2015; Loong *et al*., 2022). Several studies have documented the co-infection of leptospirosis with febrile illnesses like dengue, malaria, and scrub typhus in tropical countries (Lindo *et al*., 2013; Philip *et al*., 2020). An early diagnosis is critical, as prompt antibiotic therapy involving drugs, such as doxycycline, azithromycin, and amoxicillin is effective in disease management (Kumar *et al*., 2012; Karpagam & Ganesh, 2020).

Non-native domestic animals, such as rats, dogs, pigs, and cattle serve as major reservoirs for *Leptospira* spp. in both urban and rural areas. Wildlife, including squirrels, shrews, and herpetofauna, are also implicated in the transmission and environmental maintenance of this pathogen (Bradley & Lockaby, 2023). Commensal rats, such as *Rattus rattus* and *Rattus norvegicus* are the principal carriers of this bacterium worldwide, especially in urban areas (Boey *et al*., 2019; Koizumi *et al*., 2019). However, a diverse species of infected rats has been reported across the urban, semi-urban, rural, and recreational areas in SEA (Blasdell *et al*., 2019a; Yusof *et al*., 2019; Shafie *et al*., 2022). In addition to *R. norvegicus* (Azhari *et al*., 2018; Kudo *et al*., 2018; Blasdell *et al*., 2019a; Koizumi *et al*., 2019) and *R. rattus* (Benacer *et al*., 2016; Noh *et al*., 2024), *Leptospira* spp. has been detected in *Rattus exulans* (Krairojananan *et al*., 2020), *Rattus tanezumi* (Widiastuti *et al*., 2016), *Bandicota bengalensis* (Sunaryo & Priyanto, 2022), *Mus cookii, Bandicota indica* (Cosson *et al*., 2014), *Berylmys bowersi, Bandicota savilei, Niviventer fulvescens*, and *Rattus nitidus* (Anh *et al*., 2021) in SEA (Table 1). In Malaysia, multiple studies have detected infected rodents around residential areas and commercial sites, like wet markets (Pui *et al*., 2017; Mohd-Taib *et al*., 2020; Wan *et al*., 2022). These anthropogenic sites are usually rodent breeding grounds that further amplify the risk of disease transmission to humans (Ikbal *et al*., 2019). Interestingly, rodents from industrial areas in Singapore were also heavily infested with *Leptospira* spp. (53.2%) (Griffiths *et al*., 2022). Recently, Anh *et al*. (2021) reported multiple infections of leptospiral agents with other bacteria, such as *Bartonella* spp. and *Rickettsia* spp. in several rodents including, *B. bowersi*, *B. savilei*, *N. fulvescens, R. rattus*, and *R. tanezumi* from Vietnam. The pervasive distribution of infected rodents in various landscapes of SEA has a larger implication for potential zoonotic transmission of leptospirosis. Thus, the continuous monitoring of reservoir animals is necessary in preventive management of the disease.

Past studies have shown that rats shed the highest concentration of leptospiral agents (5.7×10^6 cells/mL) in their urine compared to other reservoirs, such as deer, cattle, mice, and dogs (Barragan *et al*., 2017a). An infected animal may remain asymptomatic while continuously shedding the infectious agent in its urine for periods ranging from two weeks to several months, with rare cases of life-long persistence (Karpagam & Ganesh, 2020). Several studies found that, *R. norvegicus* had a higher leptospiral infection rate (Azhari *et al*., 2018; Mohd-Taib *et al*., 2020; Griffiths *et al*., 2022), possibly due to an increased susceptibility towards the pathogen (Boey *et al*., 2019), and a wider spatial distribution (Wibowo *et al*., 2022). In contrast, other studies have found *R. rattus* to be more susceptible to leptospiral infections (Benacer *et al*., 2013, 2016). Thus far, host specificity has not been established for leptospiral agents carried by rodents (Ikbal *et al*., 2019). However, Benacer *et al*. (2013) implied a potential association between infection and the habitat of the carrier animals rather than the species of the carriers. Various factors, including host weight, urine volume, disease prevalence, and local host densities, influence the distribution of *Leptospira* spp. in soil and water (Barragan *et al*., 2017b). Despite these factors, rodents still pose a high infection and transmission risk to humans due to their ubiquitous presence in the environment (Barragan *et al*., 2017a, 2017b).

In the Philippines, leptospirosis has become a significant public health concern in recent years, with reported cases increasing from 182 in 2020 to 2,794 in 2022. Alarmingly, there was a 188% rise in cases within three months in 2023 compared to the same period in 2022 (Nazir *et al*., 2023). Over the years, numerous leptospirosis outbreaks in the Philippines have been linked to typhoons, heavy rainfall, and flooding (Amilasan *et al*., 2012; Nazir *et al*., 2023) (Figure 1). The incidence and case fatality rate (CFR) in Malaysia ranged from 8.63 to 17.2, and 0.6% to 2.4% per 100 000 population, respectively, based on data collected from 2011 to 2021. States such as Selangor, Kelantan, and Sarawak recorded some of the highest clinical cases in recent years (Philip & Ahmed, 2023). According to past research, multiple factors attributed to the elevated cases of leptospirosis in developed areas such as Selangor. This includes, improper waste management, increased rodent densities, rising temperatures, flooding events, and lack of awareness among the inhabitants (Lau *et al*., 2010; Abdullah *et al*., 2019). Furthermore, several outbreaks have occurred following flash floods in Kelantan and during a search operation at the Lubuk Yu waterfall in Pahang (Hin *et al*., 2012; Sapian *et al*., 2012; Mohd Radi *et al*., 2018) (Figure 1). The flash floods in Kelantan may justify the peak in clinical cases at the end of 2014 in Malaysia. Besides that, leptospiral antibodies have been detected in individuals across various socioeconomic backgrounds, including poor urban communities (12.6%), refugee students (24.7%), wet market workers (33.6%), rural residents (37.4%), urban sanitation workers (43.8%), and the Orang Asli populations (60.7%), suggesting that the disease is widespread in Malaysia (Suut *et al*., 2016; Loong *et al*., 2018; Rahman *et al*., 2018; Sahimin *et al*., 2019; Jeffree *et al*., 2020; Mohd Hanapi *et al*., 2021).

In some endemic regions of Malaysia, such as Perak, high incidences of leptospirosis (12.5 per 100 000 population) and a CFR of 14.3% have been reported among hospitalized patients. However, nearly 79.5% of these cases are only diagnosed after the patient is discharged or has died, hampering effective disease management (Fann *et al*., 2020). Recently, Philip *et al*. (2020) detected a 56% infection prevalence among hospitalized individuals in Selangor and Perak, with pathogenic strains such as *Leptospira interrogans* and *Leptospira kirschneri* predominantly infecting the patients. *L. interrogans* have also been reported among patients with fever of unknown origin (FUO) that tested negative for dengue in Selangor (Loong *et al*., 2022). In East Malaysia, several studies employed the gold standard microscopic agglutination (MAT) test to further characterise *Leptospira* serovars by detecting specific antibody titres in serum samples. In Sabah, three serovars; Patoc, Sarawak, and Terengganu predominantly infected the urban sanitation workers, indicating potential occupational risks (Jeffree *et al*., 2020). Meanwhile, in Sarawak, antibodies against 20 local serovars were detected in 37.4% of seropositive samples, with pathogenic serovars like Djasiman and Shermani, previously implicated in alveolar haemorrhage and tubulonephritis, being prevalent (Suut *et al*., 2016). In contrast, fewer seroprevalence studies have been conducted in countries like the Philippines, despite the rising leptospirosis incidence reported recently. One prospective study confirmed leptospirosis in 7.4% of patients presenting with acute fever, using culture, serology, and molecular methods (Saiton *et al*., 2022), with much of the other information remaining obscure.

Thailand reports several thousand leptospirosis cases annually (Tangkanakul *et al*., 2005). In 2008, the country ranked among the top ten globally for annual leptospirosis incidence (48.9 cases per 1 000 000 population) (Pappas *et al*., 2008). However, these figures came from passive surveillance based on suspected cases, without laboratory confirmation or details on serovar patterns (Hinjoy, 2014). More recently in 2023, an outbreak involving 2,700 cases was reported in the northern and southern regions of Thailand following heavy rainfall (The Nation, 2023) (Figure 1). Luenam & Puttannapong (2019) noted an increasing CFR for leptospirosis

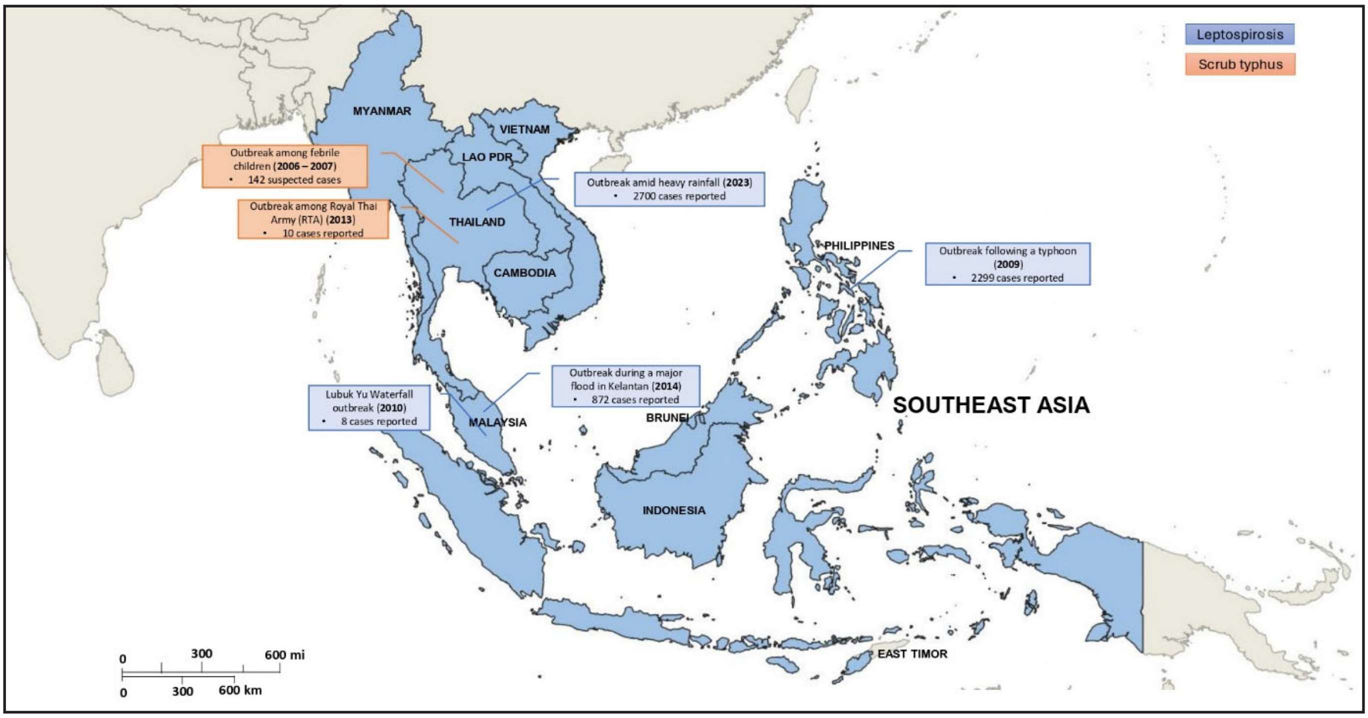

Figure 1. Map showing major leptospirosis and scrub typhus outbreaks in Southeast Asia.

nationwide from 2013 to 2015, despite a decline in the incidence. Severe complications, including multiple organ failure, pulmonary haemorrhage, and reliance on support (mechanical ventilator), were associated with higher mortality rates among patients with AUFI (Thipmontree *et al*., 2014). A retrospective study found that 50% of confirmed leptospirosis cases in Songkhla required admission to the Medical Intensive Care Unit (MICU), with clinical presentations such as septic shock, acute respiratory failure, and neurologic dysfunction common among these patients (Ajjimarungsi *et al*., 2020). Several studies reported leptospirosis seropositivity among healthy blood donors (1.7%), young Thai men (28%), and patients presenting typical leptospirosis clinical symptoms (23.8%) (Chadsuthi *et al*., 2017; Gonwong *et al*., 2017; Limothai *et al*., 2023). Nevertheless, comprehensive nationwide seroprevalence data for the Thai general population remains lacking.

In Singapore, information available on leptospirosis is limited, with one case study from 1981 reporting the infection in a pregnant woman (Shaked *et al*., 1993). In 2016, leptospirosis was gazetted as a notifiable disease in the country. Since then, the number of reported cases has been fluctuating (Ho *et al*., 2019). In 2023, Singapore recorded the highest incidence in eight years, with 62 cases (Abdurrahman *et al*., 2024). In Vietnam, children are also at risk of contracting leptospirosis with 12.8% testing positive for anti-*Leptospira* IgG antibodies, indicating a past exposure, primarily linked to activities in water bodies like swimming or wading (Thai *et al*., 2006). In 2019, Tran *et al*. (2021) detected leptospiral antibodies in 9.5% (57 individuals) of healthy Vietnamese people indicating a past exposure, with farmers identified as being at high risk. However, between 2014 and 2017, fewer than 20 cases were reported nationwide in Vietnam (official data), and in 2018, the overall morbidity and mortality were reported as zero (Tokarevich & Blinova, 2022). These discrepancies indicate that the nationwide leptospirosis registry in Vietnam does not accurately reflect the true incidence or disease burden. Similar underreporting was observed in Lao PDR and Cambodia. In Cambodia, males aged between 15 and 19 showed the highest seropositivity for IgM leptospiral antibodies at 40.5% in both acute and convalescent samples (Hem *et al*., 2016). Furthermore, in Lao PDR, 23.9% of healthy individuals in rural areas of the Khammouane Province were seropositive and had previously been exposed to the spirochete (Kawaguchi *et al*., 2008).

In Indonesia, leptospirosis predominantly affects men aged between 31 and 40, and those over 45 years of age (Ristiyanto *et al*., 2018; Gasem *et al*., 2020). The higher incidence in men is usually linked to occupational and recreational exposure, differences in physiological responses, disease severity in males, and underdiagnosis in women (Skufca & Arima, 2012). Additionally, between 2007 and 2017, Brunei reported only five clinical cases of leptospirosis, with much of the other information unavailable (Abdurrahman *et al*., 2024). The current data on leptospirosis in SEA indicates potential underreporting, particularly in Brunei, Vietnam, Lao PDR, and Cambodia. These countries were previously confirmed as endemic regions based on seroprevalence data, despite the absence of official reporting (Pappas *et al*., 2008). In contrast, Malaysia and Thailand have a more systematic national reporting system, likely due to leptospirosis being a notifiable disease in Malaysia. A more comprehensive and coordinated approach across the Southeast Asian countries is necessary to accurately track incidence, assess disease burden, and recognize risks, ensuring better disease management and mitigation of the impact on communities.

Haemorrhagic fever with renal syndrome (HFRS)

HFRS is a rodent-borne viral haemorrhagic fever widespread across Asia and Europe. The causative agent, orthohantaviruses (order: *Bunyavirales*, family: *Hantaviridae*, genus: *Orthohantavirus*), also causes HPS, a disease endemic to regions in America (Tariq & Kim, 2022). These viruses are divided into Old World and New World strains based on the geographical distribution of their reservoir hosts, genetic relatedness, and disease manifestations in humans (Jonsson *et al*., 2010; Lederer *et al*., 2013). Old World hantaviruses, typically associated with rodents from the *Murinae* and *Arvicolinae* subfamilies, cause HFRS (Sehgal *et al*., 2023). Globally, over 40 hantaviruses have been discovered, with at least 20 pathogenic genotypes (Watson *et al*., 2014; Guterres & de Lemos, 2018). The close association between hantaviruses and their natural reservoirs has geographically confined the distribution of HFRS to European-Asian regions, and HPS to America (Krüger *et al*., 2011). However, recent diagnostic advances have resulted in the detection of hantavirus antibodies in African patients (Witkowski *et al*., 2014).

Rodents are the primary reservoirs for hantaviruses, although bats, moles, shrews, fish, and reptiles can also carry the virus (Avšič-Županc *et al*., 2019; Laenen *et al*., 2019). Hantaviruses are well-adapted to their reservoirs and coexist without requiring an intricate host-vector transmission cycle. Studies suggest that the coevolution between hantaviruses and their rodent reservoirs has resulted in infection persistence among hosts without deleterious effects (Meyer & Schmaljohn, 2000). Infected rodents usually remain asymptomatic while maintaining significant viral loads for transmission (Watson *et al*., 2014). Rodent-to-rodent transmission is mainly facilitated by horizontal routes, such as biting or aggression, although aerosol transmission may also occur (Padula *et al*., 2004). Humans, as dead-end hosts, contract the disease by inhaling aerosolized urine, faeces, or saliva from infected rodents (De Oliveira *et al*., 2014).

Worldwide, an estimated 150 000 to 200 000 HFRS cases are reported annually, with China accounting for 70% to 90% of these cases (Bi *et al*., 2008; Manigold & Vial, 2014; Zou & Sun, 2020). Clinically significant agents causing HFRS include Hantaan (HTNV), Dobrava (DOBV), Puumala (PUUV), Saaremaa (SAAV), and Seoul (SEOV) viruses (Schmaljohn & Hjelle, 1997). In Europe and Asia, the seroprevalence of infection ranges between 0.48% and 20%, and fatality rates vary from 0.4% to 10% (Vapalahti *et al*., 2003; Bi *et al*., 2008; Hjelle & Torres-Pérez, 2010). HFRS progresses through five clinical phases that are febrile, hypotensive, oliguric, diuretic, and convalescent (Jonsson *et al*., 2010). Early diagnosis may be challenging due to the similarities of symptoms with other infectious diseases (Hamidon & Saadiah, 2003; Knust *et al*., 2012; Jiang *et al*., 2016). For example, two confirmed cases of SEOV infection in asymptomatic febrile patients from Indonesia clinically manifested as thrombocytopenia and elevated liver enzymes, that are usually associated with dengue fever. This could simply lead to a misdiagnosis of infection (Lie *et al*., 2018).

In several Southeast Asian countries, such as Brunei and Cambodia, clinical cases of HFRS are rare or absent (Blasdell *et al*., 2009). Hitherto, only three cases have been reported in Singapore (Chan *et al*., 1996). In an earlier study, hantavirus exposure was observed among patients suspected of dengue haemorrhagic fever, hepatitis, leptospirosis, and acute nephritis when tested with immunofluorescence assay (IFA). However, the IFA titres were low, and the diagnostic specificity remained equivocal (Wong *et al*., 1989). Serological evidence of hantavirus cases among chronic renal failure patients in Kelantan dates back to 2001 when 2.52% of the patients were seropositive for HNTV and Sin Nombre virus (SNV) (Lam *et al*., 2001). Another seroprevalence study in Johor confirmed a past exposure in 23.3% of soldiers using IgM immunochromatographic rapid test (Arichandra *et al*., 2006). The lower incidence or underestimation of hantavirus cases in these countries is often attributed to the lack of routine serological testing (Lam *et al*., 2001).

In the Philippines, 6.1% of rural, urban, and urban-poor residents were seropositive for hantavirus antibodies (Quelapio *et al*., 2000). Despite the prevalence being comparable to infection rates reported in other developing countries, no further follow-up studies have been conducted in the Philippines. Surveillance records of hantavirus cases in Indonesia are sporadic and geographically limited. A recent retrospective serological study reported that 11.6% of patients with AFI in major cities such as Semarang, Denpasar, and Makassar, tested positive for past exposure, with the majority of cases found in adult males (Lukman *et al*., 2019). The higher prevalence in men is usually associated with increased outdoor activities, occupational exposure, and lifelong contact with reservoir animals (Bi *et al*., 2008; Kr ger *et al*., 2011). Another case study detected a SEOV-related strain in two patients from Surabaya and Jakarta (Lie *et al*., 2018). Although neither patient had direct contact with rodents, they lived in densely populated areas close to open rubbish-filled gutters with abundant rodents, suggesting an accidental exposure.

In Thailand, hantavirus antibodies are widespread among rodents in various regions; however, only one clinical study has been published thus far. A serological study identified hantavirus antibodies in the serum of 15 FUO patients, with five individuals showing past exposure (IgG seropositive), eight indicating potential early infection (IgM seropositive), and one seropositive for both IgM and IgG antibodies (Suputthamongkol *et al*., 2005). A study in Vietnam found that febrile patients had twice the rate of hantavirus infection compared to healthy individuals (Truong *et al*., 2009). Another study in the Dong Thap farming community of Vietnam detected SEOV and DOBV seropositivity among 3.7% of the farmers (Cuong *et al*., 2015). A surveillance study in Cambodia, conducted among hospitalized patients with acute fever between 2006 and 2009 confirmed past hantavirus exposure in 8.1% of the patients (Kasper *et al*., 2012). Most human cases reported in SEA are geographically limited to certain regions, and many studies focused on individuals with acute febrile illnesses. Serological methods dominate these studies, while molecular methods for hantavirus detection in humans receive less attention. Hence, the true burden of hantavirus infection among the general population in SEA remains largely unknown.

Although reports on humans are limited, multiple studies have investigated the presence of hantaviruses among animal reservoirs across SEA. Various rodent species in this region have been exposed to the virus, which has been detected via serological or molecular assays (Ibrahim *et al*., 1996; Reynes *et al*., 2003; Hugot *et al*., 2006; Plyusnina *et al*., 2009; Blasdell *et al*., 2011a) (Table 1). Hantavirus has been detected in *R. norvegicus* from Indonesia (Ibrahim *et al*., 1996; Susanti *et al*., 2022), Malaysia (Lam *et al*., 2001), Singapore (Johansson *et al*., 2010; Griffiths *et al*., 2022), Vietnam (Luan *et al*., 2012), and Cambodia (Blasdell *et al*., 2011a). It has also been reported in *R. tanezumi* from Lao PDR (Blasdell *et al*., 2011a), *R. rattus*, and *R. exulans* from Indonesia (Ibrahim *et al*., 1996), *R. rattus* from Singapore (Griffiths *et al*., 2022), and *Rattus argentiventer* from Vietnam (Cuong *et al*., 2015). Thailand virus (THAIV) is commonly associated with *B. indica (*Hugot *et al*., 2006), and recent studies suggest that *B. indica* may serve as a host for the Murinae-related phylogroup III hantavirus in Thailand (Wu *et al*., 2021). Additionally, Serang virus (SERV) and Jurong virus were reported in *R. tanezumi* from Indonesia (Ibrahim *et al*., 1996) and Singapore (Johansson *et al*., 2010), respectively. Phylogenetic analyses further indicate that strains such as THAIV, SERV and Jurong virus, along with the Cambodian strains from *R. rattus,* form a distinct phylogroup, despite being carried by different rodent hosts (Johansson *et al.*, 2010).

Thus, the presence of genetically similar hantaviruses in diverse host species, along with the detection of hantaviruses in non-reservoirs, suggests possible host-switching or spillover events. Other rodent species, including, *B. savilei*, *Maxomys surifer*, *Mus caroli*, *M. cookii, Niviventer* spp., and *R. nitidus* from Thailand, Lao PDR, Vietnam, and Cambodia, have tested positive for hantavirus antibodies. However, the specific virus strains carried by these rodents remain unknown (Blasdell *et al*., 2011a; Kikuchi *et al*., 2021). Kikuchi *et al*. (2021) reported that some of these strains were closely related to the HTNV Da Bie Shan (DBS) from Yunnan province, China. Notably, hantavirus-infected rodents are commonly found in human habitations, including urban cities, ports (industrial areas), and rural, forested or agricultural areas within this region (Johansson *et al*., 2010; Blasdell *et al*., 2011b; Cuong *et al*., 2015; Griffiths *et al*., 2022). Despite the potential risk of pathogen transmission to humans, recent scientific and clinical reports on hantavirus that are crucial for advocating specific prevention and cure for the community in SEA are limited. This highlights the need for more surveillance studies on hantavirus infection, diversity, distribution, and reservoirs in this region.

Rodent-borne zoonotic diseases transmitted by vectors

Bartonellosis

Bartonellosis is an umbrella term describing the zoonotic disease caused by *Bartonella* spp. Infectious agents from the *Bartonella* genus cause clinical diseases such as cat-scratch disease (CSD), trench fever, and Carrion's disease (Lins *et al*., 2019). A wide range of arthropod vectors, including fleas (Ashtiani *et al*., 2024), lice (Boodman *et al*., 2024), sandflies (Minnick *et al*., 2023), mites, and ticks (Tsai *et al*., 2011), mediate the transmission of this pathogen to natural and accidental hosts. An asymptomatic intraerythrocytic persistence is the hallmark of *Bartonella* infections among natural reservoirs, while bacteremia is rare in healthy incidental hosts (Dehio, 2004; Hong *et al*., 2016). However, recent reports indicate that bacteremia is common within asymptomatic patients, challenging the earlier notion (Vayssier-Taussat *et al*., 2016). In immunocompromised individuals, the disease manifestations are often severe, characterized by bacillary angiomatosis, hepatic peliosis, endocarditis, and osteomyelitis (Mosepele *et al*., 2012). The CFR of Carrion's disease in humans during the Oroya phase varies from 40% to 80% (Minnick *et al*., 2014; Gomes *et al*., 2016).

In addition to *Bartonella bacilliformis*, *Bartonella henselae*, and *Bartonella quintana*, at least 15 *Bartonella* spp. are pathogenic to humans and have been implicated with severe diseases (Breitschwerdt, 2017). However, currently, humans are the primary reservoirs of only two species, *B. bacilliformis* and *B. quintana*. In other cases, humans serve as accidental or incidental hosts, succumbing to opportunistic infections. Besides humans, a diverse group of mammals, including rodents, cats, dogs, macaques, rabbits, sheep, and horses, serve as the primary reservoirs of specific *Bartonella* spp. (Cheslock & Embers, 2019). Recently, two novel species, *Bartonella kosoyi* sp. nov. and *Bartonella krasnovii* sp. nov., were isolated from *R. rattus* rats and *Synosternus cleopatrae* fleas, respectively (Gutiırrez *et al*., 2020). Another strain, closely related to *Bartonella elizabethae*; *Bartonella mastomydis* sp. nov., was detected in *Mastomys erythroleucus* rodents from Senegal (Dahmani *et al*., 2018). Currently, insufficient information is known about the zoonotic potential of these novel strains.

A diverse species of rodents (approximately 90) is linked with more than 20 *Bartonella* spp. (Gutiérrez *et al*., 2015; Yao *et al*., 2022). At least 10 rodent-borne *Bartonella*, including *Bartonella doshiae*, *B. elizabethae*, *Bartonella grahamii*, *Bartonella rattimassiliensis*, *Bartonella rochalimae*, *Bartonella tribocorum*, *Bartonella washoensis*, and *Bartonella vinsonii*, are pathogenic to humans (Buffet *et al*., 2013; Krügel *et al*., 2022). The role of rodents in maintaining *Bartonella tamiae* remains unclear, even though the bacterium was initially isolated from three febrile patients in Thailand, who reported trapping or killing rodents around their home (Kosoy *et al*., 2008). Strains genetically similar to *B. tamiae* from Thai patients were subsequently detected in ticks and chigger mites collected from rodents in Thailand (Kabeya *et al*., 2010). This study suggested that chiggers may serve as the natural reservoirs of *B. tamiae* due to their single-host feeding habit during the larval stage. There have been increasing reports of *Bartonella* spp. detected from ectoparasites, such as fleas in Cambodia and

Xenopsylla cheopis in Thailand (Panthawong *et al*., 2020; Mullins *et al*., 2023). Despite the increasing prevalence of *Bartonella* reported in rodents and their ectoparasites in SEA, clinical cases remain sporadic and anecdotal (Inoue *et al*., 2008; Kr gel *et al*., 2022). Limited incidences have also been reported in humans from France, Mexico, the United States, Finland, the Netherlands, and Thailand (O'Halloran *et al*., 1988; Kerkhoff *et al*., 1999; Fenollar *et al*., 2005; Kosoy *et al*., 2010; Oksi *et al*., 2013; Corral *et al*., 2019).

Common symptoms exhibited by patients exposed to rodent-borne *Bartonella* strains include fever, headache, lethargy, arthralgia, and malaise (Bai *et al*., 2012). Rare symptoms, such as endocarditis and neuroretinitis, have been detected in cases associated with *B. elizabethae*, *B. grahamii*, and *B. vinsonii* subsp. *arupensis* (Daly *et al*., 1993; Kerkhoff *et al*., 1999; Fenollar *et al*., 2005). Another common theme observed among infected patients is their frequent association with rat exposures and tick bites (Bai *et al*., 2012; Vayssier-Taussat *et al*., 2016). To our knowledge, the overall seroprevalence data on rodent-borne bartonellosis in SEA is limited. For instance, Kosoy *et al*. (2010) reported infection in 7.7% of febrile patients from Thailand, with 71% recalling an exposure to rats a fortnight before the onset of disease. *B. elizabethae*, *B. tribocorum*, *B. rattimassiliensis*, *B. vinsonii* subsp. *arupensis*, and *B. vinsonii* subsp. *vinsonii* predominantly infected these patients. These pathogenic strains had previously been detected in rodents from Asia, Europe, and America (Saisongkorh *et al*., 2009a). Another study provided serological evidence of past exposure to *Bartonella* spp. in 28.9% of febrile and afebrile patients from rural Thailand (Bhengsri *et al*., 2011). Most of the seropositivity cases (9.8%) were associated with *B. elizabethae*. These are pioneering studies conducted in Thailand that involved large sample sizes, ranging between 200 and 500 individuals. The scarcity of biosurveillance studies suggests a potential underdiagnosis of bartonellosis in these regions. According to past research, clinical cases may be overlooked due to the lack of proper diagnostic tools or the ability of the pathogen to remain asymptomatic in immunocompetent hosts (Oksi *et al*., 2013; Kim *et al*., 2016).

In SEA, several bacterial cultures and molecular studies have determined the prevalence of *Bartonella* in rodent reservoirs (Table 1). Studies in Thailand detected diverse strains, including *Bartonella coopersplainsensis*, *Bartonella phoceensis*, *Bartonella queenslandensis*, *B. elizabethae*, *B. grahamii*, *B. rattimassiliensis*, *B. rochalimae*, and *B. tribocorum* from murine species (Pangjai *et al*., 2014). The infection prevalence in Thai rodents ranged from 8.5% to 61% (Saisongkorh *et al*., 2009b; Kim *et al*., 2016). Recently, several novel species, including *Bartonella chanthaburi* spp. nov., *Bartonella satun* spp. nov., and *Candidatus Bartonella thailandensis* were detected in *R. rattus*, *R. tanezumi*, and *Rattus surifer* using molecular techniques (Saisongkorh *et al*., 2009b; Pangjai *et al*., 2022). However, information regarding their potential vectors and pathogenicity to humans remain obscure.

Interestingly, *B. henselae*, the primary causative agent of CSD, was isolated from *R. norvegicus* and *R. rattus* in Ranong, Thailand through conventional PCR amplification (Pangjai *et al*., 2022). This was the first study in SEA to report *B. henselae* DNA in rodents. Similar observations were previously made in three other countries; New Zealand, Denmark, and Italy (Engbaek & Lawson, 2004; Nesaraj *et al*., 2018). It was therefore hypothesized that rodents might play a larger role in the ecological epidemiology of CSD (Divari *et al*., 2020). In Sri Lanka, *B. henselae* was detected in *Suncus murinus*, leading the author to suggest that these small mammals could serve as potential carriers, transmitting the pathogen to humans due to frequent contact (Böge *et al*., 2021). Oksi *et al*. (2013) reported a peculiar case of CSD in an immunocompromised patient, caused by *B. grahamii*. The patient's history of cat scratches led the authors to suggest that cats might carry *B. grahamii*-infected blood or tissues in their claws following contact with infected rodents. Therefore, it implies that cats could increase the risk of *Bartonella* transmission from rodents to humans, either by acting as mechanical flea vectors or through contaminated claws following an interaction with rodents (Castle *et al*., 2004; Oksi *et al*., 2013). However, the role of rodents in transmitting cat-borne *Bartonella* strains to humans has not been fully established. Further studies are warranted to corroborate the existence of a cat-rodent-human transmission cycle of *Bartonella*.

In Thailand, several studies found that *B. indica* and *R. rattus* were predominantly infected with *Bartonella* spp. (Castle *et al*., 2004; Bai *et al*., 2009; Klangthong *et al*., 2015; Panthawong *et al*., 2020). Other rodents from the Muridae family, including *R. norvegicus*, *R. exulans*, *R. surifer, R. tanezumi*, *Rattus losea*, *R. argentiventer*, *B. savilei,* and *Mus cervicolor* irregularly harboured *Bartonella*. According to Panthawong *et al*. (2020), 34.9% of rodents from the Nakhon Ratchasima province were bacteremic with *B. queenslandensis*. Subsequently, five pools of *X. cheopis* fleas collected from the infected *R. losea* also harboured *B. queenslandensis*. An unknown *Bartonella* genotype, previously isolated from a febrile patient in Thailand, shared more than 95% nucleotide homogeneity with the rodent-borne *B. queenslandensis* strain (Frank *et al*., 2018). This implied a potential rodent-human transmission cycle involving the particular genotype, which has not been discovered in humans outside Thailand. However, currently, there are yet to be any studies investigating the pathogenicity of *B. queenslandensis* in humans.

In urban (Bangkok) and suburban (Nakhon Sawan) regions of Thailand, 38.57% of rats tested positive for several *Bartonella* spp., including *B. phoceensis*, *B. tribocorum*, *B. grahamii*, and *B. rattimassiliensis* (Saengsawang *et al*., 2021). Additionally, the study discovered a high prevalence (26.67%) of a unique strain, *B. kosoyi* in the blood of *R. exulans*. A high nucleotide homogeneity between the bacterium and *B. tribocorum* was noted, leading the author to refer to it as the *B. kosoyi - B. tribocorum* complex. The initial discovery of *B. kosoyi* dates back to 2009, when it was first detected in *R. rattus* and provisionally termed the Tel Aviv isolates (Harrus *et al*., 2009). However, it was not until 2020 that the strain was morphologically characterized and officially named *B. kosoyi* sp. nov. (Gutierrez *et al*., 2020). Remarkably, the zoonotic potential of *B. kosoyi* (then known as the Tel Aviv strain) was suggested following its presence in a patient presenting CSD-like symptoms, including lymphadenopathy and fever, in Tbilisi, Georgia (Kandelaki *et al*., 2016). Nevertheless, experimental studies are essential to confirm the pathogenicity and zoonotic potential of *B. kosoyi*.

Another study detected a significantly higher prevalence (19.4%) of *Bartonella* spp. in ectoparasites of infected rodents compared to non-infected ones by amplifying the *gltA* and *nuoG* genes (Klangthong *et al*., 2015). Ectoparasite infestations are thought to enhance the horizontal transmission of *Bartonella* between arthropod vectors and their rodent reservoirs, especially while feeding or biting. Similarly, in Malaysia, a positive association was observed between *Bartonella* infection in rodents and infestations by lice or ticks (Blasdell *et al*., 2019b). This study substantiated the existence of a complex vector-reservoir cycle in maintaining *Bartonella* in the environment. Moreover, *B. phoceensis* DNA was identified in *Dermacentor auratus* and *Haemaphysalis hystricis* ticks, along with their host, *R. tiomanicus*, in a mangrove forest in Malaysia (Asyikha *et al*., 2020). The authors believe transmission could have occurred during a blood meal session.

In Malaysia, *Bartonella* has been detected in rodents across various environments, including urban, developing, rural, forests, and plantation areas (Asyikha *et al*., 2020; Low *et al*., 2020a; Mohd-Azami *et al*., 2023). However, only one study is available for each of these landscapes. The overall prevalence in rats ranged between 4.9% and 57.3% in previous studies. *B. phoceensis* was commonly detected among the *Rattus* rats in Malaysia across all landscapes. Interestingly, a native rodent, *Sundamys muelleri* was more frequently infected with *Bartonella* compared to *Rattus* spp. in Sarawak, Malaysia (Blasdell *et al*., 2019b). This finding differs from the common reports of *Bartonella* in *Rattus* spp. or *Bandicota* spp. around Malaysia and Thailand. The authors attributed this occurrence to the restriction of *S. muelleri* in green patches around Sarawak, where intraspecies contact increases and results in higher pathogen transmission. This warrants for more studies to be conducted for better insights on the host range of rodent-borne *Bartonella* in SEA.

In urban areas of Malaysia, a wide range of *Bartonella* species, including *B. queenslandensis*, *B. elizabethae, B. tribocorum, B. coopersplainsensis,* and *B. rattimassiliensis*, were prevalent among the *Rattus* rats (Tay *et al*., 2014b). The authors performed a subsequent genome analysis on the *B. elizabethae* (BeUM) strain recovered from *Rattus diardii* in Kuala Lumpur. The virulence profiling revealed that BeUM is more closely related to human strains (*B. elizabethae* ATCC49927 and *B. elizabethae* F9251) and possesses six putative virulence genes that are absent in other *B. elizabethae* (Tay *et al*., 2016). This finding further substantiates a potential rodent-human transmission cycle in urban landscapes. In neighbouring countries like Indonesia and Singapore, information on *Bartonella* detection is scarce. Winoto *et al*. (2005) detected *Bartonella* in 6% of rats and shrews using blood-smearing techniques followed by molecular procedures in Jakarta, Indonesia. In Singapore, 20.8% of rats and shrews were positive for *Bartonella* DNA (Neves *et al*., 2018). Phylogenetic analysis revealed that these strains were related to *B. elizabethae* and *B. queenslandensis*. In both countries, infection was more common among commensal species such as *R. tanezumi*, *R. norvegicus*, and *S. murinus*, given that the studies were mainly conducted in urban areas.

In Northern Vietnam, 31.6% of rodents were primarily infected with *Bartonella* spp. during a multiple pathogen detection study (Anh *et al*., 2021). Additionally, dual infection of *Bartonella* spp. with *Leptospira* spp. or *Rickettsia* spp. was present in approximately 40% of the rodents. Meanwhile, Loan *et al*. (2015) reported an overall infection rate of 14.9% in rodents around Southern Vietnam. These rodents were predominantly infected with zoonotic strains such as *B. rattimassiliensis*, *B. tribocorum*, and *B. elizabethae*. According to the authors, the contrast in prevalence between the two regions was presumptively due to climate and natural conditions. Another study detected *Bartonella* DNA in 10.7% of rodents from regions in Lao PDR, Cambodia, and Thailand, providing dawning evidence of *Bartonella* spp. in rodents such as *N. fulvescens*, *M. cookii*, and *Rattus andamanensis* for the first time around SEA (Jiyipong *et al*., 2012). In addition, a high prevalence of *Bartonella* (25.5%) was found in rodents from Lao PDR. The study identified additional putative species like *Bartonella* sp. Lao/Nh1 and *Bartonella* sp. Lao/Nh2 using the *gltA*, *rpoB*, and *ITS* genes (Angelakis *et al*., 2009). Currently, minimal data is available on the pathogenicity, reservoir hosts, and potential vectors of these putative strains.

The detection of pathogenic *Bartonella* spp. in rodents, especially in urban and agricultural areas of Thailand and Malaysia, heightens the potential for zoonotic spillover into human populations (Blasdell *et al*., 2019b; Panthawong *et al*., 2020). Therefore, monitoring *Bartonella* prevalence in rodents is crucial for assessing, managing, and mitigating the risk of disease transmission to humans, pets, and livestock, especially in densely populated areas. Currently, there is a paucity of clinical data on *Bartonella* infections in most Southeast Asian countries, suggesting a serious underdiagnosis issue. Hence, enhanced surveillance is essential for accurately determining the true disease burden in SEA, identifying the principal reservoirs in the region, and evaluating the zoonotic risks towards the community. Further studies on ectoparasites are also important in establishing the pathogen maintenance and transmission cycle in endemic regions.

Borreliosis

The genus *Borrelia* is typically classified into Lyme borreliosis (LB)-inducing pathogens and relapsing fever (RF)-inducing pathogens (Margos *et al*., 2020). Both diseases are distinct in terms of ecological, clinical, and epidemiological features. Recent studies suggest the existence of a novel echidna-reptile-related monophyletic cluster consisting of *Borrelia mahuryensis, Borrelia tachyglossi*, *Borrelia turcica*, and several unclassified strains. It is unclear whether these species can induce human infections (Trevisan *et al*., 2021a). LB is the most common hard tick-borne (*Ixodes* spp.) zoonotic disease, widespread across the Northern Hemisphere and Europe (Radolf *et al*., 2021). Pathogenic species such as *Borrelia afzelii, Borrelia burgdorferi sensu stricto*, *Borrelia garinii*, and *Borrelia mayonii*, within the *sensu lato* complex, are commonly associated with LB (Tay *et al*., 2002; Strle *et al*., 2006; Khor *et al*., 2019; Madison-Antenucci *et al*., 2020). Strains such as *B. afzelii* and *B. garinii* are known to cause neuroborreliosis (Strle *et al*., 2006). Other spirochetes associated with human disease include *Borrelia bavariensis*, *Borrelia lusitaniae*, and *Borrelia spielmanii* (Marques *et al*., 2021). RF is predominantly transmitted via soft ticks (argasid), although *Borrelia miyamotoi* and *Borrelia recurrentis* are spread by hard ticks and lice, respectively. Notably, *B. recurrentis* is the only RF agent without an animal reservoir, as it is transmitted solely by the human body lice, *Pediculus humanus corporis*. RF is therefore classified into soft tick-borne RF, hard tick-borne RF, and louse-borne RF based on its arthropod vectors. These diseases predominantly occur in the Americas, Africa, Asia, and Europe (Trevisan *et al*., 2021b).

The enzootic transmission cycle of *Borrelia* spp. is complex. The spirochete bacterium requires both competent reservoirs and tick vectors for its ecological maintenance. Infected reservoirs play a key role in transmitting the bacterium to naive arthropod vectors (Lopez *et al*., 2021). As dead-end hosts, humans acquire the pathogen from tick saliva during a blood meal. Infected nymphs and adult ticks are more likely to bite humans, leading to clinical disease, although ticks of all life stages can transmit the pathogen (Eisen *et al*., 2017; Strnad *et al*., 2023). While rodents are the primary reservoirs for LB-associated *B. burgdorferi sensu lato* (Bbsl) complex, other animals such as rabbits, bank voles, shrews, carnivores, birds, and lizards can also carry the spirochete bacterium (Margos *et al*., 2019). Some ungulates, such as deer, are incompetent reservoirs of *Borrelia*, but are essential in tick reproduction and population maintenance of the bacteria (Jaenson & Talleklint, 1992).

Over the past two decades, LB has accounted for 82% of all tick-borne diseases in the United States (Rosenberg *et al*., 2018). Its annual incidence is reaching endemic levels in Europe, especially in Western European countries (Sykes & Makiello, 2017). In the United States, clinical cases are mainly caused by *B. burgdorferi sensu stricto*, although newer cases related to *B. mayonii* have been reported in this region (Pritt *et al*., 2016; Marques *et al*., 2021). In Europe, infections are associated with genospecies like *B. afzelii* and *B. garinii* (Marques *et al*., 2021). In Asia, LB has been reported in China (Wu *et al*., 2013), Japan, Korea (Im *et al*., 2019), and Taiwan. Recently, LB was detected in Nepal for the first time in a patient presenting with arthralgia, headache, and fatigue (Pun *et al*., 2018). In South Korea, LB was gazetted as a notifiable disease in 2010, with rising incidences since then (Acharya & Park, 2021).

Contrastingly, information on the epidemiology of LB in SEA is scarce. Hitherto, cases have only been reported in Malaysia and Indonesia. The first seroprevalence study in Malaysia detected antibodies against *B. afzelii* in a blood donor. In addition, IgM (19.8%) and IgG (4.1%) antibodies against *Borrelia* were detected using Western blot assay in patients suspected of febrile illnesses such as leptospirosis and melioidosis (Tay *et al*., 2002). Almost two decades later, using the IgG ELISA method, Khor *et al*. (2019) detected antibodies against *B. burgdorferi* in 8.1% of the Orang Asli community in Peninsular Malaysia. In Indonesia, 7.32% of patients with a history of tick bites were exposed to LB (Rotan *et al*., 2018). In Singapore, attempts to detect LB in patients with annular erythema were futile (Goh *et al*., 1996). Furthermore, a patient with neuroretinitis was suspected of having LB, but no conclusive diagnosis was made (Lam & Sanjay, 2012). Recently in Thailand, 17.9% of human sera tested positive for *B. miyamotoi*, the causative agent of RF (Takhampunya *et al*., 2023). However, LB has not been detected in this region so far, and RF has not been detected in any Southeast Asian countries except for Thailand.

Similar to clinical cases, the distribution of borrelial agents in rodents is underexplored in SEA, with studies largely restricted to Malaysia and Thailand (Table 1). Recently, Mohd-Azami *et al*. (2023) detected both LB and RF-associated *Borrelia* spp. in 5.9% of rodents from an oil palm plantation. RF agents were found in several rodents, including, *R. tanezumi* R3 mitotype, *R. tiomanicus*, and *Tupaia glis*, while LB strains genetically similar to *B. burgdorferi sensu stricto* and *Borrelia yangtzensis* were limited to the *Rattus tanezumi* R3 mitotype. Notably, one of the rodents infected with the *B. burgdorferi* strain was captured in Kampung Tumbuh Hangat, Perak, an oil palm plantation bordering human settlements. Khor *et al*. (2019) previously reported that the indigenous population (Orang Asli) from Kampung Tumbuh Hangat are 1.65 times more likely to be seropositive for anti-*B. burgdorferi* antibodies. However, the zoonotic spillover of *B. burgdorferi* has not been established in the this region, despite findings showing similar strains in both humans and rodents. More surveillance studies are required to establish the maintenance cycle of *B. burgdorferi* and its transmission route to humans in this region.

Recently, the first clinical infection of *B. yangtzensis* was reported in a Korean individual who travelled to the Taean Peninsula (Kim *et al*., 2021). In China and Japan, *B. yangtzensis* is maintained in rodent reservoirs such as *N. fulvescens*, *R. rattus*, and *M. caroli*, and transmitted by the *Ixodes* ticks (Margos *et al*., 2015). In Sarawak, Lau *et al*. (2020) detected borrelial pathogens in 8.9% of rodents and 43.8% of *Ixodes granulatus* ticks. LD agents such as *B. yangtzensis* and *B. valasiana*-related genospecies were isolated from *Rattus* rats, while *B. miyamotoi* was detected in *S. muelleri*. The circulation of *B. yangtzensis* in both *Ixodes* ticks and rodents suggests the existence of a pathogen maintenance cycle in the environment, where rodents and ticks may play the roles of natural reservoirs and vectors, respectively. A separate study in Malaysia, detected a high prevalence (46.2%) of *B. yangtzensis* in *I. granulatus* ticks, but the presence of borrelial agents in the respective rodent hosts was not investigated (Khoo *et al*., 2018). An increasing detection of *B. yangtzensis* in tick vectors suggests an impending risk of pathogen transmission to humans in the environment. This postulation is supported by the recent incident of *B. yangtzensis* infection following a tick bite in a Korean woman (Kim *et al*., 2021).

I. granulatus is one of the most widespread and commonly encountered ticks from the *Ixodes* genus in SEA (Petney *et al*., 2019). Despite its wide distribution and tendency to infest humans, relatively little is known about the frequency of human bites and subsequent infections. The vector competence of various human-biting ticks from the *Ixodes, Amblyomma*, and *Dermacentor* genera for the Bbsl complex has been investigated experimentally; however, a formal demonstration for *I. granulatus* is lacking (Eisen, 2020). In Malaysia and Thailand, *I. granulatus* ticks, which occasionally bite humans, have been associated with carrying LD agents, indicating the potential for this species to serve as competent vectors (Khoo *et al*., 2018; Lau *et al*., 2020; Takhampunya *et al*., 2021). These field evidences justify an experimental demonstration for the vector competence of *I. granulatus* ticks. Experimental studies could shed a light on the roles of the ticks in the ecological maintenance of borrelial spirochetes. Although humans are typically the incidental hosts for tick species, further evaluation is necessary to understand the pathogenicity of borrelial diseases in humans and the transmission cycle of Bbsl complex in SEA.

In Thailand, studies have reported a low prevalence of borrelial agents in rodents, ranging from 1.2% to 3.2% (Takhampunya *et al*., 2019, 2021, 2023). In contrast, 14% to 22% of the infesting ticks were infected with borrelial spirochetes. Some of these spirochetes including, *B. miyamotoi* and *B. yangtzensis*, are pathogenic to humans (Kim *et al*., 2021; Takhampunya *et al*., 2023). Despite the presence of a pathogen maintenance cycle in the environment, data on clinical cases of borreliosis in Thailand are scarce. It is currently unknown whether the paucity of information stems from a lack of surveillance and monitoring. Overall, insufficient information is available on the competence of rodents and their arthropod vectors in maintaining borrelial agents in SEA. Even though the prevalence in Southeast Asian rodents is relatively low, it cannot be dismissed that they pose a threat to humans, as recent studies show increasing infection rates in humans. Moreover, an expanding detection of pathogenic *Borrelia* spp. in tick pools insinuates the existence of a maintenance cycle in the environment. Thus, continuous surveillances are essential in corroborating these postulations. Currently, the lower prevalence of clinical cases in SEA could be attributed to inadequate disease regulation systems. Hence, continuous monitoring and experimental studies are crucial in identifying the competent reservoirs and vectors of LB and RF in SEA.

Rickettsiosis

There is an increasing body of knowledge on the prevalence of rickettsioses, including scrub typhus, murine typhus, and spotted fever in SEA [reviewed in (Low *et al*., 2020b)]. Findings from serological studies have attributed rickettsial infections as the cause of many AUFI cases in Southeast Asian countries (Tay *et al*., 2000; Wangrangsimakul *et al*., 2018; Luvira *et al*., 2019; Lokida *et al*., 2020). *Orientia tsutsugamushi*, the causative agent of scrub typhus, and various *Rickettsia* spp. are transmitted via the bites of arthropods such as chiggers, fleas, and ticks. The role of rodents in the ecology of rickettsial diseases is well-established for scrub typhus and murine typhus, as rodents are the primary animal hosts for the arthropod vectors of the causative agents. However, the role of rodents in the transmission of spotted fever is less clear.

Scrub typhus - Orientia tsutsugamushi

Previously confined to the Tsutsugamushi Triangle, scrub typhus and its etiological agent are now found in a wider geographical area, including Chile, Africa, and the United Arab Emirates as reviewed by Xu *et al*. (2017) and Richards & Jiang. (2020). *O. tsutsugamushi* is the causative agent of scrub typhus in SEA, while the newly reported species, *Orientia chuto* causes scrub typhus in other parts of the world (Richards & Jiang, 2020). The ecological roles of rodents and their chigger vectors in the transmission of scrub typhus have been widely investigated since the disease was first described in Japan in the 1800s [reviewed in (Elliott *et al*., 2019; Richards & Jiang, 2020)]. Epidemiological investigations of recent outbreaks continue to associate the presence of rodents and chiggers with the disease upsurge (Tilak *et al*., 2011; Rodkvamtook *et al*., 2018) (Figure 1). For example, during a recent scrub typhus outbreak among training soldiers in Chonburi, Thailand, follow-up studies detected a high prevalence of *O. tsutsugamushi* infections in rodents and chiggers nearby the training site (Rodkvamtook *et al*., 2018). Another outbreak among febrile children in Chiang Mai was linked to infected rodent reservoirs (65.5%) in the surrounding areas (Rodkvamtook *et al*., 2013). Several factors may influence the acquisition of scrub typhus, including direct contact with household floors, households with poor sanitation, high-risk occupational environments, frequent rodent exposures, and low awareness of personal protective equipment usage (Tran *et al*., 2021).

Common *O. tsutsugamushi* strains circulating in SEA include Karp, TA763, Kato, Gilliam, UT176, TA678, TA686, TA716, TA763, JG-v, and TH1817. Moreover, most of these strains are based on data collected in Thailand, where the Thai strains closely resembled Japanese and Taiwanese strains (Elisberg *et al*., 1968; Shirai *et al*., 1981; Blacksell *et al*., 2008; Duong *et al*., 2013a, 2013b; Wongprompitak *et al*., 2013; Mohd-Azami *et al*., 2023). Recently, efforts have been made to develop a sensitive tool that detects the recent *O. tsutsugamushi* strains, alongside studying the disease model of scrub typhus to enable vaccine development (Elliott *et al*., 2021b; Linsuwanon *et al*., 2021b; Chankate *et al*., 2022; Indrawattana *et al*., 2022; Inthawong *et al*., 2023). However, more studies are necessary to evaluate the pathogenicity of these strains in humans and the roles of synanthropic small mammals in maintaining the scrub typhus transmission cycle.

The transmission of *O. tsutsugamushi* is facilitated by the larvae of *Trombiculidae* mites, commonly known as chiggers. The pathogenicity of *O. tsutsugamushi* has been demonstrated in rhesus macaques, with chiggers requiring only a minimum of an hour of feeding to transmit the pathogen (Linsuwanon *et al*., 2021b). The primary vectors for *O. tsutsugamushi* are chiggers from the *Leptotrombidium* genus, including *Leptotrombidium pallidum*, *Leptotrombidium deliense*, *Leptotrombidium scutellare*, *Leptotrombidium fletcheri*, and *Leptotrombidium chiangraiensis* (Lerdthusnee *et al*., 2003; Elliott *et al*., 2019). Several chigger species have been associated with specific habitats: *Ascoschoengastia indica, Eutrombicula wichmanni, Leptotrombidium arenicola, L. deliense, Trombiculindus paniculatum, Walchia disparunguis pingue, Walchia kritochaeta,* and *Walchiella oudemansi* are associated with human-modified habitats, whereas three chiggers (*Gahrliepia rutila, Walchia ewingi ewingi,* and *Walchia rustica*) are predominantly found within forested areas (Alkathiry *et al*., 2022).

In Thailand, a few species of chiggers tested positive for *O. tsutsugamushi* infection, including *L. deliense*, *Leptotrombidium imphalum*, and *W. kritochaeta* (Elliott *et al*., 2021a). In contrast, in Malaysia, only *L. deliense* collected from *R. rattus* and *Tupaia* spp. has tested positive for the Karp prototype strain thus far (Ernieenor *et al*., 2021). In Lao PDR, a low detection rate was reported, with only a single pool of chiggers testing positive for *O. tsutsugamushi* and no positive detections in small mammals (Elliott *et al*., 2022). An outbreak investigation in India suggested *Schoengastiella ligula* as a potential vector for scrub typhus (Tilak *et al*., 2011). Chiggers that are not the primary vectors may also contribute to the maintenance of scrub typhus agents in rodent hosts. In addition to Muridae infestations, chiggers have also been reported infesting Tupaiidae and Sciuridae hosts (Paramasvaran *et al*., 2009; Adrus *et al*., 2021). Chiggers are successful vectors because they can maintain the transmission cycle of *O. tsutsugamushi* via transovarial and transstadial routes, as well as by co-feeding on animal hosts (Phasomkusolsil *et al*., 2009).

Rodents are the well-established primary hosts for chiggers, playing a key role in the dispersal of scrub typhus vectors. They may also be infected with *O. tsutsugamushi*, potentially serving as reservoirs of the pathogen (Rodkvamtook *et al*., 2018). However, a recent study suggests that rodents may be the dead-end host of *O. tsutsugamushi*, with the increase in rodent populations contributing to the growth of chigger populations (Linsuwanon *et al*., 2021a). A survey in rural Thailand found that approximately 42% of rodents, including *R. rattus, R. exulans, R. losea, R. norvegicus,* and *B. indica*, were infected with *O. tsutsugamushi* (Lerdthusnee *et al*., 2008) (Table 1). In Indonesia, a recent study reported the prevalence of *O. tsutsugamushi* in *R. norvegicus*, raising concerns as the pathogen is no longer restricted to rural landscapes (Susanti *et al*., 2022). Data from Thailand indicates that the host, *R. tanezumi* and vector, *Leptotrombidium* spp. are habitat generalists (Elliott *et al*., 2021a). The study also found that *R. tanezumi* and *B. indica* were heavily infested with chiggers, and their chigger pools tested positive for *O. tsutsugamushi*.

In Northern Thailand, approximately 25% of rodents including *R. tanezumi, R. andamanensis, R. exulans, B. indica, M. cookii, Berylmys berdmorei*, and *R. nitidus* were infected with *O. tsutsugamushi* (Elliott *et al*., 2021a). Previous exposure was confirmed in 42.6% of rodents trapped in Chiang Rai, Thailand (Linsuwanon *et al*., 2021a). Lerdthusnee *et al*. (2008) suggest that the dry season is associated with higher risks of scrub typhus due to increased rodent populations and chigger densities. The dry season also aligned with greater species richness of chiggers, with a high infestation rate of 94%, compared to 55% during the wet season (Alkathiry *et al*., 2022). Linsuwanon *et al*. (2021a) further supported this, by detecting the highest infection rate in rodents during December, the dry-cool season. Moreover, Elliott *et al*. (2021a), observed higher *O. tsutsugamushi* infections during season transition. In contrast, a clinical study found that scrub typhus cases were higher during the wet season in Lao PDR (Roberts *et al*., 2021). More studies are warranted across SEA to gather comprehensive data on the epidemiology of scrub typhus in relation to seasonal patterns.

O. tsutsugamushi-infected rodents are more commonly found in forested and lowland habitats (Chaisiri *et al*., 2017; Elliott *et al*., 2021a). A recent ecological study presented evidence of a positive correlation between chigger species richness and latitude, with the incidence of scrub typhus in Thailand (Chaisiri *et al*., 2019). Chigger abundance decreases with increasing distance from forests, thus reducing humans contact (Linsuwanon *et al*., 2021a). The study also suggests that anthropogenic activities may reduce chigger populations. These findings highlight the need for further research into the ecology of scrub typhus. Other Southeast Asian countries, including Indonesia (Richards *et al*., 1997), Malaysia (Hanifah, 2013; Mohd-Azami *et al*., 2023), and the Philippines (Van Peenen *et al*., 1977), have also reported *O. tsutsugamushi* in rodents. Commonly infected rodents within the Muridae family include *Apodemus agrarius*, *R. rattus*, *R. norvegicus*, *R. tiomanicus*, and *B. indica* as reviewed by Elliott *et al*. (2019). In addition, *R. exulans, R. tiomanicus, M. cookii, R. nitidus, R. argentiventer, R. bowersi, Rattus mackenziei, Leopoldamys sabanus, T. glis,* and *B. berdmorei* have also carried *O. tsutsugamushi* (Elliott *et al*., 2021a; Linsuwanon *et al*., 2021a; Mohd-Azami *et al*., 2023). Since most recent ecological studies on scrub typhus are based in Thailand, further research from other Southeast Asian countries is necessary to account for differences in rural and agricultural landscapes.

Murine typhus – Rickettsia typhi

Members of the typhus group *Rickettsia* spp., including *Rickettsia typhi* and *Rickettsia prowazekii,* cause murine typhus (endemic typhus) and louse-borne typhus (epidemic typhus), respectively (Rauch *et al*., 2018). Murine typhus is the only type endemic in SEA (Barbara *et al*., 2010; Vallée *et al*., 2010). Globally, around 60% of patients have been infected by *R. typhi* (Vaca *et al*., 2022). The illness is generally mild but can be fatal if not diagnosed and treated promptly (Osterloh *et al*., 2016). In SEA, murine typhus is a common cause of undifferentiated fevers, especially in urban areas [reviewed in (Low *et al*., 2020b)]. In Thailand, approximately 3.5% of patients in Chiang Rai and 5% in Bangkok tested positive for murine typhus (Wangrangsimakul *et al*., 2018; Luvira *et al*., 2019).

In Lao PDR, a patient diagnosed with meningoencephalitis was positive for anti-*R. typhi* IgM antibodies (Uy *et al*., 2022). The diagnosis of murine typhus is challenging due to symptoms overlapping with other endemic tropical diseases, leading to some patients receiving ineffective antibiotics. Seroprevalence studies indicate that murine typhus is prevalent in both rural and urban areas (Strickman *et al*., 1994; Vallée *et al*., 2010; Trung *et al*., 2017; Tappe *et al*., 2018; Chaisiri *et al*., 2022). The pathogen is transmitted via the oriental rat fleas, *X. cheopis*, from rodents (Barbara *et al*., 2010). Common rodents in SEA including *R. tanezumi* (Widjaja *et al*., 2016; Pramestuti *et al*., 2018), *R. rattus* (Ibrahim *et al*., 1999; Griffiths *et al*., 2022), *R. exulans*, *R. norvegicus* (Ibrahim *et al*., 1999; Griffiths *et al*., 2022), and *Mus musculus* (Chareonviriyaphap *et al*. 2014), have been reported to be infected with *R. typhi*. These rodents are likely the reservoirs for murine typhus agent in SEA.

In Singapore, rodents captured in schools had the highest seropositivity for *R. typhi*, with 60% of 1,143 individuals testing positive (Griffiths *et al*., 2022) (Table 1). In Indonesia, *R. norvegicus* had significant infection compared to other rodent species, with most positive cases occurring in Jakarta (Ibrahim *et al*., 1999). Similar findings were reported in other studies from Indonesia (Richards *et al*., 2002), Singapore (Griffiths *et al*., 2022), and

Table 1. The summary of peridomestic rodents/shrews and their associated pathogens reported in SEA

Country	Prevalence (%)	Host	Pathogen	Specimen	Method	Reference
Malaysia	34.7	*R. rattus*	*L. interrogans* Malaya, IMR LEP 75, *L. interrogans* Bataviae, *L. interrogans* Gurungi, *L. interrogans* Hardjo, *L. interrogans* Copenhageni	Blood, kidney	Serology, molecular	Noh *et al*., 2024
Malaysia	20.0	*R. tiomanicus, T. glis, M. rajah, M. whiteheadi, S. muelleri*	*L. interrogans*	Kidney	Molecular	Shafie *et al*., 2022
Malaysia	36.7	Rats	*L. interrogans, L. borgpetersenii*	Kidney	Molecular	Wan *et al*., 2022
Malaysia	15.7	*R. norvegicus, R. rattus, T. glis, S. murinus*	Pathogenic *Leptospira* spp.	Kidney	Molecular	Mohd-Taib *et al*., 2020
Malaysia	31.6	*R. rattus R3, R. tanezumi, R. tiomanicus, S. muelleri, M. ochraceiventer, M. whiteheadi, N. cremoriventer*	*L. interrogans, L. borgpetersenii*	Kidney	Molecular	Blasdell *et al*., 2019a
Malaysia	39.2	*R. rattus*	*L. borgpetersenii, L. interrogans*	Kidney, liver	Molecular	Ikbal *et al*., 2019
Malaysia	14.9	*R, norvegicus, R. rattus, M. whiteheadi, S. muelleri, R. tiomanicus, T. glis, S. murinus*	Pathogenic *Leptospira* spp.	Kidney	Molecular	Yusof *et al*., 2019
Malaysia	14.3	*R. norvegicus, R. rattus, M. whiteheadi, S. muelleri, R. tiomanicus, T. glis, S. murinus*	*L. interrogans, L. kirschneri, L. borgpetersenii, L. weilii*	Kidney	Culture, molecular	Azhari *et al*., 2018
Malaysia	15.9	Rats	*L. interrogans* Icterohaemorrhagiae, *L. noguchii, L. meyeri*	Kidney, liver	Culture, molecular	Pui *et al*., 2017
Malaysia	11.0	*R. rattus, R. norvegicus, R. exulans*	*L. interrogans* Bataviae, *L. borgpetersenii* Javanica	Urine, kidney, blood	Culture, molecular, serology	Benacer *et al*., 2016
Malaysia	6.7	*R. rattus, R. norvegicus*	*L. borgpetersenii* Javanica, *L. interrogans* Bataviae	Urine, kidney	Culture, molecular, serology	Benacer *et al*., 2013
Thailand	3.6	*R. exulans, R. rattus, B. indica*	*L. interrogans, L. borgpetersenii*	Kidney	Molecular	Krairojananan *et al*., 2020
Indonesia	8.0	*R. tanezumi, R. norvegicus, B. indica, B. bengalensis*	*Leptospira* spp.	Kidney	Molecular	Sunaryo & Priyanto, 2022
Indonesia	6.6	*R. tanezumi, R. argentiventer, S. murinus*	*L. borgpetersenii* Sejroe	Kidney	Molecular	Widiastuti *et al*., 2016
Vietnam	18.0	*R. tanezumi, Rattus* cf. *rattus, B. bowersi, Callosciurus erythraeus, B. savilei, N. fulvescens, R. nitidus*	*Leptospira* spp.	Kidney, liver	Molecular	Anh *et al*., 2021
Vietnam	Culture: 12.6 Molecular: 28.4	*R. norvegicus*	*L. interrogans* Bataviae, *L. interrogans* Pomona	Kidney	Culture, molecular	Koizumi *et al*., 2019
Cambodia	12.3	*R. norvegicus, R. argentiventer, Rattus* spp.	*L. interrogans, L. noguchii*	Kidney, bladder	Molecular	Kudo *et al*., 2018
Lao PDR-Cambodia-Thailand	7.1	*M. cookii, R. tanezumi, M. cervicolor, R. losea, M. caroli, R. argentiventer, M. surifer, B. berdmorei, B. indica, B. savilei, R. exulans*	*L. borgpetersenii, L. interrogans, L. kirschneri, L. weilii*	Kidney	Molecular	Cosson *et al*., 2014
Singapore	46.8	*R. norvegicus, R. rattus*	*Leptospira* spp.	Kidney	Molecular	Griffiths *et al*., 2022
Malaysia	13.7	*R. norvegicus*	HNTV, PUUV, SNV, SEOV	Sera	Serology	Lam *et al*., 2001

Thailand	6.6	*B. indica*	THAIV	Lungs, liver	Serology, molecular	Hugot *et al*., 2006
Indonesia	N/A	*R. tanezumi*	SERV	Sera, lungs	Serology, molecular	Plyusnina *et al*., 2009
Indonesia	4.0	*R. norvegicus, R. exulans, R. rattus*	SEOV	Sera	Serology	Ibrahim *et al*., 1996
Vietnam	1.6	*Niviventer cf. confucianus*	HTNV	Lungs	Molecular	Kikuchi *et al*., 2021
Vietnam	6.9	*B. indica, R. argentiventer, R. norvegicus, R. tanezumi*	DOBV, SEOV	Sera, blood	Serology	Cuong *et al*., 2015
Vietnam	0.4	*R. argentiventer*	SEOV	Lungs	Molecular	
Vietnam Vietnam	2.8 13.11	*R. norvegicus* *S. murinus*	HTNV strain 76-118, SEOV strain SR-11 Thottapalayam virus	Sera Sera	Serology Serology	Luan *et al*., 2012
Cambodia	8.2 87.0	*R. norvegicus, R. rattus, Rattus* spp. *R. norvegicus, R. rattus, Rattus* spp.	HTNV SEOV	Sera Liver, kidney, lungs	Serology Molecular	Reynes *et al*., 2003
Laos-Cambodia-Thailand	3.0	*B. inidca, B. savilei, M. surifer, R. exulans, R. nitidus, R. norvegicus, R. tanezumi, M. caroli, M. cookii*	Hantavirus	Sera	Serology	Blasdell *et al*., 2011a
Laos-Cambodia-Thailand	1.9	*B. indica, R. tanezumi, R. norvegicus*	THAIV, SEOV	Lungs	Molecular	
Singapore	35.5	*R. norvegicus, R. rattus*	SEOV	Sera	Serology	Griffiths *et al*., 2022
Singapore Singapore	34.0 2.4	*R. norvegicus, R. tanezumi* *R. norvegicus, R. tanezumi*	Hantavirus Seoul Singapore virus, Jurong TJK/06 virus	Sera Lungs, kidney	Serology Molecular	Johansson *et al*., 2010
Malaysia	4.9	*R. tanezumi R3 mitotype*	*B. phoceensis*	Spleen	Molecular	Mohd-Azami *et al*., 2023
Malaysia	N/A	*R. tiomanicus*	*B. phoceensis*	N/A	Molecular	Asyikha *et al*., 2020
Malaysia	3.7	*R. rattus diardii, R. norvegicus, R. argentiventer, R. tiomanicus, R. exulans*	*B. phoceensis*	Blood	Molecular	Low *et al*., 2020a
Malaysia	57.3	*S. muelleri, R. rattus super group M. whiteheadi, N. cremoriventer*	*B. phoceensis, B. rattimassiliensis, B. queenslandensis, B. tribocorum, B. elizabethae, undescribed clade*	Spleen	Molecular	Blasdell *et al*., 2019b
Malaysia	13.7	*Rattus diardii, R. norvegicus*	*B. queenslandensis, B. elizabethae, B. tribocorum, B. rattimassiliensis, B. coopersplainsensis*	Spleen, kidney	Culture, molecular	Tay *et al*., 2014b
Thailand	11.5	*R. rattus, R. norvegicus, R. exulans, M. musculus, B. indica, S. murinus, R. tanezumi*	*B. tribocorum, B. rattimassiliensis, B. queenslandensis, B. elizabethae, Bartonella chanthaburi* spp. nov., *B. coopersplainsensis, Bartonella satun* spp. nov., *Bartonella ranong* spp. nov., *B. henselae*	Blood	Culture, molecular	Pangjai *et al*., 2022
Thailand	34.9	*R. rattus, B. indica, R. argentiventer, B. savilei, R. losea, R. exulans, R. norvegicus*	*B. queenslandensis*	Blood	Molecular	Panthawong *et al*., 2020
Thailand	38.5	*R. tanezumi, R. exulans*	*B. phoceensis, B. kosoyi-B. tribocorum complex, Bartonella* spp., *B. tribocorum, B. grahamii, B. rattimassiliensis,*	Blood	Molecular	Saengsawang *et al*., 2021
Thailand	61.0	*R. rattus, R. exulans*	*B. queenslandensis, B. rattimassiliensis, B. tribocorum, B. elizabethae, B. phoceensis*	Blood	Culture, molecular	Kim *et al*., 2016
Thailand	17.6	*R. rattus, B, indica, R. norvegicus, B. savilei, R. exulans, R. sabanus*	*B. rattimassiliensis, B. coopersplainsensis, B. tribocorum*	Liver, blood	Molecular, culture	Klangthong *et al*., 2015
Thailand	15.5	*R. norvegicus, R. rattus, R. tanezumi, R. exulans, B. indica, R. muelleri, R. nitidus, R. bukit bukit*	*B. tribocorum, B. rattimassiliensis, B. elizabethae, B. queenslandensis,*	Blood	Culture, molecular	Pangjai *et al*., 2014

Thailand	41.5	*R. rattus, R. norvegicus, B. inidica, B. savilei, R. exulans, M. cervicolor, R. argentiventer, R. nitidus, R. remotus, B. berdmorei*	*B. rattimassiliensis, B. tribocorum, B. phoceensis, B. coopersplainsensis, B. elizabethae,* unknown genogroup	Blood	Culture, molecular	Bai *et al*., 2009
Thailand	8.5	*R. surifer, B. berdmorei, R. rattus, B. savilei, M. cervicolor, R. exulans*	*B. coopersplainsensis, B. queenslandensis, B. phoceensis, Candidatus Bartonella thailandensis, B. rochalimae, Bartonella* sp. *RN24BJ*	Blood	Molecular	Saisongkorh *et al*., 2009b
Thailand	8.7	*B. indica, R. rattus, R. losea*	*B. elizabethae, B. grahamii*	Blood	Culture, molecular	Castle *et al*., 2004
Indonesia	6.0	*R. tanezumi, S. murinus, R. norvegicus*	*B. phoceensis, B. rattimassiliensis, B. elizabethae*	Blood, spleen	Microscopy, molecular	Winoto *et al*., 2005
Vietnam	31.6	*R. tanezumi, N. fulvescens, R. cf. rattus, B. savilei, R. norvegicus, R. nitidus, N. mekongis, N. lotipes, B. bowersi, C. inornatus, R. andamanensis, N. confucianus, L. edwardsi*	*Bartonella* spp.	Liver, kidney	Molecular	Anh *et al*., 2021
Vietnam	14.9	*R. argentiventer, B. indica, R. tanezumi, R. norvegicus*	*B. rattimassiliensis, B. tribocorum, B. elizabethae, B. coopersplainsensis, B. queenslandensis*	Blood	Culture, molecular	Loan *et al*., 2015
Lao PDR-Cambodia-Thailand	8.7	*Bandicota* spp., *Mus* spp., *Rattus* spp., *Berylmys* spp., *Maxomys* spp., *Niviventer* spp.	*B. queenslandensis, B. rattimassiliensis, B. tribocorum, B. elizabethae, B. coopersplainsensis, B. phoceensis*	Blood	Culture, molecular	Jiyipong *et al*., 2012
Lao PDR	25.5	*R. exulans, R. rattus, M. cervicolor, M. caroli, C. badius*	*B. phoceensis, B. elizabethae, B. tribocorum, Bartonella* sp. Lao/Nh2, *Bartonella* sp. Lao/Nh1	Spleen, liver	Molecular	Angelakis *et al*., 2009
Singapore	20.8	*R. tanezumi, S. murinus, R. norvegicus, T. glis, M. castaneus*	*B. queenslandensis, B. elizabethae, Bartonella* spp.	Spleen	Molecular	Neves *et al*., 2018
Malaysia	5.9	*R. tanezumi* R3 mitotype *R. tanezumi* R3 mitotype, *R. tiomanicus, T. glis*	*B. burgdorferi* s.s, *B. yangtzensis* Relapsing fever *Borrelia* spp.	Spleen	Molecular	Mohd-Azami *et al*., 2023
Malaysia	8.9	*Rattus* spp. *S. muelleri*	*B. yangtzensis, B. valasiana*-related genospecies *B. miyamotoi*	Spleen	Molecular	Lau *et al*., 2020
Thailand	2.3	*B. berdmorei, B. indica, M. caroli, M. parahi, B. bowersi* *B. indica, Mus* spp., *M. caroli, L. sabanus*	*B. yangtzensis* *B. miyamotoi, B. theileri*	Spleen, kidney	Molecular	Takhampunya *et al*., 2023
Thailand	9.0	*B. indica, R. exulans, M. caroli, R. tanezumi, B. berdmorei, M. cookii, B. mackenziei, M. pahari*	*B. miyamotoi*	Blood	Serology	
Thailand	1.2	*R. rattus, B. indica, L. sabanus, C. fuliginosa, M. cookii, N. tenaster, M. caroli*	*B. theileri/ B. lonestari, B. miyamotoi*	Spleen	Molecular	Takhampunya *et al*., 2021
Thailand	3.2	*R. rattus* *Niviventer tenaster*	*B. yangtzensis* *B. miyamotoi*	Spleen, kidney	Molecular	Takhampunya *et al*., 2019
Malaysia	12.3	*R. tanezumi* R3 mitotype, *R. exulans, R. argentiventer, T. glis, R. tiomanicus*	*O. tsutsugamushi* strain UT176, *O. tsutsugamushi* strain TA763, *O. tsutsugamushi* Karp, *O. tsutsugamushi* strain Wuj/2014	Spleen	Molecular	Mohd-Azami *et al*., 2023
Malaysia	11.7	*R. tanezumi R3 mitotype, R. exulans, R. argentiventer, T. glis, R. tiomanicus*	*O. tsutsugamushi*	Spleen	Molecular	Alkathiry *et al*., 2022
Malaysia	1.14	*L. sabanus*	*O. tsutsugamushi* Gilliam	Blood	Molecular	Hanifah, 2013
Thailand	25	*R. tanezumi, R. andamanensis, B. indica, R. exulans, M. cookii, R. nitidus, B. bowersi, Rattus* spp., *B. berdmorei*	*O. tsutsugamushi*	Spleen, lungs, liver	Molecular	Elliott *et al*., 2021a

Thailand	5.5	*R. tanezumi, T. glis, B. berdmorei*	*O. tsutsugamushi* Karp, *O. tsutsugamushi* TA	Spleen, lungs, liver	Molecular	Linsuwanon *et al*., 2021a
Thailand	42.6	*R. tanezumi, R. bowersi, B. berdmorei, R. mackenziei, L. sabanus*	*O. tsutsugamushi*	Serum	Serology	
Thailand	71.1	*R. rattus, B. indica, R. exulans*	N/A	Blood	Serology	Rodkvamtook *et al*., 2018
Thailand	22.2	*R. rattus, R. exulans, B. savilei, Menetes berdmorei*	*O. tsutsugamushi* Karp, *O. tsutsugamushi* Gilliam	Spleen, liver	Molecular	
Thailand	2.3	*Rattus sp. clade 3, R. tanezumi, B. savilei, B. bowersi, L. edwardsi, R. exulans*	*O. tsutsugamushi*	Spleen	Molecular	Chaisiri *et al*., 2017
Thailand	18.3	*R. norvegicus, R. rattus, B. indica*	*O. tsutsugamushi*	Sera	Serology	Chareonviriyaphap *et al*. 2014
Thailand	42.0	Small mammals	*Orientia* spp.	N/A	Molecular, serology	Lerdthusnee *et al*., 2008
Indonesia	0 - 25	*R. tanezumi, R. tiomanicus, R. norvegicus, R. exulans, R. sabanus, R. whiteheadi, Maxomys* spp.	*O. tsutsugamushi*	Sera	Serology	Widjaja *et al*., 2016
Indonesia	2.6	*Maxomys* spp., *R. exulans, R. whiteheadi*	*O. tsutsugamushi*	Spleen, kidney	Molecular	
Indonesia	11.3	*R. norvegicus*	*O. tsutsugamushi*	N/A	Serology	Susanti *et al*., 2022
Indonesia	12.5	*Rattus* spp.	*O. tsutsugamushi*	Sera	Serology	Richards *et al*., 2002
Indonesia	5.1	*R. tiomanicus, R. rattus, C. gloroides*	*O. tsutsugamushi*	Blood	Serology	Richards *et al*., 1997
Philippines	12.5	*R. exulans, R. mindanensis, R. everetti*	*O. tsutsugamushi*	Spleen, kidney	Molecular	Van Peenen *et al*., 1977
Philippines	84.0	*R. rattus, R. everetti, R. panglima, R. exulans, R. mindanensis*	*O. tsutsugamushi*	Ocular sinuses, heart puncture	Serology	
Thailand	23.7	*R. norvegicus, R. exulans, M. mucurus, C. murina*	*R. typhi*	Sera	Serology	Chareonviriyaphap *et al*. 2014
Thailand	5.0	*R. norvegicus, R. rattus, R. exulans, M. musculus*	*R. typhi*	N/A	Serology	Siritantikorn *et al*., 2003
Indonesia	0 - 78	*R. tanezumi, R. norvegicus*	*R. typhi*	Sera	Serology	Widjaja *et al*., 2016
Indonesia	2.6	*R. tanezumi*	*R. typhi*	Spleen, kidney	Molecular	
Indonesia	14.7	*R. norvegicus, R. rattus, R. exulans*	*R. typhi* Wilmington	Sera	Serology	Ibrahim *et al*., 1999
Singapore	32.2	*R. norvegicus, R. rattus*	*R. typhi* Wilmington	Blood	Serology	Griffiths *et al*., 2022
Malaysia	13.7	*R. diardii, R. norvegicus*	*R. honei, R. conorii, R. raoultii*	Spleen, kidney, heart, liver	Molecular	Tay *et al*., 2014a
Thailand	66.2	*B. indica, R. argentiventer*	*R. honei* Wilmington, *R. japonica* YH	Sera	Serology	Okabayashi *et al*., 1996
Indonesia	9 – 73	*R. tanezumi, R. tiomanicus, R. norvegicus, R. exulans, R. sabanus, Maxomys* spp.	*R. rickettsii*	Sera	Serology	Widjaja *et al*., 2016
Indonesia	39.1	*R. norvegicus, R. exulans, R. rattus, R. tiomanicus*	*R. conorii* Moroccan	Sera	Serology	Ibrahim *et al*., 1999
Indonesia	40.0	*R. norvegicus, R. exulans, R. rattus, R. tiomanicus*	*R. honei*	Sera	Serology	
Philippines	12.2	*R. rattus*	*R. japonica*	Sera	Serology	Camer *et al*., 2000

Thailand (Siritantikorn *et al*., 2003; Chareonviriyaphap *et al*., 2014), highlighting a higher prevalence of *R. typhi* in *R. norvegicus* from urban vicinities. However, the overall molecular studies on the prevalence of *R. typhi* in rodents are limited. An attempt by Mohd-Azami *et al*. (2023) to detect *R. typhi* from rodents was unsuccessful and this was likely due to the difference in rodent habitats, since the authors sampled rodents away from urban areas.

Spotted fever rickettsiosis (SFR)

The spotted fever group of *Rickettsiae* (SFGR) includes at least 30 species globally, with 21 classified as pathogenic strains (Satjanadumrong *et al*., 2019). In SEA, the seroprevalence of SFR has been reported in most countries [reviewed in (Low *et al*., 2020b)]. However, most serological assays are based on antigens from SFGR species not endemic to this region, leaving the exact pathogens causing human infections largely unknown. Molecular assays have detected *Rickettsia felis*, *Rickettsia* sp. RF2125 or *Rickettsia asembonensis*, *Rickettsia raoultii*, *Rickettsia honei* TT-118, and *Rickettsia japonica* in humans (Jiang *et al*., 2005; Gaywee *et al*., 2007; Kho *et al*., 2016). Seroprevalence studies suggest a higher risk of SFR in upland forested areas compared to lowland urban areas, indicating frequent host-vector interactions in rural regions (Chaisiri *et al*., 2022). SFGR are primarily transmitted by the Ixodid ticks, which commonly infest rodents in forested or agricultural areas. For example, *Rickettsia* sp. closely related to *R. honeii* was reported in *I. granulatus* collected from *R. rattus* across three provinces of Thailand (Kollars *et al*., 2001). In Malaysia, ticks like *Haemaphysalis* spp., *Dermacentor atrosignatus, and Amblyomma helvolum,* collected from rodents like *Maxomys rajah* and *L. sabanus*, harboured *Rickettsia* spp. closely related to *R. raoultii*, *Rickettsia heilongjiangensis,* and *Rickettsia* sp. RF2125 (Kho *et al*., 2019).

Domestic animals, including rodents, dogs, cattle, buffalo, cats, and ferret-badgers are potential carriers of SFGR (Singh *et al*., 2011; Kuo *et al*., 2017; Ishak *et al*., 2018; Ehlers *et al*., 2020; Khoo *et al*., 2021; Chaisiri *et al*., 2022; Hirunkanokpun *et al*., 2022). In Indonesia, serological studies revealed that *R. tanezumi, R. norvegicus, R. exulans, R. tiomanicus,* and *Maxomys* spp. were exposed to SFGR pathogens (Widjaja *et al*., 2016). Additionally, *R. honei* TT-118 and *R. japonica* were detected in *B. indica* and *R. argentiventer* from Thailand (Okabayashi *et al*., 1996). In the Phillippines, 12.2% of rats captured in selected areas showed past exposures to SFGR based on IFA with *R. japonica* antigens (Camer *et al*., 2000) (Table 1). Ibrahim *et al*. (1999) found that 40% of rats from Indonesian ports and 39.1% of rats from inland areas had antibodies against *R. honei* TT-118 and *Rickettsia conorii*, respectively. In Malaysia, molecular studies identified SFGR related to *R. honei, R. conorii, R. raoultii*, and *Rickettsia* sp. TCM1 in wild rodents from markets in Kuala Lumpur and Penang (Tay *et al*., 2014a). In contrast, no rickettsial agents were found in rodents from rural areas in Johor and Perak, suggesting a lower risk in these regions (Mohd-Azami *et al*., 2023). Further molecular studies are required to detect SFGR agents circulating in Southeast Asian rodents, and assess their roles in pathogen transmission to humans and pathogen maintenance in tick vectors.

CONCLUSIONS

This review attempted to provide an overview of the available epidemiological data on significant rodent-borne diseases around SEA. First, there is a notable lack of comprehensive clinical surveillance data for several rodent-borne diseases in this region. Diseases such as bartonellosis and borreliosis remain understudied, despite the growing anecdotal evidence of their occurrence. Serological studies also indicate sporadic cases across SEA, but annual national records for many of these diseases are completely lacking. For instance, clinical records of hantavirus infections are outdated, with the most recent reports from over two decades ago, except for sporadic acute incidences reported in Indonesia. Thus, implementing multi-centre screening studies in endemic regions where these diseases are prevalent, may improve the disease management across SEA. Furthermore, limited knowledge is available on the pathogenicity, competent reservoirs, and transmission routes of several endemic strains, such as *B. tamiae, B. chanthaburi* spp. nov., *B. satun* spp. nov., *Ca. B. thailandensis*, THAIV, SERV, and Jurong virus, detected in rodents from Thailand, Indonesia, and Singapore, respectively. Additionally, most surveillance studies in humans and rodents have relied on serological methods such as ELISA, MAT, and IFA, which may delay pathogen detection, especially when symptoms such as fever and myalgia are common. Serological detection is essential in determining past exposures and provides fundamental information on the infecting strains or serovars. However, many rodent-borne diseases manifest as AFI; hence, additional molecular methods are essential for differential diagnosis. Thus, combining both serological and molecular diagnosis is crucial for the timely and accurate detection of endemic rodent-borne diseases in SEA. Finally, a deeper understanding of the infectious agents causing rodent-borne diseases in SEA is essential in curbing the diseases. More research is warranted to identify rodent reservoirs, arthropod vectors, and their roles in maintaining and transmitting these diseases to humans. Experimental studies are deemed necessary to determine the competence of rodent reservoirs and their vectors in spreading diseases in SEA. Therefore, conducting such studies on pathogenic or novel endemic strains may widen our perspective on the particular disease ecology in SEA.

Conflict of interest disclosure statement

The authors declare that they have no known competing interests that could constitute a conflict of interest or to have influenced the work reported in this paper.

ACKNOWLEDGEMENTS

This study was supported in parts by the Ministry of Higher Education, Malaysia under the Higher Institution Centre of Excellence (HICoE) program (Grant nos. MO002-2019 and TIDREC-2023), the Dana Langganan Sukuk Pakej Rangsangan Ekonomi Prihatin Rakyat (SUKUK PRIHATIN) – Fasa 2 (Grant no. MO002-2021), and the French National Research Institute for Sustainable Development (Grant nos. IF028-2022 and IF027-2022).

REFERENCES

Abdullah, N.M., Mohammad, W.M.Z.W., Shafei, M.N., Sukeri, S., Idris, Z., Arifin, W.N., Nozmi, N., Saudi, S.N.S., Samsudin, S., Zainudin, A.W. *et al*. (2019). Leptospirosis and its prevention: Knowledge, attitude and practice of urban community in Selangor, Malaysia. *BMC Public Health* **19**: 628. https://doi.org/10.1186/s12889-019-6981-0

Abdurrahman, M.P.H., Rosyad, H.R., Nursetyo, A.A., Ibrahim, A.H., Sasongko, D., Pratiwi, A.S., Pratiwi, S., Kaamila, D. & Putri, N.A. (2024). Leptospirosis in the ASEAN region. ASEAN Biodiaspora Virtual Centre. https://ritm.gov.ph/wp-content/uploads/2025/01/ABVC-Leptospirosis-in-The-ASEAN-Region_Focus-Report_2024.pdf. Accessed 23 January 2025.

Abela-Ridder, B., Sikkema, R. & Hartskeerl, R.A. (2010). Estimating the burden of human leptospirosis. *International Journal of Antimicrobial Agents* **36**: 5-7. https://doi.org/10.1016/j.ijantimicag.2010.06.012

Acharya, D. & Park, J.H. (2021). Seroepidemiologic survey of Lyme disease among forestry workers in national park offices in South Korea. *International Journal of Environmental Research and Public Health* **18**: 2933. https://doi.org/10.3390/ijerph18062933

Adrus, M., Jazman, N.A.M., Azizi, R.N.A.R., Ahamad, M. & Tajuddin, A.M. (2021). Ectoparasites fauna of rodents and scandents at different habitats of Sarawak, Malaysia. *Serangga* **26**: 26-46.

Ajjimarungsi, A., Bhurayanontachai, R. & Chusri, S. (2020). Clinical characteristics, outcomes, and predictors of leptospirosis in patients admitted to the medical intensive care unit: A retrospective analysis. *Journal of Infection and Public Health* **13**: 2055-2061. https://doi.org/10.1016/j.jiph.2020.10.004

Alkathiry, H., Al-Rofaai, A., Ya'cob, Z., Cutmore, T.S., Mohd-Azami, S.N.I., Husin, N.A., Lim, F.S., Koosakulnirand, S., Mahfodz, N.H., Ishak, S.N. *et al*. (2022). Habitat and season drive chigger mite diversity and abundance on small mammals in Peninsular Malaysia. *Pathogens* **11**: 1087. https://doi.org/10.3390/pathogens11101087

Althaus, T., Thaipadungpanit, J., Greer, R.C., Swe, M.M.M., Dittrich, S., Peerawaranun, P., Smit, P.W., Wangrangsimakul, T., Blacksell, S., Winchell, J.M. *et al*. (2020). Causes of fever in primary care in Southeast Asia and the performance of C-reactive protein in discriminating bacterial from viral pathogens. *International Journal of Infectious Diseases* **96**: 334-342. https://doi.org/10.1016/j.ijid.2020.05.016

Amilasan, A.S.T., Ujiie, M., Suzuki, M., Salva, E., Belo, M.C.P., Koizumi, N., Yoshimatsu, K., Schmidt, W.P., Marte, S., Dimaano, E.M. *et al*. (2012). Outbreak of leptospirosis after flood, the Philippines, 2009. *Emerging Infectious Diseases* **18**: 91-94. https://doi.org/10.3201/eid1801.101892

Angelakis, E., Khamphoukeo, K., Grice, D., Newton, P.N., Roux, V., Aplin, K., Raoult, D. & Rolain, J.M. (2009). Molecular detection of *Bartonella* species in rodents from the Lao PDR. *Clinical Microbiology and Infection* **15**: 95-97. https://doi.org/10.1111/j.1469-0691.2008.02177.x

Anh, L.T.L., Balakirev, A.E. & Van Chau, N. (2021). Investigation of multiple infections with zoonotic pathogens of rodents in Northern Vietnam. *Journal of Vector Borne Diseases* **58**: 47-53. https://doi.org/10.4103/0972-9062.321750

Arichandra, N., Knight, V.F. & Abdullah, S. (2006). An unusual finding of hantavirus exposure in a leptospirosis outbreak in rural Johor. *Malaysian Society of Health* **23**: 19-25.

Ashtiani, Z.T., Ahmadinezhad, M., Amiri, F.B. & Esmaeili, S. (2024). Geographical distribution of *Bartonella* spp in the countries of the WHO Eastern Mediterranean Region (WHO-EMRO). *Journal of Infection and Public Health* **17**: 612-618. https://doi.org/10.1016/j.jiph.2024.02.009

Asyikha, R., Sulaiman, N. & Mohd-Taib, F.S. (2020). Detection of *Bartonella* sp. in ticks and their small mammal hosts in mangrove forests of Peninsular Malaysia. *Tropical Biomedicine* **37**: 919-931. https://doi.org/10.47665/tb.37.4.919

Av iꝹ- upanc, T., Saksida, A. & Korva, M. (2019). Hantavirus infections. *Clinical Microbiology and Infection* **21**: e6-e16. https://doi.org/10.1111/1469-0691.12291

Azhari, N.N., Ramli, S.N.A., Joseph, N., Philip, N., Mustapha, N.F., Ishak, S.N., Mohd-Taib, F.S., Md Nor, S., Yusof, M.A., Mohd Sah, S.A. *et al*. (2018). Molecular characterization of pathogenic *Leptospira* sp. in small mammals captured from the human leptospirosis suspected areas of Selangor state, Malaysia. *Acta Tropica* **188**: 68-77. https://doi.org/10.1016/j.actatropica.2018.08.020

Bai, Y., Kosoy, M.Y., Lerdthusnee, K., Peruski, L.F. & Richardson, J.H. (2009). Prevalence and genetic heterogeneity of *Bartonella* strains cultured from rodents from 17 provinces in Thailand. *The American Journal of Tropical Medicine and Hygiene* **81**: 811-816. https://doi.org/10.4269/ajtmh.2009.09-0294

Bai, Y., Kosoy, M.Y., Diaz, M.H., Winchell, J., Baggett, H., Maloney, S.A., Boonmar, S., Bhengsri, S., Sawatwong, P. & Peruski, L.F. (2012). *Bartonella vinsonii* subsp. *arupensis* in humans, Thailand. *Emerging Infectious Diseases* **18**: 989-991. https://doi.org/10.3201/eid1806.111750

Barbara, K.A., Farzeli, A., Ibrahim, I.N., Antonjaya, U., Yunianto, A., Winoto, I., Ester, Perwitasari, D., Widjaya, S., Richards, A.L. *et al*. (2010). Rickettsial infections of fleas collected from small mammals on four islands in Indonesia. *Journal of Medical Entomology* **47**: 1173-1178. https://doi.org/10.1603/me10064

Barragan, V., Nieto, N., Keim, P. & Pearson, T. (2017a). Meta-analysis to estimate the load of *Leptospira* excreted in urine: beyond rats as important sources of transmission in low-income rural communities. *BMC Research Notes* **10**: 71. https://doi.org/10.1186/s13104-017-2384-4

Barragan, V., Olivas, S., Keim, P. & Pearson, T. (2017b). Critical knowledge gaps in our understanding of environmental cycling and transmission of *Leptospira* spp. *Applied and Environmental Microbiology* **83**: e01190-17. https://doi.org/10.1128/AEM.01190-17

Benacer, D., Mohd Zain, S.N., Amran, F., Galloway, R.L. & Thong, K.L. (2013). Isolation and molecular characterization of *Leptospira interrogans* and *Leptospira borgpetersenii* isolates from the urban rat populations of Kuala Lumpur, Malaysia. *The American Journal of Tropical Medicine and Hygiene* **88**: 704-709. https://doi.org/10.4269/ajtmh.12-0662

Benacer, D., Mohd Zain, S.N., Sim, S.Z., Mohd Khalid, M.K.N., Galloway, R.L., Souris, M. & Thong, K.L. (2016). Determination of *Leptospira borgpetersenii* serovar Javanica and *Leptospira interrogans* serovar Bataviae as the persistent *Leptospira* serovars circulating in the urban rat populations in Peninsular Malaysia. *Parasites & Vectors* **9**: 117. https://doi.org/10.1186/s13071-016-1400-1

Bhengsri, S., Baggett, H.C., Peruski, L.F., Morway, C., Bai, Y., Fisk, T.L., Sitdhirasdr, A., Maloney, S.A., Dowell, S.F. & Kosoy, M. (2011). *Bartonella* seroprevalence in rural Thailand. *The Southeast Asian Journal of Tropical Medicine and Public Health* **42**: 687-692.

Bi, Z., Formenty, P.B.H. & Roth, C.E. (2008). Hantavirus Infection: a review and global update. *The Journal of Infection in Developing Countries* **2**: 3-23. https://doi.org/10.3855/jidc.317

Blacksell, S.D., Luksameetanasan, R., Kalambaheti, T., Aukkanit, N., Paris, D.H., McGready, R., Nosten, F., Peacock, S.J. & Day, N.P.J. (2008). Genetic typing of the *56-kDa* type-specific antigen gene of contemporary *Orientia tsutsugamushi* isolates causing human scrub typhus at two sites in north-eastern and western Thailand. *FEMS Immunology & Medical Microbiology* **52**: 335-342. https://doi.org/10.1111/j.1574-695X.2007.00375.x

Blasdell, K., Herbreteau, V., Henttonen, H., Phonekeo, D., Hugot, J.P. & Buchy, P. (2009). Rodent-borne zoonotic viruses in Southeast Asia. *Kasetsart Journal - Natural Science* **43**: 94-105.

Blasdell, K., Cosson, J.F., Chaval, Y., Herbreteau, V., Douangboupha, B., Jittapalapong, S., Lundqvist, A., Hugot, J.P., Morand, S. & Buchy, P. (2011a). Rodent-borne hantaviruses in Cambodia, Lao PDR, and Thailand. *EcoHealth* **8**: 432-443. https://doi.org/10.1007/s10393-011-0725-7

Blasdell, K.R., Morand, S., Chaval, Y., Herbreteau, V., Douangboupha, B., Jittapalapong, S., Cosson, J.F. & Buchy, P. (2011b). Hantaviruses and the dilution effect in Southeast Asia. *BMC Proceedings* **5**: 53. https://doi.org/10.1186/1753-6561-5-S1-P53

Blasdell, K.R., Morand, S., Perera, D. & Firth, C. (2019a). Association of rodent-borne *Leptospira* spp. with urban environments in Malaysian Borneo. *PLOS Neglected Tropical Diseases* **13**: e0007141. https://doi.org/10.1371/journal.pntd.0007141

Blasdell, K.R., Perera, D. & Firth, C. (2019b). High prevalence of rodent-borne *Bartonella* spp. in urbanizing environments in Sarawak, Malaysian Borneo. *The American Journal of Tropical Medicine and Hygiene* **100**: 506-509. https://doi.org/10.4269/ajtmh.18-0616

Boey, K., Shiokawa, K. & Rajeev, S. (2019). *Leptospira* infection in rats: A literature review of global prevalence and distribution. *PLoS Neglected Tropical Disease* **13**: e0007499. https://doi.org/10.1371/journal.pntd.0007499

Bɣge, I., Pfeffer, M., Htwe, N.M., Maw, P.P., Sarathchandra, S.R., Sluydts, V., Piscitelli, A.P., Jacob, J. & Obiegala, A. (2021). First detection of *Bartonella* spp. in small mammals from rice storage and processing facilities in Myanmar and Sri Lanka. *Microorganisms* **9**: 658. https://doi.org/10.3390/microorganisms9030658

Boodman, C., Gupta, N., van Griensven, J. & Van Bortel, W. (2024). *Bartonella quintana* detection among arthropods and their hosts: a systematic review and meta-analysis. *Parasites & Vectors* **17**: 328. https://doi.org/10.1186/s13071-024-06413-3

Bordes, F., Herbreteau, V., Dupuy, S., Chaval, Y., Tran, A. & Morand, S. (2013). The diversity of microparasites of rodents: a comparative analysis that helps in identifying rodent-borne rich habitats in Southeast Asia. *Infection Ecology & Epidemiology* **3**: 20178. https://doi.org/10.3402/iee.v3i0.20178

Bradley, E.A. & Lockaby, G. (2023). Leptospirosis and the environment: A review and future directions. *Pathogens* **12**: 1167. https://doi.org/10.3390/pathogens12091167

Breitschwerdt, E.B. (2017). Bartonellosis, One Health and all creatures great and small. *Veterinary Dermatology* **28**: 96-e21. https://doi.org/10.1111/vde.12413

Bressan, C.D.S., Teixeira, M.L.B., Gouvךa, M.I.F.D.S., de Pina-Costa, A., Santos, H. F. P., Calvet, G.A., Lupi, O., Siqueira, A.M., Valls-de-Souza, R., Valim, C. *et al*. (2023). Challenges of acute febrile illness diagnosis in a national infectious diseases center in Rio de Janeiro: 16-year experience of syndromic surveillance. *PLoS Neglected Tropical Diseases* **17**: e0011232. https://doi.org/10.1371/journal.pntd.0011232

Brown, P.D., McKenzie, M., Pinnock, M. & Mcgrowder, D. (2011). Environmental risk factors associated with leptospirosis among butchers and their associates in Jamaica. *The International Journal of Occupational and Environmental Medicine* **2**: 47-57.

Buffet, J.P., Kosoy, M. & Vayssier-Taussat, M. (2013). Natural history of *Bartonella*-infecting rodents in light of new knowledge on genomics, diversity and evolution. *Future Microbiology* **8**: 1117-1128. https://doi.org/10.2217/fmb.13.77

Camer, A., Masangkay, J., Satoh, H., Okabayashi, T., Norizuki, S., Motoi, Y., Ueno, H. & Morita, C. (2000). Prevalence of spotted fever rickettsial antibodies in dogs and rodents in the Philippines. *Japanese Journal of Infectious Diseases* **53**: 162-163.

Cardoso, J., Gaspar, A. & Esteves, C. (2022). Severe leptospirosis: A case report. *Cureus* **14**: e30712. https://doi.org/10.7759/cureus.30712

Castle, K.T., Kosoy, M., Lerdthusnee, K., Phelan, L., Bai, Y., Gage, K.L., Leepitakrat, W., Monkanna, T., Khlaimanee, N., Chandranoi, K. *et al*. (2004). Prevalence and diversity of *Bartonella* in rodents of Northern Thailand: A comparison with *Bartonella* in rodents from Southern China. *The American Society of Tropical Medicine and Hygiene* **70**: 429-433. https://doi.org/10.4269/ajtmh.2004.70.429

Chacko, C.S., Lakshmi, S.S., Jayakumar, A., Binu, S.L., Pant, R.D., Giri, A., Chand, S. & Nandakumar, U.P. (2021). A short review on leptospirosis: Clinical manifestations, diagnosis, and treatment. *Clinical Epidemiology and Global Health* **11**: 100741. https://doi.org/10.1016/j.cegh.2021.100741

Chadsuthi, S., Bicout, D.J., Wiratsudakul, A., Suwancharoen, D., Petkanchanapong, W., Modchang, C., Triampo, W., Ratanakorn, P. & Chalvet-Monfray, K. (2017). Investigation on predominant *Leptospira* serovars and its distribution in humans and livestock in Thailand, 2010-2015. *PLoS Neglected Tropical Diseases* **11**: e0005228. https://doi.org/10.1371/journal.pntd.0005228

Chaisiri, K., Cosson, J.F. & Morand, S. (2017). Infection of rodents by *Orientia tsutsugamushi*, the agent of scrub typhus in relation to land use in Thailand. *Tropical Medicine and Infectious Disease* **2**: 53. https://doi.org/10.3390/tropicalmed2040053

Chaisiri, K., Gill, A.C., Stekolnikov, A.A., Hinjoy, S., McGarry, J.W., Darby, A.C., Morand, S. & Makepeace, B.L. (2019). Ecological and microbiological diversity of chigger mites, including vectors of scrub typhus, on small mammals across stratified habitats in Thailand. *Animal Microbiome* **1**: 18. https://doi.org/10.1186/s42523-019-0019-x

Chaisiri, K., Tanganuchitcharnchai, A., Kritiyakan, A., Thinphovong, C., Tanita, M., Morand, S. & Blacksell, S.D. (2022). Risk factors analysis for neglected human rickettsioses in rural communities in Nan Province, Thailand: A community-based observational study along a landscape gradient. *PLoS Neglected Tropical Diseases* **16**: e0010256. https://doi.org/10.1371/journal.pntd.0010256

Chan, K.P., Chan, Y.C. & Doraisingham, S. (1996). A severe case of hemorrhagic fever with renal syndrome in Singapore. *The Southeast Asian Journal of Tropical Medicine and Public Health* **27**: 408-410.

Chankate, P., Kalambaheti, T., Kosoltanapiwat, N., Tanganuchitcharnchai, A., Blacksell, S.D., Chantratita, N. & Leaungwutiwong, P. (2022). A use of *56-kDa* recombinant protein of *Orientia tsutsugamushi* Karp serotype in serodiagnosis of scrub typhus by enzyme-linked immunosorbent assay in Thais. *Tropical Medicine and Infectious Disease* **8**: 10. https://doi.org/10.3390/tropicalmed8010010

Chareonviriyaphap, T., Leepitakrat, W., Lerdthusnee, K., Chao, C.C. & Ching, W.M. (2014). Dual exposure of *Rickettsia typhi* and *Orientia tsutsugamushi* in the field-collected *Rattus* rodents from Thailand. *Journal of Vector Ecology* **39**: 182-189. https://doi.org/10.1111/j.1948-7134.2014.12085.x

Cheslock, M.A. & Embers, M.E. (2019). Human bartonellosis: An underappreciated public health problem? *Tropical Medicine and Infectious Disease* **4**: 69. https://doi.org/10.3390/tropicalmed4020069

Corral, J., Manr□quez Robles, A., Toussaint Caire, S., Hern□ndez-Castro, R. & Moreno-Couti□o, G. (2019). First report of bacillary angiomatosis by *Bartonella elizabethae* in an HIV-positive patient. *The American Journal of Dermapathology* **41**: 750-753. https://doi.org/10.1097/DAD.0000000000001439

Cosson, J.F., Picardeau, M., Mielcarek, M., Tatard, C., Chaval, Y., Suputtamongkol, Y., Buchy, P., Jittapalapong, S., Herbreteau, V. & Morand, S. (2014). Epidemiology of *Leptospira* transmitted by rodents in Southeast Asia. *PLoS Neglected Tropical Diseases* **8**: e2902. https://doi.org/10.1371/journal.pntd.0002902

Costa, F., Hagan, J.E., Calcagno, J., Kane, M., Torgerson, P., Martinez-Silveira, M.S., Stein, C., Abela- Ridder, B. & Ko, A.I. (2015). Global morbidity and mortality of leptospirosis: A systematic review. *PLoS Neglected Tropical Diseases* **9**: e0003898. https://doi.org/10.1371/journal.pntd.0003898

Cuong, N.V., Carrique-Mas, J., Vo Be, H., An, N.N., Tue, N.T., Anh, N.L., Anh, P.H., Phuc, N.T., Baker, S., Voutilainen, L. *et al*. (2015). Rodents and risk in the Mekong Delta of Vietnam: Seroprevalence of selected zoonotic viruses in rodents and humans. *Vector-Borne and Zoonotic Diseases* **15**: 65-72. https://doi.org/10.1089/vbz.2014.1603

Dahmani, M., Diatta, G., Labas, N., Diop, A., Bassene, H., Raoult, D., Granjon, L., Fenollar, F. & Mediannikov, O. (2018). Noncontiguous finished genome sequence and description of *Bartonella mastomydis* sp. nov. *New Microbes and New Infections* **25**: 60-70. https://doi.org/10.1016/j.nmni.2018.03.005

Daly, J.S., Worthington, M.G., Brenner, D.J., Moss, C.W., Hollis, D.G., Weyant, R.S., Steigerwalt, A.G., Weaver, R.E., Daneshvar, M.I. & O'Connor, S.P. (1993). *Rochalimaea elizabethae* sp. nov. isolated from a patient with endocarditis. *Journal of Clinical Microbiology* **31**: 872-881. https://doi.org/10.1128/jcm.31.4.872-881.1993

De Oliveira, R.C., Guterres, A., Fernandes, J., D'Andrea, P.S., Bonvicino, C.R. & De Lemos, E.R.S. (2014). Hantavirus reservoirs: Current status with an emphasis on data from Brazil. *Viruses* **6**: 1929-1973. https://doi.org/10.3390/v6051929

Dehio, C. (2004). Molecular and cellular basis of *Bartonella* pathogenesis. *Annual Review of Microbiology* **58**: 365-390. https://doi.org/10.1146/annurev.micro.58.030603.123700

Divari, S., Pregel, P., Zanet, S., Ferroglio, E., Giannini, F., Scaglione, F.E., Grinberg, A., Biolatti, B. & Bollo, E. (2020). Molecular evidence of *Bartonella* spp. in rodents: A study in Pianosa Island, Italy. *Animals* **10**: 2070. https://doi.org/10.3390/ani10112070

Douchet, L., Goarant, C., Mangeas, M., Menkes, C., Hinjoy, S. & Herbreteau, V. (2022). Unraveling the invisible leptospirosis in mainland Southeast Asia and its fate under climate change. *Science of The Total Environment* **832**: 155018. https://doi.org/10.1016/j.scitotenv.2022.155018

Duong, V., Blassdell, K., May, T.T., Sreyrath, L., Gavotte, L., Morand, S., Frutos, R. & Buchy, P. (2013a). Diversity of *Orientia tsutsugamushi* clinical isolates in Cambodia reveals active selection and recombination process. *Infection, Genetics and Evolution* **15**: 25-34. https://doi.org/10.1016/j.meegid.2010.08.015

Duong, V., Mai, T.T., Blasdell, K., Lo, L.V., Morvan, C., Lay, S., Anukool, W., Wongprompitak, P., Suputtamongkol, Y., Laurent, D. *et al*. (2013b). Molecular epidemiology of *Orientia tsutsugamushi* in Cambodia and Central Vietnam reveals a broad region-wide genetic diversity. *Infection, Genetics and Evolution* **15**: 35-42. https://doi.org/10.1016/j.meegid.2011.01.004

Eisen, L. (2020). Vector competence studies with hard ticks and *Borrelia burgdorferi sensu lato* spirochetes: A review. *Ticks and Tick-Borne Diseases* **11**: 101359. https://doi.org/10.1016/j.ttbdis.2019.101359

Eisen, R.J., Kugeler, K.J., Eisen, L., Beard, C.B. & Paddock, C.D. (2017). Tick-borne zoonoses in the United States: Persistent and emerging threats to human health. *ILAR Journal* **58**: 319-335. https://doi.org/10.1093/ilar/ilx005

Elisberg, B.L., Campbell, J.M. & Bozeman, F.M. (1968). Antigenic diversity of *Rickettsia tsutsugamushi*: epidemiologic and ecologic significance. *Journal of Hygiene, Epidemiology, Microbiology, and Immunology* **12**: 18-25.

Elliott, I., Pearson, I., Dahal, P., Thomas, N.V., Roberts, T. & Newton, P.N. (2019). Scrub typhus ecology: a systematic review of *Orientia* in vectors and hosts. *Parasites & Vectors* **12**: 513. https://doi.org/10.1186/s13071-019-3751-x

Elliott, I., Thangnimitchok, N., Chaisiri, K., Wangrangsimakul, T., Jaiboon, P., Day, N.P.J., Paris, D.H., Newton, P.N. & Morand, S. (2021a). *Orientia tsutsugamushi* dynamics in vectors and hosts: ecology and risk factors for foci of scrub typhus transmission in Northern Thailand. *Parasites & Vectors* **14**: 540. https://doi.org/10.1186/s13071-021-05042-4

Elliott, I., Thangnimitchok, N., de Cesare, M., Linsuwanon, P., Paris, D.H., Day, N.P.J., Newton, P.N., Bowden, R. & Batty, E.M. (2021b). Targeted capture and sequencing of *Orientia tsutsugamushi* genomes from chiggers and humans. *Infection, Genetics and Evolution* **91**: 104818. https://doi.org/10.1016/j.meegid.2021.104818

Elliott, I., Kumlert, R., Thangnimitchok, N., Blacksell, S.D., Tanganuchitcharnchai, A., Paris, D.H., Newton, P.N. & Morand, S. (2022). *Orientia tsutsugamushi* in chiggers and small mammals in Laos. *Vector Borne and Zoonotic Diseases* **22**: 505-511. https://doi.org/10.1089/vbz.2022.0029

Ehlers, J., Krüger, A., Rakotondranary, S.J., Ratovonamana, R.Y., Poppert, S., Ganzhorn, J.U. & Tappe, D. (2020). Molecular detection of *Rickettsia* spp., *Borrelia* spp., *Bartonella* spp. and *Yersinia pestis* in ectoparasites of endemic and domestic animals in Southwest Madagascar. *Acta Tropica* **205**: 105339. https://doi.org/10.1016/j.actatropica.2020.105339

Engbaek, K. & Lawson, P.A. (2004). Identification of *Bartonella* species in rodents, shrews and cats in Denmark: detection of two *B. henselae* variants, one in cats and the other in the long-tailed field mouse. *Journal of Pathology, Microbiology and Immunology* **112**: 336-341. https://doi.org/10.1111/j.1600-0463.2004.apm1120603.x

Engel, K. & Ziegler, S. (2020). A report on the human zoonotic disease risk in Southeast Asia with a focus on wildlife markets. WWF Deutschland. https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF-Report-Human-Zoonotic-Disease-Risk-in-Southeast-Asia-with-a-Focus-on-Wildlife-Markets.pdf. Accessed 23 July 2024.

Ernieenor, F.C.L., NorJaiza, M.J., Fadillah, A., Canedy, J. & Mariana, A. (2021). Screening and genotyping of *Orientia tsutsugamushi* from field-collected on-host chiggers (Acari: Prostigmata) recovered from a positive scrub typhus locality in Kelantan, Malaysia. *Experimental and Applied Acarology* **84**: 171-182. https://doi.org/10.1007/s10493-021-00609-3

Fann, R.J., Rani, V.R., Chong, H.E., Vaithlingam, I. & Chan, C.W.S. (2020). Clinical presentations and predictors of mortality for leptospirosis – A study from suburban area in Malaysia. *The Medical Journal of Malaysia* **75**: 52-56.

Fenollar, F., Sire, S., Wilhelm, N. & Raoult, D. (2005). *Bartonella vinsonii* subsp. *arupensis* as an agent of blood culture-negative endocarditis in a human. *Journal of Clinical Microbiology* **43**: 945-947. https://doi.org/10.1128/jcm.43.9.4923.2005

Frank, H.K., Boyd, S.D. & Hadly, E.A. (2018). Global fingerprint of humans on the distribution of *Bartonella* bacteria in mammals. *PLoS Neglected Tropical Diseases* **12**: e0006865. https://doi.org/10.1371/journal.pntd.0006865

Gasem, M.H., Hadi, U., Alisjahbana, B., Tjitra, E., Hapsari, M.M.D.E.A.H., Lestari, E.S., Aman, A.T., Lokida, D., Salim, G., Kosasih, H. *et al*. (2020). Leptospirosis in Indonesia: diagnostic challenges associated with atypical clinical manifestations and limited laboratory capacity. *BMC Infectious Diseases* **20**: 179. https://doi.org/10.1186/s12879-020-4903-5

Gaywee, J., Sunyakumthorn, P., Rodkvamtook, W., Ruang-areerate, T., Mason, C.J. & Sirisopana, N. (2007). Human infection with *Rickettsia* sp. related to *R. Japonica*, Thailand. *Emerging Infectious Diseases* **13**: 657-659. https://doi.org/10.3201/eid1304.060585

Goh, C.L., Kamarudin, A. & Khatija, M. (1996). Lyme disease is not prevalent in patients presenting with annular erythema in Singapore. *Singapore Medical Journal* **37**: 250-251.

Gomes, C., Pons, M.J., del Valle Mendoza, J. & Ruiz, J. (2016). Carrion's disease: An eradicable illness? *Infectious Diseases of Poverty* **5**: 105. https://doi.org/10.1186/s40249-016-0197-7

Gonwong, S., Chuenchitra, T., Khantapura, P., Islam, D., Ruamsap, N., Swierczewski, B.E. & Mason, C.J. (2017). Nationwide seroprevalence of leptospirosis among young Thai men, 2007-2008. *American Journal of Tropical Medicine and Hygiene* **97**: 1682-1685. https://doi.org/10.4269/ajtmh.17-0163

Griffiths, J., Yeo, H.L., Yap, G., Mailepessov, D., Johansson, P., Low, H.T., Siew, C.C., Lam, P. & Ng, L.C. (2022). Survey of rodent-borne pathogens in Singapore reveals the circulation of *Leptospira* spp., Seoul hantavirus, and *Rickettsia typhi*. *Scientific Reports* **12**: 2692. https://doi.org/10.1038/s41598-021-03954-w

Guterres, A. & de Lemos, E.R.S. (2018). Hantaviruses and a neglected environmental determinant. *One Health* **5**: 27-33. https://doi.org/10.1016/j.onehlt.2017.12.002

Gutiérrez, R., Krasnov, B., Morick, D., Gottlieb, Y., Khokhlova, I.S. & Harrus, S. (2015). *Bartonella* infection in rodents and their flea ectoparasites: An overview. *Vector-Borne and Zoonotic Diseases* **15**: 27-39. https://doi.org/10.1089/vbz.2014.1606

Gutiérrez, R., Shalit, T., Markus, B., Yuan, C., Nachum-Biala, Y., Elad, D. & Harrus, S. (2020). *Bartonella kosoyi* sp. nov. and *Bartonella krasnovii* sp. nov., two novel species closely related to the zoonotic *Bartonella elizabethae*, isolated from black rats and wild desert rodent-fleas. *International Journal of Systematic and Evolutionary Microbiology* **70**: 1656-1665. https://doi.org/10.1099/ijsem.0.003952

Haake, D.A. & Levett, P.N. (2015). Leptospirosis in humans. In: Leptospira and Leptospirosis, Adler, B. (editor) 1st edition. Berlin, Heidelberg: Springer, pp. 65-97.

Hamidon, B.B. & Saadiah, S. (2003). Seoul hantavirus infection mimicking dengue fever. *The Medical Journal of Malaysia* **58**: 786-787.

Han, B.A., Schmidt, J.P., Bowden, S.E. & Drake, J.M. (2015). Rodent reservoirs of future zoonotic diseases. *Proceedings of the National Academy of Sciences of the United States of America* **112**: 7039-7044. https://doi.org/10.1073/pnas.1501598112

Hanifah, A.L. (2013). Detection of *Orientia tsutsugamushi* in chiggers and tissues of small mammals using polymerase chain reactions. *The Experiment* **11**: 683-689.

Harrus, S., Bar-Gal, G.K., Golan, A., Elazari-Volcani, R., Kosoy, M.Y., Morick, D., Avidor, B. & Baneth, G. (2009). Isolation and genetic characterization of a *Bartonella* strain closely related to *Bartonella tribocorum* and *Bartonella elizabethae* in Israeli commensal rats. *The American Journal of Tropical Medicine and Hygiene* **81**: 55-58. https://doi.org/10.4269/ajtmh.2009.81.55

Nesaraj, J., Grinberg, A., Gedye, K., Potter, M. & Harrus, S. (2018). Molecular detection of *Bartonella coopersplainsensis* and *B. henselae* in rats from New Zealand. *New Zealand Veterinary Journal* **66**: 257-260. https://doi.org/10.1080/00480169.2018.1483781

Hem, S., Ly, S., Votsi, I., Vogt, F., Asgari, N., Buchy, P., Heng, S., Picardeau, M., Sok, T., Ly, S. *et al*. (2016). Estimating the burden of leptospirosis among febrile subjects aged below 20 years in Kampong Cham communities, Cambodia, 2007-2009. *PLoS ONE* **11**: e0151555. https://doi.org/10.1371/journal.pone.0151555

Hin, H.S., Ramalingam, R., Chunn, K.Y., Ahmad, N., Ab Rahman, J. & Mohamed, M.S. (2012). Case report: Fatal co-infection-melioidosis and leptospirosis. *The American Journal of Tropical Medicine and Hygiene* **87**: 737-740. https://doi.org/10.4269/ajtmh.2012.12-0165

Hinjoy, S. (2014). Epidemiology of leptospirosis from Thai National Disease Surveillance System, 2003-2012. *Outbreak, Surveillance, Investigation & Response (OSIR) Journal* **7**: 1-5. https://doi.org/10.59096/osir.v7i2.263289

Hirunkanokpun, S., Ahantarig, A., Baimai, V., Pramual, P., Rakthong, P. & Trinachartvanit, W. (2022). Spotted fever group *Rickettsia, Anaplasma*, and *Coxiella*-like endosymbiont in *Haemaphysalis* ticks from mammals in Thailand. *Veterinary Research Communications* **46**: 1209-1219. https://doi.org/10.1007/s11259-022-09980-x

Hjelle, B. & Torres-Pérez, F. (2010). Hantaviruses in the Americas and their role as emerging pathogens. *Viruses* **2**: 2559-2586. https://doi.org/10.3390/v2122559

Ho, C.W.W., Tan, N.W.H., Thoon, K.C. & Chong, C.Y. (2019). A review of four cases of leptospirosis presenting for acute care to a tertiary paediatric hospital in Singapore. *Annals Academy of Medicine Singapore* **48**: 104-108.

Ho, J., Changbunjong, T., Weluwanarak, T., Hussain, S. & Sparagano, O. (2021). The pests of a pest: A systematic review of ectoparasitic fauna among synanthropic rodents in the 21st century with meta-analysis. *Acta Tropica* **215**: 105802. https://doi.org/10.1016/j.actatropica.2020.105802

Hong, J., Li, Y., Hua, X., Bai, Y., Wang, C., Zhu, C., Du, Y., Yang, Z. & Yuan, C. (2016). Lymphatic circulation disseminates *Bartonella* infection into bloodstream. *The Journal of Infectious Diseases* **215**: 303-311. https://doi.org/10.1093/infdis/jiw526

Hugot, J.P., Plyusnina, A., Herbreteau, V., Nemirov, K., Laakkonen, J., Lundkvist, Å, Supputamongkol, Y., Henttonen, H. & Plyusnin, A. (2006). Genetic analysis of Thailand hantavirus in *Bandicota indica* trapped in Thailand. *Virology Journal* **3**: 72. https://doi.org/10.1186/1743-422X-3-72

Ibrahim, I.N., Sudomo, M., Morita, C., Uemura, S., Muramatsu, Y., Ueno, H. & Kitamura, T. (1996). Seroepidemiological survey of wild rats for Seoul virus in Indonesia. *Japanese Journal of Medical Science and Biology* **49**: 69-74. https://doi.org/10.7883/yoken1952.49.69

Ibrahim, I.N., Okabayashi, T., Ristiyanto, Lestari, E.W., Yanase, T., Muramatsu, Y., Ueno, H. & Morita, C. (1999). Serosurvey of wild rodents for rickettsioses (spotted fever, murine typhus and Q fever) in Java Island, Indonesia. *European Journal of Epidemiology* **15**: 89-93. https://doi.org/10.1023/a:1007547721171

Ikbal, N.H.M., Bhassu, S., Simarani, K., Uni, S., Chan, C.C. & Omar, H. (2019). Prevalence and genetic divergence of *Leptospira interrogans* and *Leptospira borgpetersenii* in house rats (*Rattus rattus*) from Peninsular Malaysia. *Asian Pacific Journal of Tropical Medicine* **12**: 463-471. https://doi.org/10.4103/1995-7645.269906

Im, J.H., Baek, J.H., Durey, A., Kwon, H.Y., Chung, M.H. & Lee, J.S. (2019). Current status of tick-borne diseases in South Korea. *Vector-Borne and Zoonotic Diseases* **19**: 225-233. https://doi.org/10.1089/vbz.2018.2298

Indrawattana, N., Aiumurai, P., Sae-Lim, N., Seesuay, W., Reamtong, O., Chongsa-Nguan, M., Chaicumpa, W. & Sookrung, N. (2022). *GroEL* chaperonin-based assay for early diagnosis of scrub typhus. *Diagnostics* **12**: 136. https://doi.org/10.3390/diagnostics12010136

Inoue, K., Maruyama, S., Kabeya, H., Yamada, N., Ohashi, N., Sato, Y., Yukawa, M., Masuzawa, T., Kawamori, F., Kadosaka, T. *et al*. (2008). Prevalence and genetic diversity of *Bartonella* species isolated from wild rodents in Japan. *Applied and Environmental Microbiology* **74**: 5086-5092. https://doi.org/10.1128/AEM.00071-08

Inthawong, M., Pinthong, N., Thaiprakhong, A., Wangrangsimakul, T., Sunyakumthorn, P., Hill, J., Sonthayanon, P., Paris, D.H., Dunachie, S.J. & Kronsteiner, B. (2023). A whole blood intracellular cytokine assay optimised for field site studies demonstrates polyfunctionality of CD4+ T cells in acute scrub typhus. *PLoS Neglected Tropical Diseases* **17**: e0010905. https://doi.org/10.1371/journal.pntd.0010905

Ishak, S.N., Yusof, M.A., Md-Nor, S., Mohd Sah, S.A., Lim, F.S., Khoo, J.J. & Mohd-Taib, F.S. (2018). Prevalence of on-host ticks (Acari: Ixodidae) in small mammals collected from forest near to human vicinity in Selangor, Malaysia. *Systematic and Applied Acarology* **23**: 1531-1544. https://doi.org/10.11158/saa.23.8.4

Jaenson, T.G.T. & Talleklint, L. (1992). Incompetence of roe deer as reservoirs of the lyme borreliosis spirochete. *Journal of Medical Entomology* **29**: 813-817. https://doi.org/10.1093/jmedent/29.5.813

Jeffree, M.S., Mori, D., Yusof, N.A., Atil, A.B., Lukman, K.A., Othman, R., Hassan, M.R., Suut, L. & Ahmed, K. (2020). High incidence of asymptomatic leptospirosis among urban sanitation workers from Kota Kinabalu, Sabah, Malaysian Borneo. *Scientific Reports* **10**: 19442. https://doi.org/10.1038/s41598-020-76595-0

Jiang, H., Du, H., Wang, L.M., Wang, P.Z. & Bai, X.F. (2016). Hemorrhagic fever with renal syndrome: Pathogenesis and clinical picture. *Frontiers in Cellular and Infection Microbiology* **6**: 1. https://doi.org/10.3389/fcimb.2016.00001

Jiang, J., Sangkasuwan, V., Lerdthusnee, K., Sukwit, S., Chuenchitra, T., Rozmajzl, P.J., Eamsila, C., Jones, J.W. & Richards, A.L. (2005). Human infection with *Rickettsia honei*, Thailand. *Emerging Infectious Diseases* **11**: 1473-1475. https://doi.org/10.3201/eid1109.050011

Jiyipong, T., Jittapalapong, S., Morand, S., Raoult, D. & Rolain, J.M. (2012). Prevalence and genetic diversity of *Bartonella* spp. in small mammals from Southeastern Asia. *Applied and Environmental Microbiology* **78**: 8463-8466. https://doi.org/10.1128/AEM.02008-12

Johansson, P., Yap, G., Low, H.T., Siew, C.C., Kek, R., Ng, L.C. & Bucht, G. (2010). Molecular characterization of two hantavirus strains from different *Rattus* species in Singapore. *Virology Journal* **7**: 15. https://doi.org/10.1186/1743-422X-7-15

Jonsson, C.B., Figueiredo, L.T.M. & Vapalahti, O. (2010). A global perspective on hantavirus ecology, epidemiology, and disease. *Clinical Microbiology Reviews* **23**: 412-441. https://doi.org/10.1128/CMR.00062-09

Kabeya, H., Colborn, J.M., Bai, Y., Lerdthusnee, K., Richardson, J.H., Maruyama, S. & Kosoy, M.Y. (2010). Detection of *Bartonella tamiae* DNA in ectoparasites from rodents in Thailand and their sequence similarity with bacterial cultures from Thai patients. *Vector-Borne and Zoonotic Diseases* **10**: 429-434. https://doi.org/10.1089/vbz.2009.0124

Kandelaki, G., Malania, L., Bai, Y., Chakvetadze, N., Katsitadze, G., Imnadze, P., Nelson, C.A., Harrus, S. & Kosoy, M.Y. (2016). Human lymphadenopathy caused by rat-borne *Bartonella*, Tbilisi, Georgia. *Emerging Infectious Diseases* **22**: 544-546. https://doi.org/10.3201/eid2203.151823

Karpagam, K.B. & Ganesh, B. (2020). Leptospirosis: a neglected tropical zoonotic infection of public health importance – an updated review. *European Journal of Clinical Microbiology & Infectious Diseases* **39**: 835-846. https://doi.org/10.1007/s10096-019-03797-4

Kasper, M.R., Blair, P.J., Touch, S., Sokhal, B., Yasuda, C.Y., Williams, M., Richards, A.L., Burgess, T.H., Wierzba, T.F. & Putnam, S.D. (2012). Infectious etiologies of acute febrile illness among patients seeking health care in South-Central Cambodia. *American Journal of Tropical Medicine and Hygiene* **86**: 246-253. https://doi.org/10.4269/ajtmh.2012.11-0409

Kawaguchi, L., Sengkeopraseuth, B., Tsuyuoka, R., Koizumi, N., Akashi, H., Vongphrachanh, P., Watanabe, H. & Aoyama, A. (2008). Seroprevalence of leptospirosis and risk factor analysis in flood-prone rural areas in Lao PDR. *The American Journal of Tropical Medicine and Hygiene* **78**: 957-961. https://doi.org/10.4269/ajtmh.2008.78.957

Kerkhoff, F.T., Bergmans, A.M.C., van der Zee, A. & Rothova, A. (1999). Demonstration of *Bartonella grahamii* DNA in ocular fluids of a patient with neuroretinitis. *Journal of Clinical Microbiology* **37**: 4034-4038. https://doi.org/10.1128/jcm.37.12.4034-4038.1999

Kho, K.L., Koh, F.X., Singh, H.K.L., Mohamed Zan, H.A., Kukreja, A., Ponnampalavanar, S. & Tay, S.T. (2016). Spotted fever group rickettsioses and murine typhus in a Malaysian teaching hospital. *The American Journal of Tropical Medicine and Hygiene* **95**: 765-768. https://doi.org/10.4269/ajtmh.16-0199

Kho, K.L., Tan, P.E. & Tay, S.T. (2019). Diversity of rickettsiae in feeding and questing ticks collected from a Malaysian forest reserve area. *Journal of Medical Entomology* **56**: 547-552. https://doi.org/10.1093/jme/tjy168

Khoo, J.J., Ishak, S.N., Lim, F.S., Mohd-Taib, F.S., Khor, C.S., Loong, S.K. & AbuBakar, S. (2018). Detection of a *Borrelia* sp. from *Ixodes granulatus* ticks collected from rodents in Malaysia. *Journal of Medical Entomology* **55**: 1642-1647. https://doi.org/10.1093/jme/tjy122

Khoo, J.J., Husin, N.A., Lim, F.S., Oslan, S.N.H., Mohd Azami, S.N.I., To, S.W., Abd Majid, M.A., Lee, H.Y., Loong, S.K., Khor, C.S. *et al*. (2021). Molecular detection of pathogens from ectoparasites recovered from peri-domestic animals, and the first description of a *Candidatus Midichloria* sp. from *Haemaphysalis wellingtoni* from rural communities in Malaysia. *Parasitology International* **80**: 102202. https://doi.org/10.1016/j.parint.2020.102202

Khor, C.S., Hassan, H., Mohd-Rahim, N.F., Chandren, J.R., Nore, S.S., Johari, J., Loong, S.K., Abd-Jamil, J., Khoo, J.J., Lee, H.Y. *et al*. (2019). Seroprevalence of *Borrelia burgdorferi* among the Indigenous people (Orang Asli) of Peninsular Malaysia. *The Journal of Infection in Developing Countries* **13**: 449-454. https://doi.org/10.3855/jidc.11001

Kikuchi, F., Senoo, K., Arai, S., Tsuchiya, K., Sყn, N.T., Motokawa, M., Ranorosoa, M.C., Bawm, S., Lin, K.S., Suzuki, H. *et al*. (2021). Rodent-borne orthohantaviruses in Vietnam, Madagascar and Japan. *Viruses* **13**: 1343. https://doi.org/10.3390/v13071343

Kim, C.M., Yun, N.R. & Kim, D.M. (2021). Case report: The first *Borrelia yangtzensis* infection in a human in Korea. *The American Journal of Tropical Medicine and Hygiene* **106**: 45-46. https://doi.org/10.4269/ajtmh.21-0052

Kim, K.S., Inuoe, K., Kabeya, H., Sato, S., Takada, T., Decha, P., Chiu, S.H., Fujita, H., Kawabata, H., Takada, N. *et al*. (2016). Prevalence and diversity of *Bartonella* species in wild small mammals in Asia. *Journal of Wildlife Diseases* **52**: 10-21. https://doi.org/10.7589/2015-01-015

Klangthong, K., Promsthaporn, S., Leepitakrat, S., Schuster, A.L., McCardle, P.W., Kosoy, M. & Takhampunya, R. (2015). The distribution and diversity of *Bartonella* species in rodents and their ectoparasites across Thailand. *PLoS ONE* **10**: e0140856. https://doi.org/10.1371/journal.pone.0140856

Knust, B., Macneil, A. & Rollin, P.E. (2012). Hantavirus pulmonary syndrome clinical findings: evaluating a surveillance case definition. *Vector Borne and Zoonotic Diseases* **12**: 393-399. https://doi.org/10.1089/vbz.2011.0764

Koizumi, N., Miura, K., Sanai, Y., Takemura, T., Ung, T.T.H., Le, T.T., Hirayama, K., Hasebe, F., Nguyen, H.L.K., Hoang, P.V.M. *et al*. (2019). Molecular epidemiology of *Leptospira interrogans* in *Rattus norvegicus* in Hanoi, Vietnam. *Acta Tropica* **194**: 204-208. https://doi.org/10.1016/j.actatropica.2019.02.008

Kollars, T.M., Tippayachai, B. & Bodhidatta, D. (2001). Short report: Thai tick typhus, *Rickettsia honei*, and a unique *Rickettsia* detected in *Ixodes granulatus* (Ixodidae: Acari) from Thailand. *The American Journal of Tropical Medicine and Hygiene* **65**: 535-537. https://doi.org/10.4269/ajtmh.2001.65.535

Kosoy, M., Morway, C., Sheff, K.W., Bai, Y., Colborn, J., Chalcraft, L., Dowell, S.F., Peruski, L.F., Maloney, S.A., Baggett, H. *et al*. (2008). *Bartonella tamiae* sp. nov., a newly recognized pathogen isolated from three human patients from Thailand. *Journal of Clinical Microbiology* **46**: 772-775. https://doi.org/10.1128/JCM.02120-07

Kosoy, M., Bai, Y., Sheff, K., Morway, C., Baggett, H., Maloney, S.A., Boonmar, S., Bhengsri, S., Dowell, S.F., Sitdhirasdr, A. *et al*. (2010). Identification of *Bartonella* infections in febrile human patients from Thailand and their potential animal reservoirs. *The American Journal of Tropical Medicine and Hygiene* **82**: 1140-1145. https://doi.org/10.4269/ajtmh.2010.09-0778

Krairojananan, P., Thaipadungpanit, J., Leepitakrat, S., Monkanna, T., Wanja, E.W., Schuster, A.L., Costa, F., Poole-Smith, B.K. & McCardle, P.W. (2020). Low prevalence of *Leptospira* carriage in rodents in leptospirosis-endemic Northeastern Thailand. *Tropical Medicine and Infectious Disease* **5**: 154. https://doi.org/10.3390/tropicalmed5040154

Krügel, M., Król, N., Kempf, V.A.J., Pfeffer, M. & Obiegala, A. (2022). Emerging rodent-associated *Bartonella*: a threat for human health? *Parasites & Vectors* **15**: 113. https://doi.org/10.1186/s13071-022-05162-5

Krüger, D.H., Schönrich, G. & Klempa, B. (2011). Human pathogenic hantaviruses and prevention of infection. *Human Vaccines* **7**: 685-693. https://doi.org/10.4161/hv.7.6.15197

Kudo, Y., Vansith, K., Rin, E., Uchida, K., Kodama, S., Fukui, T., Masuda, S. & Masuzawa, T. (2018). Molecular epidemiological survey of *Leptospira* infection of wild rodents in the urban settlement of Cambodia. *Vector-Borne and Zoonotic Diseases* **18**: 144-150. https://doi.org/10.1089/vbz.2017.2198

Kumar, A., Balachandran, V., Dominic, A., Dinesh, K.R., Karim, S. & Rao, G. (2012). Serological evidence of leptospirosis and dengue coinfection in an endemic region in South India. *Annals of Tropical Medicine & Public Health* **5**: 286-290.

Kuo, C.C., Lin, Y.F., Yao, C.T., Shih, H.C., Chung, L.H., Liao, H.C., Hsu, Y.C. & Wang, H.C. (2017). Tick-borne pathogens in ticks collected from birds in Taiwan. *Parasites & Vectors* **10**: 587. https://doi.org/10.1186/s13071-017-2535-4

Laenen, L., Vergote, V., Calisher, C.H., Klempa, B., Klingström, J., Kuhn, J.H. & Maes, P. (2019). *Hantaviridae*: Current classification and future perspectives. *Viruses* **11**: 788. https://doi.org/10.3390/v11090788

Lam, J.S. & Sanjay, S. (2012). Lyme neuroretinitis in Singapore: A diagnostic dilemma. *Annals of The Academy of Medicine, Singapore* **41**: 178-179.

Lam, S.K., Chua, K.B., Myshrall, T., Devi, S., Zainal, D., Afifi, S.A., Nerome, K. & Lee, H.W. (2001). Serological evidence of hantavirus infections in Malaysia. *The Southeast Asian Journal of Tropical Medicine and Public Health* **32**: 809-813.

Lau, A.C.C., Qiu, Y., Moustafa, M.A.M., Nakao, R., Shimozuru, M., Onuma, M., Mohd-Azlan, J. & Tsubota, T. (2020). Detection of *Borrelia burgdorferi sensu lato* and relapsing fever borrelia in feeding *Ixodes* ticks and rodents in Sarawak, Malaysia: New geographical records of *Borrelia yangtzensis* and *Borrelia miyamotoi*. *Pathogens* **9**: 846. https://doi.org/10.3390/pathogens9100846

Lau, C.L., Smythe, L.D., Craig, S.B. & Weinstein, P. (2010). Climate change, flooding, urbanisation and leptospirosis: Fuelling the fire? *Transactions of the Royal Society of Tropical Medicine & Hygiene* **104**: 631-638. https://doi.org/10.1016/j.trstmh.2010.07.002

Lederer, S., Lattwein, E., Hanke, M., Sonnenberg, K., Stoecker, W., Lundkvist, Å, Vaheri, A., Vapalahti, O., Chan, P.K.S., Feldmann, H. *et al*. (2013). Indirect immunofluorescence assay for the simultaneous detection of antibodies against clinically important old and new world hantaviruses. *PLoS Neglected Tropical Diseases* **14**: e0008864. https://doi.org/10.1371/journal.pntd.0008864

Lerdthusnee, K., Khuntirat, B., Leepitakrat, W., Tanskul, P., Monkanna, T., Khlaimanee, N., Inlao, I., Kengluecha, A., Mungviriya, S., Chandranoi, K. *et al*. (2003). Scrub typhus: vector competence of *Leptotrombidium chiangraiensis* chiggers and transmission efficacy and isolation of *Orientia tsutsugamushi*. *Annals of the New York Academy of Sciences* **990**: 25-35. https://doi.org/10.1111/j.1749-6632.2003.tb07333.x

Lerdthusnee, K., Nigro, J., Monkanna, T., Leepitakrat, W., Leepitakrat, S., Insuan, S., Charoensongsermkit, W., Khlaimanee, N., Akkagraisee, W., Chayapum, K. *et al*. (2008). Surveys of rodent-borne disease in Thailand with a focus on scrub typhus assessment. *Integrative Zoology* **3**: 267-273. https://doi.org/10.1111/j.1749-4877.2008.00100.x

Lie, K.C., Aziz, M.H., Kosasih, H., Neal, A., Halim, C.L., Wulan, W.N., Karyana, M. & Hadi, U. (2018). Case report: Two confirmed cases of human Seoul virus infections in Indonesia. *BMC Infectious Diseases* **18**: 578. https://doi.org/10.1186/s12879-018-3482-1

Limothai, U., Tachaboon, S., Dinhuzen, J., Singh, J., Jirawannaporn, S., Leewongworasingh, A., Thongpin, M., Brameld, S., Watanaboonyongcharoen, P., Sitprija, V. *et al*. (2023). Seroprevalence of leptospirosis among blood donors in an endemic area. *Scientific Reports* **13**: 12336. https://doi.org/10.1038/s41598-023-39461-3

Lindo, J., Brown, P.D., Vickers, I., Brown, M., Jackson, S.T. & Lewis-Fuller, E. (2013). Leptospirosis and malaria as causes of febrile illness during a dengue epidemic in Jamaica. *Pathogens and Global Health* **107**: 329-334. https://doi.org/10.1179/2047773213Y.0000000112

Lins, K.D.A., Drummond, M.R. & Velho, P.E.N.F. (2019). Cutaneous manifestations of bartonellosis. *Anais Brasileiros de Dermatologia* **94**: 594-602. https://doi.org/10.1016/j.abd.2019.09.024

Linsuwanon, P., Auysawasdi, N., Wongwairot, S., Leepitakrat, S., Rodkhamtook, W., Wanja, E., Monkanna, T., Wegner, M., Davidson, S., Poovorawan, Y. *et al*. (2021a). Assessing scrub typhus and rickettsioses transmission risks in the Chiang Rai province of Northern Thailand. *Travel Medicine and Infectious Disease* **42**: 102086. https://doi.org/10.1016/j.tmaid.2021.102086

Linsuwanon, P., Wongwairot, S., Auysawasdi, N., Monkanna, T., Richards, A.L., Leepitakrat, S., Sunyakumthorn, P., Im-Erbsin, R., Poole-Smith, K. & McCardle, P. (2021b). Establishment of a rhesus macaque model for scrub typhus transmission: Pilot study to evaluate the minimal *Orientia tsutsugamushi* transmission time by *Leptotrombidium chiangraiensis* chiggers. *Pathogens* **10**: 1028. https://doi.org/10.3390/pathogens10081028

Loan, H.K., Cuong, N.V., Takhampunya, R., Klangthong, K., Osikowicz, L., Kiet, B.T., Campbell, J., Bryant, J., Promstaporn, S., Kosoy, M. *et al*. (2015). *Bartonella* species and trombiculid mites of rats from the Mekong Delta of Vietnam. *Vector-Borne and Zoonotic Diseases* **15**: 40-47. https://doi.org/10.1089/vbz.2014.1604

Lokida, D., Hadi, U., Lau, C.Y., Kosasih, H., Liang, C.J., Rusli, M., Sudarmono, P., Lukman, N., Laras, K., Asdie, R.H. *et al*. (2020). Underdiagnoses of *Rickettsia* in patients hospitalized with acute fever in Indonesia: observational study results. *BMC Infectious Diseases* **20**: 364. https://doi.org/10.1186/s12879-020-05057-9

Loong, S.K., Khor, C.S., Chen, H.W., Chao, C.C., Ling, I.S.C., Abdul Rahim, N.F., Hassan, H., Nellis, S., Ching, W.M. & Abubakar, S. (2018). Serological evidence of high *Leptospira* exposure among indigenous people (Orang Asli) in Peninsular Malaysia using a recombinant antigen-based ELISA. *Tropical Biomedicine* **35**: 001-009.

Loong, S.K., Abd-Majid, M.A., Teoh, B.T., Cheh, M.J., Khor, C.S., Chao, C.C., Khoo, J.J. & AbuBakar, S. (2022). Leptospirosis among dengue-negative febrile patients in Selangor, Malaysia. *The American Journal of Tropical Medicine and Hygiene* **107**: 397-400. https://doi.org/10.4269/ajtmh.20-0656

Lopez, J., Hovius, J.W. & Bergström, S. (2021). Pathogenesis of relapsing fever. *Current Issues in Molecular Biology* **42**: 519-550. https://doi.org/10.21775/cimb.042.519

Low, V.L., Tan, T.K., Ibrahim, J., Abubakar, S. & Lim, Y.A.L. (2020a). First evidence of *Bartonella phoceensis* and *Candidatus Mycoplasma haemomuris* subsp. *ratti* in synanthropic rodents in Malaysia. *Asian Pacific Journal of Tropical Medicine* **13**: 94-96. https://doi.org/10.4103/1995-7645.275418

Low, V.L., Tan, T.K., Khoo, J.J., Lim, F.S. & AbuBakar, S. (2020b). An overview of rickettsiae in Southeast Asia: Vector-animal-human interface. *Acta Tropica* **202**: 105282. https://doi.org/10.1016/j.actatropica.2019.105282

Luan, V.D., Yoshimatsu, K., Endo, R., Taruishi, M., Huong, V.T., Dat, D.T., Tien, P.C., Shimizu, K., Koma, T., Yasuda, S.P. *et al*. (2012). Studies on hantavirus infection in small mammals captured in Southern and Central highland area of Vietnam. *Journal of Veterinary Medical Science* **74**: 1155-1162. https://doi.org/10.1292/jvms.11-0567

Luenam, A. & Puttannapong, N. (2019). Spatial and statistical analysis of leptospirosis in Thailand from 2013 to 2015. *Geospatial Health* **14**: 739. https://doi.org/10.4081/gh.2019.739

Lukman, N., Kosasih, H., Ibrahim, I.N., Pradana, A.A., Neal, A. & Karyana, M. (2019). A review of hantavirus research in Indonesia: Prevalence in humans and rodents, and the discovery of Serang virus. *Viruses* **11**: 698. https://doi.org/10.3390/v11080698

Luvira, V., Silachamroon, U., Piyaphanee, W., Lawpoolsri, S., Chierakul, W., Leaungwutiwong, P., Thawornkuno, C. & Wattanagoon, Y. (2019). Etiologies of acute undifferentiated febrile illness in Bangkok, Thailand. *The American Journal of Tropical Medicine and Hygiene* **100**: 622-629. https://doi.org/10.4269/ajtmh.18-0407

Madison-Antenucci, S., Kramer, L.D., Gebhardt, L.L. & Kauffman, E. (2020). Emerging tick-borne diseases. *Clinical Microbiology Reviews* **33**: e00083-18. https://doi.org/10.1128/CMR.00083-18

Manigold, T. & Vial, P. (2014). Human hantavirus infections: Epidemiology, clinical features, pathogenesis and immunology. *Swiss Medical Weekly* **144**: 13937. https://doi.org/10.4414/smw.2014.13937

Margos, G., Chu, C.Y., Takano, A., Jiang, B.G., Liu, W., Kurtenbach, K., Masuzawa, T., Fingerle, V., Cao, W.C. & Kawabata, H. (2015). *Borrelia yangtzensis* sp. nov., a rodent-associated species in Asia, is related to *Borrelia valaisiana*. *International Journal of Systematic and Evolutionary Microbiology* **65**: 3836-3840. https://doi.org/10.1099/ijsem.0.000491

Margos, G., Fingerle, V. & Reynolds, S. (2019). *Borrelia bavariensis*: Vector switch, niche invasion, and geographical spread of a tick-borne bacterial parasite. *Frontiers in Ecology and Evolution* **7**: 401. https://doi.org/10.3389/fevo.2019.00401

Margos, G., Fingerle, V., Cutler, S., Gofton, A., Stevenson, B. & Estrada-Peña, A. (2020). Controversies in bacterial taxonomy: The example of the genus *Borrelia*. *Ticks and Tick-Borne Diseases* **11**: 101335. https://doi.org/10.1016/j.ttbdis.2019.101335

Marques, A.R., Strle, F. & Wormser, G.P. (2021). Comparison of lyme disease in the United States and Europe. *Emerging Infectious Diseases* **27**: 2017-2024. https://doi.org/10.3201/eid2708.204763

McFarlane, R., Sleigh, A. & McMichael, T. (2012). Synanthropy of wild mammals as a determinant of emerging infectious diseases in the Asian – Australasian region. *Eco Health* **9**: 24-35. https://doi.org/10.1007/s10393-012-0763-9

Meerburg, B.G., Singleton, G.R. & Kijlstra, A. (2009). Rodent-borne diseases and their risks for public health. *Critical Reviews in Microbiology* **35**: 221-270. https://doi.org/10.1080/10408410902989837

Meyer, B.J. & Schmaljohn, C.S. (2000). Persistent hantavirus infections: characteristic and mechanisms. *Trends in Microbiology* **8**: 61-67. https://doi.org/10.1016/s0966-842x(99)01658-3

Minnick, M.F., Anderson, B.E., Lima, A., Battisti, J.M., Lawyer, P.G. & Birtles, R.J. (2014). Oroya fever and verruga peruana: Bartonelloses unique to South America. *PLoS Neglected Tropical Diseases* **8**: e2919. https://doi.org/10.1371/journal.pntd.0002919

Minnick, M.F., Robinson, A.J., Powell, R.D. & Rowland, T.E. (2023). Experimental colonization of sand flies (*Lutzomyia longipalpis*; Diptera: Psychodidae) by *Bartonella ancashensis*. *Vector-Borne and Zoonotic Diseases* **23**: 324-330. https://doi.org/10.1089/vbz.2022.0087

Mohammed, H., Nozha, C., Hakim, K., Abdelaziz, F. & Rekia, B. (2011). *Leptospira*: Morphology, classification and pathogenesis. *Journal of Bacteriology and Parasitology* **2**: 1000120. https://doi.org/10.4172/2155-9597.1000120

Mohd Hanapi, I.R., Sahimin, N., Maackara, M.J.B., Annisa, A.S., Abdul Mutalib, R.N.S., Lewis, J.W., Behnke, J.M., Lau, Y.L. & Mohd Zain, S.N. (2021). Prevalence of anti-*Leptospira* antibodies and associated risk factors in the Malaysian refugee communities. *BMC Infectious Diseases* **21**: 1128. https://doi.org/10.1186/s12879-021-06830-0

Mohd Radi, M.F., Hashim, J.H., Jaafar, M.H., Hod, R., Ahmad, N., Mohammed Nawi, A., Baloch, G.M., Ismail, R. & Ayub, N.I.F. (2018). Leptospirosis outbreak after the 2014 major flooding event in Kelantan, Malaysia: A spatial-temporal analysis. *The American Journal of Tropical Medicine and Hygiene* **98**: 1281-1295. https://doi.org/10.4269/ajtmh.16-0922

Mohd-Azami, S.N.I., Loong, S.K., Khoo, J.J., Husin, N.A., Lim, F.S., Mahfodz, N.H., Ishak, S.N., Mohd-Taib, F.S., Makepeace, B.L. & AbuBakar, S. (2023). Molecular surveillance for vector-borne bacteria in rodents and tree shrews of Peninsular Malaysia oil palm plantations. *Tropical Medicine and Infectious Disease* **8**: 74. https://doi.org/10.3390/tropicalmed8020074

Mohd-Taib, F.S., Ishak, S.N., Yusof, M.A., Azhari, N.N., Md-Lasim, A., Md. Nor, S., Mohd-Sah, S.A. & Neela, V.K. (2020). Leptospirosis: An insight into community structure of small mammal's host in urban environment. *Tropical Biomedicine* **37**: 142-154.

Mosepele, M., Mazo, D. & Cohn, J. (2012). *Bartonella* infection in immunocompromised hosts: Immunology of vascular infection and vasoproliferation. *Journal of Immunology Research* **2012**: 612809. https://doi.org/10.1155/2012/612809

Mullins, K., Canal, E., Ouch, P., Prasetyo, D., Tagoe, J., Attram, N., Yeboah, C., Kumordjie, S., Fox, A., Letizia, A.G. *et al*. (2023). *Bartonella* species in Cambodia, Ghana, Laos, and Peru: results from vector and serosurveys. *Vector-Borne and Zoonotic Diseases* **23**: 9-17. https://doi.org/10.1089/vbz.2021.0090

Nazir, A., Oduoye, M.O., Nazir, A., Uzoamaka, C.B., Ali Muzammil, M., Sakr, S.M., Scott, G.Y. & Khan suheb, M. (2023). Unraveling the leptospirosis epidemic: tales from the Philippine outbreak – a short communication. *Annals of Medicine & Surgery* **86**: 1238-1242. https://doi.org/10.1097/ms9.0000000000001535

Neves, E.S., Mendenhall, I.H., Borthwick, S.A., Su, Y.C.F. & Smith, G.J.D. (2018). Detection and genetic characterization of diverse *Bartonella* genotypes in the small mammals of Singapore. *Zoonoses and Public Health* **65**: e207-e215. https://doi.org/10.1111/zph.12430

Noh, M.A., Masri, S.N., Zulkapli, A., Mohd Ali, M.R. & Amran, F. (2024). *Leptospira* infection and carrier survey on rats from wet market areas in Kuala Lumpur, Malaysia. *Journal of Vector Borne Diseases* **61**: 43-50. https://doi.org/10.4103/0972-9062.383644

O'Halloran, H.S., Draud, K., Minix, M., Rivard, A.K. & Pearson, P.A. (1998). Leber's neuroretinitis in a patient with serological evidence of *B. elizabethae*. *The Journal of Retinal and Vitreous Diseases* **18**: 276-278. https://doi.org/10.1097/00006982-199803000-00015

Okabayashi, T., Tsutiya, K., Muramatsu, Y., Ueno, H. & Morita, C. (1996). Serological survey of spotted fever group *Rickettsia* in wild rats in Thailand in the 1970s. *Microbiology and Immunology* **40**: 895-898. https://doi.org/10.1111/j.1348-0421.1996.tb01157.x

Oksi, J., Rantala, S., Kilpinen, S., Silvennoinen, R., Vornanen, M., Veikkolainen, V., Eerola, E. & Pulliainen, A.T. (2013). Cat scratch disease caused by *Bartonella grahamii* in an immunocompromised patient. *Journal of Clinical Microbiology* **51**: 2781-2784. https://doi.org/10.1128/jcm.00910-13

Osterloh, A., Papp, S., Moderzynski, K., Kuehl, S., Richardt, U. & Fleischer, B. (2016). Persisting *Rickettsia typhi* causes fatal central nervous system inflammation. *Infection and Immunity* **84**: 1615-1632. https://doi.org/10.1128/iai.00034-16

Padula, P., Figueroa, R., Navarrete, M., Pizarro, E., Cadiz, R., Bellomo, C., Jofre, C., Zaror, L., Rodriguez, E. & Murúa, R. (2004). Transmission study of Andes hantavirus infection in wild sigmodontine rodents. *Journal of Virology* **78**: 11972-11979. https://doi.org/10.1128/jvi.78.21.11972-11979.2004

Pangjai, D., Maruyama, S., Boonmar, S., Kabeya, H., Sato, S., Nimsuphan, B., Petkanchanapong, W., Wootta, W., Wangroongsarb, P., Boonyareth, M. *et al*. (2014). Prevalence of zoonotic *Bartonella* species among rodents and shrews in Thailand. *Comparative Immunology, Microbiology and Infectious Diseases* **37**: 109-114. https://doi.org/10.1016/j.cimid.2013.12.001

Pangjai, D., Nimsuphan, B., Petkanchanapong, W., Wootta, W., Boonyareth, M., Rodkvamtook, W. & Boonmar, S. (2022). First report of three novel *Bartonella* species isolated in rodents and shrews from nine provinces of Thailand. *Veterinary World* **15**: 1624-1631. https://doi.org/10.14202/vetworld.2022.1624-1631

Panthawong, A., Grieco, J.P., Ngoen-klan, R., Chao, C.C. & Chareonviriyaphap, T. (2020). Detection of *Anaplasma* spp. and *Bartonella* spp. from wild-caught rodents and their ectoparasites in Nakhon Ratchasima Province, Thailand. *Journal of Vector Ecology* **45**: 241-253. https://doi.org/10.1111/jvec.12395

Pappas, G., Papadimitriou, P., Siozopoulou, V., Christou, L. & Akritidis, N. (2008). The globalization of leptospirosis: worldwide incidence trends. *International Journal of Infectious Diseases* **12**: 351-357. https://doi.org/10.1016/j.ijid.2007.09.011

Paramasvaran, S., Sani, R.A., Hassan, L., Krishnasamy, M., Jeffery, J., Oothuman, P., Salleh, I., Lim, K.H., Sumarni, M.G. & Santhana, R.L. (2009). Ectoparasite fauna of rodents and shrews from four habitats in Kuala Lumpur and the states of Selangor and Negeri Sembilan, Malaysia and its public health significance. *Tropical Biomedicine* **26**: 303-311.

Petney, T.N., Saijuntha, W., Boulanger, N., Chitimia-Dobler, L., Pfeffer, M., Eamudomkarn, C., Andrews, R.H., Ahamad, M., Putthasorn, N., Muders, S.V. *et al*. (2019). Ticks (Argasidae, Ixodidae) and tick-borne diseases of continental Southeast Asia. *Zootaxa* **4558**: 1-89. https://doi.org/10.11646/zootaxa.4558.1.1

Phasomkusolsil, S., Tanskul, P., Ratanatham, S., Watcharapichat, P., Phulsuksombati, D., Frances, S.P., Lerdthusnee, K. & Linthicum, K.J. (2009). Transstadial and transovarial transmission of *Orientia tsutsugamushi* in *Leptotrombidium imphalum* and *Leptotrombidium chiangraiensis* (Acari: Trombiculidae). *Journal of Medical Entomology* **46**: 1442-1445. https://doi.org/10.1603/033.046.0628

Philip, N., Affendy, N.B., Ramli, S.N.A., Arif, M., Raja, P., Nagandran, E., Renganathan, P., Mohd Taib, N., Masri, S.N., Yuhana, M.Y. *et al*. (2020). *Leptospira interrogans* and *Leptospira kirschneri* are the dominant *Leptospira* species causing human leptospirosis in Central Malaysia. *PLoS Neglected Tropical Diseases* **14**: e0008197. https://doi.org/10.1371/journal.pntd.0008197

Philip, N. & Ahmed, K. (2023). Leptospirosis in Malaysia: current status, insights, and future prospects. *Journal of Physiological Anthropology* **42**: 30. https://doi.org/10.1186/s40101-023-00347-y

Plyusnina, A., Ibrahim, I.N. & Plyusnin, A. (2009). A newly recognized hantavirus in the Asian house rat (*Rattus tanezumi*) in Indonesia. *Journal of General Virology* **90**: 205-209. https://doi.org/10.1099/vir.0.006155-0

Pothuri, P., Ahuja, K., Kumar, V., Lal, S., Tumarinson, T. & Mahmood, K. (2016). Leptospirosis presenting with rapidly progressing acute renal failure and conjugated hyperbilirubinemia: A case report. *American Journal of Case Reports* **17**: 567-569. https://doi.org/10.12659/AJCR.897741

Pramestuti, N., Umniyati, S., Mulyaningsih, B., Widiastuti, D. & Raharjo, J. (2018). Evidence of *Rickettsia typhi* in rat fleas of various habitat and the potential transmission of murine typhus in Banjarnegara, Central Java, Indonesia. *Indian Journal of Public Health Research & Development* **9**: 1548-1554. https://doi.org/10.5958/0976-5506.2018.00952.X

Pritt, B.S., Mead, P.S., Johnson, D.K.H., Neitzel, D.F., Respicio-Kingry, L.B., Davis, P.J.P., Schiffman, E., Sloan, L.M., Schriefer, M.E., Replogle, A.J. *et al*. (2016). Identification of a novel pathogenic *Borrelia* species causing Lyme borreliosis with unusually high spirochaetaemia: a descriptive study. *The Lancet Infectious Diseases* **16**: 556-564. https://doi.org/10.1016/S1473-3099(15)00464-8

Pui, C.F., Bilung, L.M., Apun, K. & Su'ut, L. (2017). Diversity of *Leptospira* spp. in rats and environment from urban areas of Sarawak, Malaysia. *Journal of Tropical Medicine* **2017**: 3760674. https://doi.org/10.1155/2017/3760674

Pun, S.B., Agrawal, S., Jha, S., Bhandari, L.N., Chalise, B.S., Mishra, A. & Shah, R. (2018). First report of Lyme disease in Nepal. *JMM Case Reports* **5**: 1-3. https://doi.org/10.1099/jmmcr.0.005128

Quelapio, I.D., Villa, L., Clarin, S.M., Bacosa, M. & Tupasi, T.E. (2000). Seroepidemiology of hantavirus in the Philippines. *International Journal of Infectious Diseases* **4**: 104-107. https://doi.org/10.1016/s1201-9712(00)90103-6

Radolf, J.D., Strle, K., Lemieux, J.E. & Strle, F. (2021). Lyme disease in humans. *Current Issues in Molecular Biology* **42**: 333-384. https://doi.org/10.21775/cimb.042.333

Rahman, M.H.A.A., Hairon, S.M., Hamat, R.A., Jamaluddin, T.Z.M.T., Shafei, M.N., Idris, N., Osman, M., Sukeri, S., Wahab, Z.A., Wan Mohammad, W.M.Z. *et al*. (2018). Seroprevalence and distribution of leptospirosis serovars among wet market workers in Northeastern, Malaysia: A cross sectional study. *BMC Infectious Diseases* **18**: 569. https://doi.org/10.1186/s12879-018-3470-5

Rauch, J., Eisermann, P., Noack, B., Mehlhoop, U., Muntau, B., Schäfer, J. & Tappe, D. (2018). Typhus group rickettsiosis, Germany, 2010-2017. *Emerging Infectious Diseases* **24**: 1213-1220. https://doi.org/10.3201/eid2407.180093

Reynes, J.M., Soares, J.L., Hüe, T., Bouloy, M., Sun, S., Kruy, S.L., Sainte Marie, F.F. & Zeller, H. (2003). Evidence of the presence of Seoul virus in Cambodia. *Microbes and Infection* **5**: 769-773. https://doi.org/10.1016/S1286-4579(03)00149-7

Richards, A.L., Soeatmadji, D.W., Widodo, M.A., Sardjono, T.W., Yanuwiadi, B., Hernowati, T.E., Baskoro, A.D., Roebiyoso, Hakim, L., Soendoro, M. *et al*. (1997). Seroepidemiologic evidence for murine and scrub typhus in Malang, Indonesia. *The American Journal of Tropical Medicine and Hygiene* **57**: 91-95. https://doi.org/10.4269/ajtmh.1997.57.91

Richards, A.L., Rahardjo, E., Rusjdi, A.F., Kelly, D.J., Dasch, G.A., Church, C.J. & Bangs, M.J. (2002). Evidence of *Rickettsia typhi* and the potential for murine typhus in Jayapura, Irian Jaya, Indonesia. *The American Journal of Tropical Medicine and Hygiene* **66**: 431-434. https://doi.org/10.4269/ajtmh.2002.66.431

Richards, A.L. & Jiang, J. (2020). Scrub typhus: Historic perspective and current status of the worldwide presence of *Orientia* species. *Tropical Medicine and Infectious Disease* **5**: 49. https://doi.org/10.3390/tropicalmed5020049

Ristiyanto, Handayani, F.D., Mulyono, A., Joharina, A.S., Wibawa, T., Budiharta, S. & Supargiono. (2018). Leptospirosis case finding for development of leptospirosis surveillance in Semarang city, Central Java, Indonesia. *Vektora* **10**: 111-116.

Roberts, T., Parker, D.M., Bulterys, P.L., Rattanavong, S., Elliott, I., Phommasone, K., Mayxay, M., Chansamouth, V., Robinson, M.T., Blacksell, S.D. *et al*. (2021). A spatio-temporal analysis of scrub typhus and murine typhus in Laos; implications from changing landscapes and climate. *PLoS Neglected Tropical Diseases* **15**: e0009685. https://doi.org/10.1371/journal.pntd.0009685

Rodkvamtook, W., Gaywee, J., Kanjanavanit, S., Ruangareerate, T., Richards, A.L., Sangjun, N., Jeamwattanalert, P. & Sirisopana, N. (2013). Scrub typhus outbreak, Northern Thailand, 2006-2007. *Emerging Infectious Diseases* **19**: 774-777. https://doi.org/10.3201/eid1905.121445

Rodkvamtook, W., Kuttasingkee, N., Linsuwanon, P., Sudsawat, Y., Richards, A.L., Somsri, M., Sangjun, N., Chao, C.C., Davidson, S., Wanja, E. *et al*. (2018). Scrub typhus outbreak in Chonburi Province, Central Thailand, 2013. *Emerging Infectious Diseases* **24**: 361-365. https://doi.org/10.3201/eid2402.171172

Rosenberg, R., Lindsey, N.P., Fischer, M., Gregory, C.J., Hinckley, A.F., Mead, P.S., Paz-Bailey, G., Waterman, S.H., Drexler, N.A., Kersh, G.J. *et al*. (2018). Vital signs: Trends in reported vectorborne disease cases- United States and territories, 2004 - 2016. *Morbidity and Mortality Weekly Report* **67**: 496-501. https://doi.org/10.15585/mmwr.mm6717e1

Rotan, H., Ginting, Y., Loesnihari, R., Kembaren, T. & Marpaung, B. (2018). Correlation between chronic arthritis patients confirmed with questionnaire and serologic test of lyme disease. *Earth and Environmental Science* **125**: 012043. https://doi.org/10.1088/1755-1315/125/1/012043

Saengsawang, P., Morand, S., Desquesnes, M., Yangtara, S. & Inpankaew, T. (2021). Molecular detection of *Bartonella* species in rodents residing in urban and suburban areas of Central Thailand. *Microorganisms* **9**: 2588. https://doi.org/10.3390/microorganisms9122588

Sahimin, N., Sharif, S.A., Mohd Hanapi, I.R., Chuan, S.N., Lewis, J.W., Douadi, B. & Mohd Zain, S.N. (2019). Seroprevalence of anti-leptospira IgG and IgM antibodies and risk assessment of leptospirosis among urban poor communities in Kuala Lumpur, Malaysia. *The American Journal of Tropical Medicine and Hygiene* **101**: 1265-1271. https://doi.org/10.4269/ajtmh.19-0003

Saisongkorh, W., Rolain, J.M., Suputtamongkol, Y. & Raoult, D. (2009a). Emerging *Bartonella* in humans and animals in Asia and Australia. *Journal of the Medical Association of Thailand* **92**: 707-731.

Saisongkorh, W., Wootta, W., Sawanpanyalert, P., Raoult, D. & Rolain, J.M. (2009b). "*Candidatus Bartonella thailandensis*": A new genotype of *Bartonella* identified from rodents. *Veterinary Microbiology* **139**: 197-201. https://doi.org/10.1016/j.vetmic.2009.05.011

Saiton, N., Solante, R.M., Guzman, F.D., Telan, E.O., Umipig, D.V., Calayon, J.P., Fraycon, C.H., Lazaro, J.C., Ribo, M.R., Dimapilisn, A.Q. *et al*. (2022). A prospective observational study of community-acquired bacterial bloodstream infections in Metro Manila, the Philippines. *PLoS Neglected Tropical Diseases* **16**: e0010414. https://doi.org/10.1371/journal.pntd.0010414

Sakundarno, M., Bertolatti, D., Maycock, B., Spickett, J. & Dhaliwal, S. (2014). Risk factors for leptospirosis infection in humans and implications for public health intervention in indonesia and the Asia-Pacific region. *Asia-Pacific Journal of Public Health* **26**: 15-32. https://doi.org/10.1177/1010539513498768

Sapian, M., Khairi, M.T., How, S.H., Rajalingam, R., Sahhir, K., Norazah, A., Khebir, V. & Jamalludin, A.R. (2012). Outbreak of melioidosis and leptospirosis co-infection following a rescue operation. *The Medical Journal of Malaysia* **67**: 293-297.

Satjanadumrong, J., Robinson, M.T., Hughes, T. & Blacksell, S.D. (2019). Distribution and ecological drivers of spotted fever group *Rickettsia* in Asia. *EcoHealth* **16**: 611-626. https://doi.org/10.1007/s10393-019-01409-3

Schmaljohn, C. & Hjelle, B. (1997). Hantavirus: A global disease problem. *Emerging Infectious Diseases* **3**: 95-104. https://doi.org/10.3201/eid0302.970202

Sehgal, A., Mehta, S., Sahay, K., Martynova, E., Rizvanov, A., Baranwal, M., Chandy, S., Khaiboullina, S., Kabwe, E. & Davidyuk, Y. (2023). Hemorrhagic fever with renal syndrome in Asia: History, pathogenesis, diagnosis, treatment, and prevention. *Viruses* **15**: 561. https://doi.org/10.3390/v15020561

Senaka, R. (2022). Leptospirosis: clinical aspects. *Clinical Medicine* **22**: 14-17. https://doi.org/10.7861/clinmed.2021-0784

Shafie, N.J., Abdul Halim, N.S., Zalipah, M.N., Mohd Amin, N.A.Z., Syed Esa, S.M., Md-Nor, S., Casanovas-Massana, A., Ko, A.I., Palma, F., Souza, F.N. *et al*. (2021). Knowledge, attitude, and practices regarding leptospirosis among visitors to a recreational forest in Malaysia. *The American Journal of Tropical Medicine and Hygiene* **104**: 1290-1296. https://doi.org/10.4269/ajtmh.20-0306

Shafie, N.J., Abdul Halim, N.S., Awoniyi, A.M., Zalipah, M.N., Md-Nor, S., Nazri, M.U.I. & Costa, F. (2022). Prevalence of pathogenic *Leptospira* spp. in non-volant small mammals of Hutan Lipur Sekayu, Terengganu, Malaysia. *Pathogens* **11**: 1300. https://doi.org/10.3390/pathogens11111300

Shaked, Y., Shpilberg, O., Samra, D. & Samra, Y. (1993). Leptospirosis in pregnancy and its effect on the fetus: Case report and review. *Clinical Infectious Diseases* **17**: 241-243. https://doi.org/10.1093/clinids/17.2.241

Shirai, A., Tanskul, P.L., Andre, R.G., Dohany, A.L. & Huxsoll, D.L. (1981). *Rickettsia tsutsugamushi* strains found in chiggers collected in Thailand. *The Southeast Asian Journal of Tropical Medicine and Public Health* **12**: 1-6.

Singh, N.K., Haque, M., Jyoti, Rath, S.S. & Ghosh, S. (2011). First report of *Ctenocephalides felis felis* infestation of buffalo calves in Punjab, India. *Journal of Parasitic Diseases* **35**: 235-236. https://doi.org/10.1007/s12639-011-0038-3

Siritantikorn, S., Sangkasuwan, V., Eamsila, C., Singchai, C., Kantakamalakul, W. & Puthavathana, P. (2003). Seroprevalence of rickettsial infection in commensal rodents and shrews trapped in the Bangkok Metropolitan area. *Journal of the Medical Association of Thailand* **86**: 516-521.

Skufca, J. & Arima, Y. (2012). Sex, gender and emerging infectious disease surveillance: a leptospirosis case study. *Western Pacific Surveillance and Response Journal* **3**: 37-39. https://doi.org/10.5365/wpsar.2012.3.3.001

Strickman, D., Tanskul, P., Eamsila, C. & Kelly, D.J. (1994). Prevalence of antibodies to rickettsiae in the human population of suburban Bangkok. *The American Journal of Tropical Medicine and Hygiene* **51**: 149-153. https://doi.org/10.4269/ajtmh.1994.51.149

Strle, F., Ružić-Sabljić, E., Cimperman, J., Lotrič-Furlan, S. & Maraspin, V. (2006). Comparison of findings for patients with *Borrelia garinii* and *Borrelia afzelii* isolated from cerebrospinal fluid. *Clinical Infectious Diseases* **43**: 704-710. https://doi.org/10.1086/506936

Strnad, M., Rudenko, N. & Rego, R.O.M. (2023). Pathogenicity and virulence of *Borrelia burgdorferi*. *Virulence* **14**: 2265015. https://doi.org/10.1080/21505594.2023.2265015

Sunaryo, S. & Priyanto, D. (2022). Leptospirosis in rats and livestock in Bantul and Gunungkidul district, Yogyakarta, Indonesia. *Veterinary World* **15**: 1449-1455. https://doi.org/10.14202/vetworld.2022.1449-1455

Suputthamongkol, Y., Nitatpattana, N., Chayakulkeeree, M., Palabodeewat, S., Yoksan, S. & Gonzalez, J.P. (2005). Hantavirus infection in Thailand first clinical case report. *The Southeast Asian Journal of Tropical Medicine and Public Health* **36**: 217-220.

Susanti, H.N., Noor, S.M., Dharmayanti, N.L.P.I., Randusari, P., Shimizu, K., Hirayama, K., Koizumi, Nobuo. & Miura, K. (2022). Serological surveillance of zoonotic pathogens in rats in markets in Bogor, Indonesia. *Vector-Borne and Zoonotic Diseases* **22**: 568-570. https://doi.org/10.1089/vbz.2022.0016

Suut, L., Mazlan, M.N.A., Arif, M.T., Yusoff, H., Abdul Rahim, N.A., Safii, R. & Suhaili, M.R. (2016). Serological prevalence of leptospirosis among rural communities in the Rejang Basin, Sarawak, Malaysia. *Asia-Pacific Journal of Public Health* **28**: 450-457. https://doi.org/10.1177/1010539516648003

Sykes, R.A. & Makiello, P. (2017). An estimate of Lyme borreliosis incidence in Western Europe. *Journal of Public Health* **39**: 74-81. https://doi.org/10.1093/pubmed/fdw017

Takhampunya, R., Korkusol, A., Pongpichit, C., Yodin, K., Rungrojn, A., Chanarat, N., Promsathaporn, S., Monkanna, T., Thaloengsok, S., Tippayachai, B. *et al*. (2019). Metagenomic approach to characterizing disease epidemiology in a disease-endemic environment in Northern Thailand. *Frontiers in Microbiology* **10**: 319. https://doi.org/10.3389/fmicb.2019.00319

Takhampunya, R., Thaloengsok, S., Tippayachai, B., Promsathaporn, S., Leepitakrat, S., Gross, K. & Davidson, S.A. (2021). Retrospective survey of *Borrelia* spp. from rodents and ticks in Thailand. *Journal of Medical Entomology* **58**: 1331-1344. https://doi.org/10.1093/jme/tjaa279

Takhampunya, R., Longkunan, A., Somchaimongkol, S., Youngdech, N., Chanarat, N., Sakolvaree, J., Tippayachai, B., Promsathaporn, S., Phanpheuch, B., Poole-Smith, B.K. *et al*. (2023). *Borrelia miyamotoi* a neglected tick-borne relapsing fever spirochete in Thailand. *PLoS Neglected Tropical Diseases* **17**: e0011159. https://doi.org/10.1371/journal.pntd.0011159

Tangkanakul, W., Smits, H.L., Jatanasen, S. & Ashford, D.A. (2005). Leptospirosis: An emerging health problem in Thailand. *The Southeast Asian Journal of Tropical Medicine and Public Health* **36**: 281-288.

Tappe, D., Gross, Y., Ngui, R., Rauch, J., Tay, S.T. & Lim, Y.A.L. (2018). High seroprevalence against typhus group and spotted fever group rickettsiae in rural Indigenous populations of Peninsular Malaysia. *Vector-Borne and Zoonotic Diseases* **19**: 323-327. https://doi.org/10.1089/vbz.2018.2391

Tariq, M. & Kim, D.M. (2022). Hemorrhagic fever with renal syndrome: Literature review, epidemiology, clinical picture and pathogenesis. *Infection & Chemotherapy* **54**: 1-19. https://doi.org/10.3947/ic.2021.0148

Tay, S.T., Ho, T.M., Rohani, M.Y. & Devi, S. (2000). Antibodies to *Orientia tsutsugamushi*, *Rickettsia typhi* and spotted fever group rickettsiae among febrile patients in rural areas of Malaysia. *Transactions of The Royal Society of Tropical Medicine and Hygiene* **94**: 280-284. https://doi.org/10.1016/S0035-9203(00)90322-5

Tay, S.T., Kamalanathan, M. & Rohani, M.Y. (2002). *Borrelia burgdorferi* (strain *B. afzelii*) antibodies among Malaysian blood donors and patients. *The Southeast Asian Journal of Tropical Medicine and Public Health* **33**: 787-793.

Tay, S.T., Mokhtar, A.S., Low, K.C., Mohd Zain, S.N., Jeffery, J., Abdul Aziz, N. & Kho, K.L. (2014a). Identification of rickettsiae from wild rats and cat fleas in Malaysia. *Medical and Veterinary Entomology* **28**: 104-108. https://doi.org/10.1111/mve.12075

Tay, S.T., Mokhtar, A.S., Mohd Zain, S.N. & Low, K.C. (2014b). Short report: Isolation and molecular identification of *Bartonellae* from wild rats (*Rattus* species) in Malaysia. *The American Journal of Tropical Medicine and Hygiene* **90**: 1039-1042. https://doi.org/10.4269/ajtmh.13-0273

Tay, S.T., Kho, K.L., Wee, W.Y. & Choo, S.W. (2016). Whole-genome sequence analysis and exploration of the zoonotic potential of a rat-borne *Bartonella elizabethae*. *Acta Tropica* **155**: 25-33. https://doi.org/10.1016/j.actatropica.2015.11.019

Thai, K.T.D., Binh, T.Q., Giao, P.T., Phuong, H.L., Hung, L.Q., Nam, N.V., Nga, T.T., Goris, M.G.A. & De Vries, P.J. (2006). Seroepidemiology of leptospirosis in Southern Vietnamese children. *Tropical Medicine and International Health* **11**: 738-745. https://doi.org/10.1111/j.1365-3156.2006.01619.x

The Nation. (2023). 2,700 cases and 31 deaths reported in leptospirosis outbreak amid heavy rains. The Nation. https://www.nationthailand.com/thailand/general/40031707. Accessed 17 September 2024.

Thipmontree, W., Suputtamongkol, Y., Tantibhedhyangkul, W., Suttinont, C., Wongswat, E. & Silpasakorn, S. (2014). Human leptospirosis trends: Northeast Thailand, 2001-2012. *International Journal of Environmental Research and Public Health* **11**: 8542-8551. https://doi.org/10.3390/ijerph110808542

Tilak, R., Kunwar, R., Wankhade, U.B. & Tilak, V.W. (2011). Emergence of *Schoengastiella ligula* as the vector of scrub typhus outbreak in Darjeeling: Has *Leptotrombidium deliense* been replaced? *Indian Journal of Public Health* **55**: 92-99. https://doi.org/10.4103/0019-557X.85239

Tokarevich, N.K. & Blinova, O.V. (2022). Leptospirosis in Vietnam. *Russian Journal of Infection and Immunity* **12**: 1019-1028. https://doi.org/10.15789/2220-7619-LIV-1988

Tran, V.D., Phuong Mai, L.T., Thu, N.T., Linh, B.K., Than, P.D., Quyet, N.T., Dung, L.P., Phuong Mai, T.N., My Hanh, N.T., Hai, H. *et al*. (2021). Seroprevalence and serovar distribution of leptospirosis among healthy people in Vietnam: Results from a multi-center study. *Clinical Epidemiology and Global Health* **10**: 100700. https://doi.org/10.1016/j.cegh.2021.100700

Trevisan, G., Cinco, M., Trevisini, S., di Meo, N., Chersi, K., Ruscio, M., Forgione, P. & Bonin, S. (2021a). *Borreliae* part 1: *Borrelia* lyme group and echidna reptile group. *Biology* **10**: 1036. https://doi.org/10.3390/biology10101036

Trevisan, G., Cinco, M., Trevisini, S., di Meo, N., Ruscio, M., Forgione, P. & Bonin, S. (2021b). *Borreliae* part 2: *Borrelia* relapsing fever group and unclassified *Borrelia*. *Biology* **10**: 1117. https://doi.org/10.3390/biology10111117

Trung, N.V., Hoi, L.T., Thuong, N.T.H., Toan, T.K., Huong, T.T.K., Hoa, T.M., Fox, A., Kinh, N.V., van Doorn, H.R., Wertheim, H.F.L. *et al*. (2017). Seroprevalence of scrub typhus, typhus, and spotted fever among rural and urban populations of Northern Vietnam. *The American Journal of Tropical Medicine and Hygiene* **96**: 1084-1087. https://doi.org/10.4269/ajtmh.16-0399

Truong, T.T., Yoshimatsu, K., Araki, K., Lee, B.H., Nakamura, I., Endo, R., Shimizu, K., Yasuda, S.P., Koma, T., Taruishi, M. *et al*. (2009). Molecular epidemiological and serological studies of hantavirus infection in Northern Vietnam. *Journal of Veterinary Medical Science* **71**: 1357-1363. https://doi.org/10.1292/jvms.001357

Tsai, Y.L., Chang, C.C., Chuang, S.T. & Chomel, B.B. (2011). *Bartonella* species and their ectoparasites: Selective host adaptation or strain selection between the vector and the mammalian host? *Comparative Immunology, Microbiology and Infectious Diseases* **34**: 299-314. https://doi.org/10.1016/j.cimid.2011.04.005

Tun, Z.M., Moorthy, M., Linster, M., Su, Y.C., Coker, R.J., Ooi, E.E., Low, J.G.H., Smith, G.J.D. & Tam, C.C. (2016). Characteristics of acute febrile illness and determinants of illness recovery among adults presenting to Singapore primary care clinics. *BMC Infectious Diseases* **16**: 612. https://doi.org/10.1186/s12879-016-1958-4

Uy, C.E., Mayxay, M., Harrison, R., Al-Diwani, A., Jacobson, L., Rattanavong, S., Dubot-Pérès, A., Vongsouvath, M., Davong, V., Chansamouth, V. *et al*. (2022). Detection and significance of neuronal autoantibodies in patients with meningoencephalitis in Vientiane, Lao PDR. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **116**: 959-965. https://doi.org/10.1093/trstmh/trac023

Vaca, D.J., Dobler, G., Fischer, S.F., Keller, C., Konrad, M., von Loewenich, F.D., Orenga, S., Sapre, S.U., van Belkum, A. & Kempf, V.A.J. (2022). Contemporary diagnostics for medically relevant fastidious microorganisms belonging to the genera *Anaplasma, Bartonella, Coxiella, Orientia,* and *Rickettsia*. *FEMS Microbiology Reviews* **46**: fuac013. https://doi.org/10.1093/femsre/fuac013

Vallée, J., Thaojaikong, T., Moore, C.E., Phetsouvanh, R., Richards, A.L., Souris, M., Fournet, F., Salem, G., Gonzalez, J.P. & Newton, P.N. (2010). Contrasting spatial distribution and risk factors for past infection with scrub typhus and murine typhus in Vientiane City, Lao PDR. *PLoS Neglected Tropical Diseases* **4**: e909. https://doi.org/10.1371/journal.pntd.0000909

Van Peenen, P.F., Ho, C.M. & Bourgeois, A.L. (1977). Indirect immunofluorescence antibodies in natural and acquired *Rickettsia tsutsugamushi* infections of Philippine rodents. *Infection and Immunity* **15**: 813-816. https://doi.org/10.1128/iai.15.3.813-816.1977

Vapalahti, O., Mustonen, J., Lundkvist, A., Henttonen, H., Plyusnin, A. & Vaheri, A. (2003). Hantavirus infections in Europe. *The Lancet Infectious Diseases* **3**: 653-661. https://doi.org/10.1016/s1473-3099(03)00774-6

Vayssier-Taussat, M., Moutailler, S., Fˈmˈnia, F., Raymond, P., Croce, O., La Scola, B., Fournier, P.E. & Raoult, D. (2016). Identification of novel zoonotic activity of *Bartonella* spp., France. *Emerging Infectious Diseases* **22**: 457-462. https://doi.org/10.3201/eid2203.150269

Villarroel, P.M.S., Gumpangseth, N., Songhong, T., Yainoy, S., Monteil, A., Leaungwutiwong, P., Missˈ, D. & Wichit, S. (2023). Emerging and re-emerging zoonotic viral diseases in Southeast Asia: One Health challenge. *Frontiers in Public Health* **11**: 1141483. https://doi.org/10.3389/fpubh.2023.1141483

Wan, S.J., Sulaiman, N., Zulkifli, N.F., Neela, V.K., Chee, H.Y., Masri, S.N., Mohd Ikbal, N.H., Bhassu, S., Omar, H., Al-Obaidi, M. *et al*. (2022). Detection of pathogenic *Leptospira* in rats and phylogenetic analysis using outer membrane lipoprotein *Lipl32* gene at two major public markets. *Malaysian Journal of Medicine and Health Sciences* **18**: 1-5.

Wangdi, K., Kasturiaratchi, K., Nery, S.V., Lau, C.L., Gray, D.J. & Clements, A.C.A. (2019). Diversity of infectious aetiologies of acute undifferentiated febrile illnesses in South and Southeast Asia: A systematic review. *BMC Infectious Diseases* **19**: 577. https://doi.org/10.1186/s12879-019-4185-y

Wangrangsimakul, T., Althaus, T., Mukaka, M., Kantipong, P., Wuthiekanun, V., Chierakul, W., Blacksell, S.D., Day, N.P., Laongnualpanich, A. & Paris, D.H. (2018). Causes of acute undifferentiated fever and the utility of biomarkers in Chiang Rai, Northern Thailand. *PLoS Neglected Tropical Diseases* **12**: e0006477. https://doi.org/10.1371/journal.pntd.0006477

Watson, D.C., Sargianou, M., Papa, A., Chra, P., Starakis, I. & Panos, G. (2014). Epidemiology of hantavirus infections in humans: A comprehensive, global overview. *Critical Reviews in Microbiology* **40**: 261-272. https://doi.org/10.3109/1040841X.2013.783555

Wibowo, A., Vazela, E., Prasetyo, A.A., Firdaus, A.F., Fajrina, L., Annisa, F., Dinilah, I., Nisrina, A., Chairunnisa, F., Aulia, F.P. *et al*. (2022). Spatial cluster modeling of rodent infestations and leptospirosis risks in SE Asian urban areas. medRxiv 2022.03.24.22272865. [**Preprint**]. https://doi.org/10.1101/2022.03.24.22272865

Widiastuti, D., Sholichah, Z., Agustiningsih. & Wijayanti, N. (2016). Identification of pathogenic *Leptospira* in rat and shrew populations using *rpoB* gene and its spatial distribution in Boyolali district. *Kesmas: National Public Health Journal* **11**: 32-38. https://doi.org/10.21109/kesmas.v11i1.798

Widjaja, S., Williams, M., Winoto, I., Farzeli, A., Stoops, C.A., Barbara, K.A., Richards, A.L. & Blair, P.J. (2016). Geographical assessment of rickettsioses in Indonesia. *Vector-Borne and Zoonotic Diseases* **16**: 20-25. https://doi.org/10.1089/vbz.2015.1840

Wijesinghe, A., Gnanapragash, N., Ranasinghe, G. & Ragunathan, M.K. (2015). Fatal co-infection with leptospirosis and dengue in a Sri Lankan male. *BMC Research Notes* **8**: 348. https://doi.org/10.1186/s13104-015-1321-7

Winoto, I.L., Goethert, H., Ibrahim, I.N., Yuniherlina, I., Stoops, C., Susanti, I., Kania, W., Maguire, J.D., Bangs, M.J., Telford, S.R. *et al*. (2005). *Bartonella* species in rodents and shrews in the greater Jakarta area. *The Southeast Asian Journal of Tropical Medicine and Public Health* **36**: 1523-1529.

Witkowski, P.T., Klempa, B., Ithete, N.L., Auste, B., Mfune, J.K.E., Hoveka, J., Matthee, S., Preiser, W. & Kruger, D.H. (2014). Hantaviruses in Africa. *Virus Research* **187**: 34-42. https://doi.org/10.1016/j.virusres.2013.12.039

Wong, T.W., Chan, Y.C., Joo, Y.G., Lee, H.W., Lee, P.W. & Yanagihara, R. (1989). Hantavirus infections in humans and commensal rodents in Singapore. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **83**: 248-251. https://doi.org/10.1016/0035-9203(89)90666-4

Wongprompitak, P., Anukool, W., Wongsawat, E., Silpasakorn, S., Duong, V., Buchy, P., Morand, S., Frutos, R., Ekpo, P. & Suputtamongkol, Y. (2013). Broad-coverage molecular epidemiology of *Orientia tsutsugamushi* in Thailand. *Infection, Genetics and Evolution* **15**: 53-58. https://doi.org/10.1016/j.meegid.2011.06.008

Wu, X.B., Na, R.H., Wei, S.S., Zhu, J.S. & Peng, H.J. (2013). Distribution of tick-borne diseases in China. *Parasites & Vectors* **6**: 119. https://doi.org/10.1186/1756-3305-6-119

Wu, Z., Han, Y., Liu, B., Li, H., Zhu, G., Latinne, A., Dong, J., Sun, L., Su, H., Liu, L. *et al*. (2021). Decoding the RNA viromes in rodent lungs provides new insight into the origin and evolutionary patterns of rodent-borne pathogens in mainland Southeast Asia. *Microbiome* **9**: 18. https://doi.org/10.1186/s40168-020-00965-z

Xu, G., Walker, D.H., Jupiter, D., Melby, P.C. & Arcari, C.M. (2017). A review of the global epidemiology of scrub typhus. *PLoS Neglected Tropical Diseases* **11**: e0006062. https://doi.org/10.1371/journal.pntd.0006062

Yao, X.Y., Liu, H., Sun, J., Zhang, Y.Q., Lv, Z.H., Zhang, X.L. & Shao, J.W. (2022). Epidemiology and genetic diversity of *Bartonella* in rodents in urban areas of Guangzhou, Southern China. *Frontiers in Microbiology* **13**: 942587. https://doi.org/10.3389/fmicb.2022.942587

Yuhana, M.Y., Hanboonkunupakarn, B., Tanganuchitcharnchai, A., Sujariyakul, P., Sonthayanon, P., Chotivanich, K., Pukrittayakamee, S., Blacksell, S.D. & Paris, D.H. (2022). Rickettsial infections are neglected causes of acute febrile illness in Teluk Intan, Peninsular Malaysia. *Tropical Medicine and Infectious Disease* **7**: 134. https://doi.org/10.3390/tropicalmed7070134

Yusof, M.A., Mohd-Taib, F.S., Ishak, S.N., Md-Nor, S., Md-Sah, S.A., Mohamed, N.Z., Azhari, N.N., Neela, V.K. & Sekawi, Z. (2019). Microhabitat factors influenced the prevalence of pathogenic *Leptospira* spp. in small mammal host. *EcoHealth* **16**: 260-274. https://doi.org/10.1007/s10393-019-01419-1

Zou, L.X. & Sun, L. (2020). Analysis of hemorrhagic fever with renal syndrome using wavelet tools in mainland China, 2004–2019. *Frontiers in Public Health* 8: 571984. https://doi.org/10.3389/fpubh.2020.571984