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# A brief review: the prevalence of tick-borne pathogens in urban and suburban areas

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Ticks are widely distributed blood-sucking ectoparasites and vectors for numerous zoonotic pathogens that cause infectious diseases in humans and animals. The increase in the incidence of tick-borne diseases (TBD) is partially associated with climatic changes, such as shorter and warmer winters, prolonged growing seasons, and also with increasing urbanisation. In recent decades, a rising number of established populations of medically important ticks have been reported in urban and suburban areas such as city parks or suburban forests over many regions in Europe. The transformation of natural ecosystems into urban areas becomes actual significant problem because it could affect the circulation of tick-borne pathogens and increase the risk of infection for humans and domestic animals. Tick-borne pathogens, including *Borrelia burgdorferi* s. l., *Rickettsia* spp., *Anaplasma phagocytophilum*, *Candidatus* Neoehrlichia *mikurensis*, and *Babesia* spp., have been detected in urban tick populations in Europe. Such places as parks, leisure-time areas, green spaces, and gardens become endemic zones of tick-borne pathogens. This review describes the investigations on the prevalence of tick-borne pathogens in urbanised areas conducted in Europe during the last fifteen years (2005–2020).

**Keywords:** ticks, tick-borne pathogens, urban and suburban habitats

## INTRODUCTION

Vector-borne diseases are one of the most important public health problems of the 21st century, which is increasing all over the world. At present, vector-borne diseases comprise a large group of worldwide diseases caused by arthropods, such as ticks, fleas, mosquitoes, and others. In Europe, one of the most well-known and widely distributed tick species is *Ixodes ricinus*. This tick is the major vector for a number of pathogens (tick-borne encephalitis virus, *Borrelia burgdorferi* sensu lato, *Borrelia miyamotoi*, *Rickettsia* spp., A*naplasma phagocytophilum, Babesia divergens, Babesia microti,* and others) and parasitizes a wide range of mammals, including the human (Parola, Raoult, 2001; Gray, 2002; García-Álvarez et al., 2013).

The increase in the incidence of tick-borne diseases (TBD) is associated with climatic changes, such as shorter and warmer winters, prolonged growing seasons, and also with rapid urbanisation. The transformation of natural ecosystems into urban areas becomes an major problem because it could affect the circulation of tick-borne pathogens

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and increase the risk of infection for humans and domestic animals. In recent decades, a rising number of established populations of medically important ticks have been reported in urban and suburban areas over many European regions. Environmental changes and the urbanisation process increase the exposure of the human population to ticks. Due to the increased risk of tick bites, it is necessary to investigate the prevalence of tick-borne infections in ticks from urban and suburban areas (Grochowska et al., 2020). Usually, the various types of developed human settlements are divided into urban, suburban, and rural. An urban area is a region surrounding a city. It can be characterised as areas with a high density of human population and infrastructure of the built environment and contains no rural land. Urban habitats comprise public parks, city forests, and green areas used for recreational activities and highly frequented by people. Suburban areas are zones of lower population density located near cities. Suburban areas have greater natural diversity. There are represented by gardens, long-distance footpaths, and leisure-time areas for hiking, biking, and horse riding. Finally, rural areas are located outside towns and cities dominated by the natural environment and the presence of farming or forestry. Suburban and rural areas are rich in species of wild animals (large and small mammals, and birds). It should be noted that some species of mammals and birds are the main hosts of ticks and reservoirs for tick-borne pathogens. In urbanised areas, wild animals and their ectoparasites adapt to the new environment, and ticks are an example of species that well adapt to new conditions. For this reason, the diversity and number of wildlife ectoparasites and pathogens transmitted by them in urbanised areas may increase (Pfäffle et al., 2013; Rizzoli et al., 2014). Several reports indicate that ticks are well adapted to urban and suburban environments (reviewed in Michalski et al., 2020).

An opinion still exists that the major risk of ticks and tick-borne diseases is associated with wooded and high grass areas. However, in recent decades, more reports have appeared which focus on tick and tick-borne infections in urban and suburban landscapes (Akimov, Nebogatkin, 2016). It is not surprising, because currently more than half of the world's population lives in urban areas; hencepublic parks, gardens, and leisure-time areas have become particularly important places where humans and domestic animals can encounter potentially infected questing ticks.

Despite the growing interest in the study of ticks in cities, the prevalence of tick-borne pathogens in urban and suburban areas is still not well known. In Europe, populations of urban ticks and pathogens transmitted by them were studied in Germany, Poland, Slovakia, the Czech Republic, Switzerland, Finland, and Italy (Table). This review describes the prevalence of tick-borne pathogens isolated from

Table. **The occurrence of tick-borne pathogens in questing ticks in urban and suburban areas in Europe**

| Localities | Habitat | Pathogenic agent | Prevalence, % | References |
|---|---|---|---|---|
| Czech Republic | urban forest, park, suburban area | *B. burgdorferi* s. l. | 17.3% | Venclikova et al., 2015; Kybicova et al., 2017 |
| | | *A. phagocytophilum* | 4.4% | |
| | | *Babesia* spp. | 0% | |
| Finland | urban city parks, yards, vegetation-flanked walkways, green public spaces | *Borrelia* spp. (*B. afzelii*, *B. garinii*, *B. valaisiana*, *B. burgdorferi* s. s.) | 18.9–23.0% | Sormunen et al., 2016, 2020; Klemola et al., 2019 |
| | | *A. phagocytophilum* | 1.1–5.1% | |
| | | *Rickettsia* spp. (*R. helvetica; R. monacensis*) | 7.9–16.2% | |
| | | *C. N. mikurensis* | 1.0–2.5% | |
| | | *Babesia* spp. (*B. venatorum*; *B. capreoli*) | 0.4–1.4% | |

Table. **(Continued)**

| Localities | Habitat | Pathogenic agent | Prevalence, % | References |
|---|---|---|---|---|
| Germany | city parks, gardens, urban woodland, public recreation areas | *Borrelia* spp. (*B. garinii/B. bavariensis; B. afzelii; B. valaisiana; B. burgdorferi s. s.; B. spielmanii; B. bissettii; B. lusitaniae*) | 24.1–34.1% | Schorn et al., 2011; Silaghi et al., 2012; Overzier et al., 2013a, 2013b; May et al., 2015; Blazejak et al., 2017, 2018 |
| | | *A. phagocytophilum* | 1.7–7.4% | |
| | | *Rickettsia* spp. | 22.9–50.8% | |
| | | *Babesia* spp. (*B. venatorum*, *B. microti*, *B. capreoli*, *B. divergens*, *B. gibsoni*) | 0.3–3.4% | |
| Italy | Urban park | *B. burgdorferi* s. l. | 26.7–36% | Mancini et al., 2014; Aureli et al., 2015 |
| | | *A. phagocytophilum* | 7.9% | |
| | | *Rickettsia* spp. | 36.0% | |
| | | *B. microti* | 4.0% | |
| Lithuania | Urban parks | *B. burgdorferi* s. l. (*B. garinii*; *B. afzelii*) | 25.0% | Žygutienė et al., 2008 |
| | | *A. phagocytophilum* | 0% | |
| | | *Babesia microti* | 0% | |
| Poland | Urban parks, forest, | *Borrelia* spp. (*B. afzelii*, *B. burgdorferi*, *B. garinii*, *B. lusitaniae*, *B. spielmani* and *B. valaisiana*) | 11–27.4% | Welc-Falęciak et al., 2012, 2014; Stanczak et al., 2015; Kowalec et al., 2017, 2019; Kubiak et al., 2019 |
| | | *A. phagocytophilum* | 3–5.3% | |
| | | *Rickettsia* spp. (*R. helvetica*; *R. monacensis*) | 6.5–7.7% | |
| | | *Ca. N. Mikurensis* | 0–0.5% | |
| | | *Babesia* spp. (*B. venatorum*, *B. canis*) | 0.6-4.5% | |
| Slovakia | Suburban, urban forests, urban parks, cementaries | *Borrelia* spp. (*B. afzelii*, *B. garinii*, *B. burgdorferi s. s.*, *B. valaisiana*, *B. spielmanii*) | 6.8–10.15% | Pangrácová et al., 2013; Špitalská et al., 2014; Svitálková et al., 2015; Hamšíková et al., 2016; Minichová et al., 2017; Chvostáč et al., 2018 |
| | | *A. phagocytophilum* | 2.69–5.9% | |
| | | *Rickettsia* spp. (*R. helvetica*, *R. monacensis*) | 0.2–13.3% | |
| | | *Ca. N. Mikurensis* | 2.39% | |
| | | *Babesia* spp. | 1.2% | |
| Switzerland | urban parks, river sides, cemeteries, suburban forests, areas | *Borrelia* spp. (*B. afzelii*, *B. burgdorferi* s. s., *B. garinii*, *B. valaisiana*, *B. miyamotoi*) | 18.0% | Oechslin et al., 2017 |
| | | *A. phagocytophilum* | 1.4% | |
| | | *Rickettsia* spp. (*R. helvetica*, *R. monacensis*) | 13.5% | |
| | | *Ca. N. Mikurensis* | 6.2% | |
| | | *B. venatorum* | 0.8% | |

ticks in urbanised areas that can potentially cause diseases in humans and domestic animals in Europe based on the data reported in the literature from 2005 to 2020.

## PATHOGENS OF MEDICAL AND VETERINARY IMPORTANCE TRANSMITTED BY TICKS IN URBAN AND SUBURBAN AREAS

**I.** In Europe, **Lyme borreliosis** is the most commonly diagnosed and widely known systemic infectious disease caused by the spirochetes of ***Borrelia burgdorferi*** **sensu lato** (s. l.) complex (now comprising about 20 named and proposed genospecies) transmitted by Ixodidae ticks (Casjens et al., 2011; Becke et al., 2016). The main vectors of *B. burgdorferi* s. l. in Europe are two tick species from the genus Ixodes: *I. ricinus* and *I. persulcatus*. Nine of *B. burgdorferi* s. l. genospecies have been detected in European *I. ricinus* ticks (Rauter, Hartung, 2005). In Europe, *B. afzelii*, *B. garinii*, *B. burgdorferi* s. s., *B. valaisiana*, and *B. lusitaniae* are the most common of them. Genospecies commonly associated with localised, disseminated, and chronic manifestations of Lyme borreliosis are *B. afzelii*, *B. burgdorferi* s. s., and *B. garinii* (Tilly et al., 2008; Rizzoli et al., 2011; Kowalec et al., 2017).

Frequently, most ticks become infected with *Borrelia* during their larval feeding on infected hosts (Tilly et al., 2008), but if a tick is infected with *Borrelia* at the larval stage, it will be infected at all other stages of its development due to transstadial transmission of bacteria. Studies conducted in Europe have demonstrated that *B. burgdorferi* s. l. infection in *I. ricinus* ticks collected in urban parks, gardens, or suburban habitats is distributed approximately at the same rate as in *I. ricinus* collected in forests. In Poland, no significant differences in the prevalence of *Borrelia* spp. between urban and natural areas was detected and the risk factors of borreliosis appear to be similar in urban and natural areas, in cities and endemic forest areas (Kowalec et al., 2017). Authors detected six species of bacteria present in both types of areas, with different frequencies: *B. afzelii* was the dominant species in urban areas, and *B. garinii* in natural areas (Kowalec et al., 2017). In Finland, the most common pathogens detected in the *I. ricinus* populations in urban areas belong to the *B. burgdorferi* s. l. complex represented by *B. afzelii*, *B. garinii*, and *B. burgdorferi* s. s. (Klemola et al., 2019; Sormunen et al., 2020). The authors' findings demonstrated that the prevalence and diversity of tick-borne pathogens in urban areas were comparable to those found in natural areas. *Borrelia* spp. infection in ticks in urban areas range from 17.9% to 24.4% in Germany (Maetzel et al., 2005; Tappe et al., 2014; May et al., 2015; Blazejak et al., 2018), from 22% to 26.7% in Italy (Mancini et al., 2014; Aureli et al., 2015), and reach 18.0% in suburban areas in Switzerland (Oechslin et al., 2017). The prevalence of *B. burgdorferi* s. l. in urban and suburban forests was recorded to reach 20.5% across various cities in Slovakia. The authors detected the presence of six species with the dominance of *B. afzelii*, *B. garinii*, *B. burgdorferi* s. s. and *B. valaisiana* (Pangrácová et al., 2013; Chvostáč et al., 2018).

*B. afzelii* and *B. garinii* species are frequently detected in ticks in inhabited urban and suburban environments. It has been shown that the presence of different *B. burgdorferi* s. l. pathogens in ticks is correlated with the abundance of reservoir hosts in urban areas (Chvostáč et al., 2018). Small rodents (especially *Apodemus* spp., *Microtus* spp., and *Myodes glareolus*) are regarded as the most important hosts for the maintenance of immature stages of *I. ricinus* and the main reservoir hosts for Lyme borreliosis pathogens such as *B. afzelii*, *B. bavariensis*, *B. burgdorferi* s. s., and *B. spielmanii* in urban and suburban habitats across Europe. Rats (*Ratus norvegicus* and *R. rattus*) can also play an important role in the urban maintenance of *B. afzelii* and *B. spielmanii*. *B. afzelii B. burgdorferi* s. s. and *B. spielmanii* can also be maintained in hedgehogs (*Erinaceus europaeus* and *E. roumanicus*) and red squirrels (*Sciurus vulgaris*) (which are usually heavily infested by ticks), especially in urban areas (reviewed in Rizzoli et al., 2014, Chvostáč et al., 2018). Birds, especially ground-foraging bird species (such as common blackbird *Turdus merula*, song thrush

*T. philomelos*, and European robin *Erithacus rubecula*) play an important role in the epidemiology of Lyme borreliosis and are associated with transmission of *B. garinii* and *B. valaisiana* to ticks in urban and suburban areas (reviewed in Rizzoli et al., 2014). Consequently, birds, rodents, and other mammals create suitable conditions for the spread of *Borrelia* pathogens transmitted by ticks in both natural habitats and urban areas.

Several studies in Lithuania have addressed the prevalence of *Borrelia burgdorferi* s. l. in questing ticks and ticks collected from their animal hosts (Turčinavičienė et al., 2006; Paulauskas et al., 2008; Žėkienė et al., 2011; Radzijevskaja et al., 2013) in different natural habitats. These studies demonstrated that the prevalence of *Borrelia burgdorferi* s. l. in questing *I. ricinus* ticks varied locally from 1.6% to 29.2% and among different habitat types (from 8.6% in pine forests to 19.4% in deciduous and mixed forests). Only one study, by Žygutienė et al. (2008), reported the prevalence of *Borrelia burgdorferi* s. l. pathogens in ticks collected in urban habitats in Lithuania. During this study, 36 adult *I. ricinus* ticks were collected in two city parks in the centre of Vilnius, and, despite the small sample size, several important tick-borne pathogens, *B. afzelii*, and *B. garinii* among them, were detected. The authors concluded that people visiting these parks were exposed to the risk of tick-borne infection transmitted by ticks, especially when resting on the grass (Žygutienė et al., 2008). However, further investigations are necessary to assess the risk of *Borrelia* infection in non-urban areas in Lithuania.

**II. *Anaplasma phagocytophilum*** is small gram-negative intracellular bacterium, which is the main agent causing tick-borne disease such as granulocytic anaplasmosis in humans (HGA) and animals (Dumler et al., 2006; Nicholson et al., 2010). *A. phagocytophilum* is wide distributed across Europe, Asia and the USA (Carlyon et al., 2003; Stuen et al., 2013). Clinical manifestations of *A. phagocytophilum* infection range from non-specific influenza-like symptoms with fever, headache, myalgia, leukopenia, thrombocytopenia, to fatal infections for patients. This bacterium is transmitted via a bite of tick of the genus *Ixodes* and infects a variety of animals, including ruminants, rodents, insectivores, birds and reptiles. *A. phagocytophilum* can also cause disease in pets, commonly in dogs. A wide range of *A. phagocytophilum* seroprevalence in dogs was determined: 43% in Germany (Jensen et al., 2007; Kohn et al., 2011), 11–12% in Latvia (Berzina et al., 2013), and 17% in Poland (Dzięgiel et al., 2017). It is suspected that the prevalence of infection in dogs is related to the distribution and seasonality of ticks (Carrade et al., 2009; Berzina et al., 2013). *A. phagocytophilum* was also detected in ticks collected from dogs in urban areas in Poland (Michalski et al., 2020).

The infection rate of *A. phagocytophilum* in ticks collected in urban and suburban areas in Slovakia, Switzerland, Poland, Germany, the Czech Republic, and Italy was found less than 10%. In Switzerland, the infection rate of *I. ricinus* by *A. phagocytophilum* in urban parks and forests, suburban forests, and cemeteries was 1.4% (Oechslin et al., 2017). In Slovakia, the prevalence of *A. phagocytophilum* was significantly higher in ticks collected in the urban/suburban habitats (7.2%) compared to that in the natural habitat (3.1%) (Svitálková et al., 2015). Similar findings come from Germany, where the prevalence of *A. phagocytophilum* in questing *I. ricinus* was 4.9–7.4% in urban areas, 1.1–2.8% in pasture, and 4.0–5.8% in natural areas (Overzier et al., 2013). In Poland, the prevalence of infection in urban sites (3%) was almost three times higher than in natural sites (1.1%) (Welc-Falęciak et al., 2014). In Europe, *A. phagocytophilum* consists of two genetically distinct ecotypes that circulate in two enzootic cycles: one involving rodents and *Ixodes trianguliceps* ticks and the other involving ungulates, carnivores, insectivores, and *I. ricinus* ticks (Bown et al., 2009; Blanarova et al., 2014). Thus, *I. ricinus* ticks could not acquire *A. phagocytophilum* while feeding on infected rodents. In recent study performed in Slovakia, *A. phagocytophilum* was detected in 5.9% of questing *I. ricinus* ticks collected in urban forested areas. Pathogen prevalence was significantly higher compared with *A. phagocytophilum* prevalence previously detected in various urban and sylvatic habitats in Slovakia (rewied in Chvostáč et al., 2018). The authors suggested that a higher infection rate may have been affected by the presence of roe deer and hedgehogs, the main reservoir hosts of *A. phagocytophilum* strains specific for *I. ricinus*, in the study area (Chvostáč et al., 2018). In Italy, where ticks were collected from three parks, *I. ricinus* was the only species found positive for *A. phagocytophilum* infection with prevalece 7.9% (Aureli et al., 2015). In the Czech Republic, comparing only the data of spring season, the highest prevalence of *Anaplasma* (8.6%) infection was found in the urban park, while the prevalences detected in rural and mountain locations were lower (0.8% and 1.6%, respectively) (Kybicová et al., 2017). It could be concluded that infection risks associated with the presence of *Anaplasma* in ticks in urban areas may be comparable to or even higher than those in natural ecosystems.

In Lithuania, *A. phagocytophilum* was detected in questing *I. ricinus* and *D. reticulatus* ticks with prevalence of 2.9% and 8%, respectively (Paulauskas et al., 2012). Using real-time PCR analysis, *A. phagocytophilum* DNAwas also detected in 35.0% of dogs presented in veterinary clinics in Lithuanian cities (Radzijevskaja et al., 2020).

**III. *Candidatus* Neoehrlichia *mikurensis***, the recently emerging pathogen, is a small, gram-negative, pleomorphic bacteria of the Anaplasmataceae family, which causes neoehrlichiosis, a severe systemic inflammatory syndrome (Kawahara et al., 2004; Silaghi et al., 2015). *Ca. N. mikurensis* was first identified as a human pathogen in 2010 (Welinder-Olsson et al., 2010). This pathogen was added to the list of tick-borne pathogens that cause human diseases in Europe. The main vector of '*Ca. N. mikurensis*' is *I. ricinus*, and rodents act as reservoir hosts. *Ca. N. mikurensis* has been detected in *I. ricinus* ticks from many European countries (including the Baltic countries) with prevalence ranging between 1% and 11%, and in ticks collected from wild and domestic vertebrates (Rizzoli et al., 2014; Portillo et al., 2018). However, very few reports on the prevalence of *Ca. N. mikurensis* in *I. ricinus* ticks in European urban areas were found. In Slovakia, the rate of infection with *Ca. N. mikurensis* in urban and suburban areas varied from 0.1% to 2.7% (Pangrácová et al., 2013; Derdáková et al., 2014; Svitálková et al., 2016). A similar infection rate was detected in *I. ricinus* in urbanised areas in Finland (0–2.5%) (Sormunen et al., 2016; Klemola et al., 2019; Sormunen et al., 2020) and in Poland (0% to 0.5%) (Welc-Falęciak et al., 2014). In Switzerland, however, the infection rate in urban areas was much higher (6.2–6.4%) (Lommano et al., 2012; Oechslin et al., 2017). In Slovakia, the prevalence of *Ca. N. mikurensis* in urban and natural habitats differed significantly: in natural areas, the percentage of *Ca. N. mikurensis*-positive ticks and rodents was significantly higher than in urban areas (Svitálková et al., 2016). *Ca. N. mikurensis* is an emerging pathogen that might be found in increasing numbers in ticks from urban sites, in small mammals, and humans in future (Rizzoli et al., 2014).

**IV. *Rickettsia*** (family *Rickettsiaceae*; order *Rickettsiales*), which is the causative agent of human rickettsiosis, is a gram-negative, obligate, intracellular bacterium transmitted by ticks, mites, fleas, and lice (Raoult, Roux, 1997). Rickettsioses are associated with hard ticks belonging to the Spotted Fever (SF) rickettsiae, with the exception of *Rickettsia akari* (mite-borne) and *R. felis* (flea-borne) (Rizzoli et al., 2014). The presence of tick-borne rickettsiae has been reported from almost all European countries. Ixodidae ticks can transmit these bacteria transstadially and transovarially and serve both as vectors and reservoirs of these pathogens (Raoult, Roux, 1997; Murray et al., 2016). *I. ricinus* and *Dermacentor* spp. are the most important hard tick species in Europe, which are implicated in the transmission of tick-borne rickettsiae. The tick *I. ricinus* is the main vector of *R. helvetica* and *R. monacensis*, while *R. raoultii* and *R. slovaca* are commonly found in *D. reticulatus* and *D. marginatus* (Parola et al., 2013). Small rodents, which are the main hosts for immature stages of ixodid ticks, are suspected to serve as reservoirs of rickettsiae (Parola et al., 2013; Obiegala et al., 2017). In Europe, *R. helvetica*, *R. raoultii*, and *R. slovaca* have been detected in rodents (Martello et al., 2013; Minichová et al., 2014; Obiegala et al., 2016, 2017; Mardosaitė-Busaitienė et al., 2018). Different species of rodents could also play an important role in the urban maintenance of ticks and *Rickettsia* pathogens.

In Europe, the prevalence of *Rickettsia* in ticks varies greatly, from 0.5% to even 66%, depending on the study location (reviewed in Rizzoli et al., 2014). Several studies conducted in Europe have investigated the prevalence of *Rickettsia* spp. in tick populations in urbanised areas. In Poland, where the relatively low overall prevalence of infection with *Rickettsia* spp. in ticks was detected (4.4%; 5.6%), more ticks were infected with these bacteria in urban areas (6.5%; 7.7%) than in natural areas (2.9%; 4.4%) (Welc-Falęciak et al., 2014; Kowalec et al., 2019). Similar infection prevalence was reported in recreational sites in the urban areas of Bavaria in Germany (6.4–7.7%), Bratislava (7.8%), Paris (5.8%), Slovakia (6.6%), and Finland (7.9–10.2%) (Schorn et al., 2011; Kowalec et al., 2019; Klemola et al., 2019; Sormunen et al., 2020). In Slovakia, where the presence of *Rickettsia* spp. was examined in different species of Ixodidae ticks collected in different habitat types, the prevalence of infection in questing *I. ricinus* ticks from suburban, natural, and rural habitats was 6.6%, 7.2%, and 2.8%, respectively, while in *D. marginatus* ticks, *Rickettsia* spp. were detected only in rural habitats with prevalence 21.4% (Špitalská et al., 2014; Minichová et al., 2017). Authors detected dominance of *I. ricinus* across all study sites, and the highest diversity of tick species in the rural habitat, where *D. marginatus*, *Haemaphysalis concinna* and *Haemaphysalis inermis* were found in addition to the dominant *I. ricinus* (Minichová et al., 2017).

In all reviewed studies, the dominant species detected in *I. ricinus* ticks in urban and suburban areas was *R. helvetica*, whereas *R. monasensis* was detected with much lower prevalence (Kowalec et al., 2019). *R. slovaca* and *R. raoultii* were identified in *D. marginatus* (Minichová et al., 2017).

Blazejak et al. (2017) showed significantly increased infection rate with *Rickettsia* spp. in tick population during a 10-year period: from 33.3% in 2005 and 26.2% in 2010 to 50.8% in 2015. This is one of examples of how the spread of pathogens can change over the years.

In Lithuania, the prevalence of *Rickettsia* spp. was investigated in *I. ricinus* and *D. reticulatus* ticks and in different species of small mammals in natural habitats (Radzijevskaja et al., 2008; Mardosaitė-Busaitienė et al., 2018; Radzijevskaja et al., 2015). The prevalence of *Rickettsia* spp. in questing *D. reticulatus* and *I. ricinus* was 4.9% and 17%, respectively. The overall prevalence detected in small mammals was 27.6%.

Different species of tick hosts presented in city parks and small urban forests, large human population, and increasing transformation of the natural environment provide ideal conditions for the circulation and spread of tick-borne *Rickettsia* spp. (Rizzoli et al., 2014).

**V. Babesiosis**, which is caused by different intraerythrocytic protozoan *Babesia* parasites, is recognized as an important tick-borne infectious disease in humans and animals. *Babesia* spp. are considered to be emerging pathogens in Europe that circulate in a natural tick-reservoir host cycle and is usually transmitted to humans, wild and domestic animals through the bite of an infected tick. In Europe, *I. ricinus* tick is the main vector of the Babesia species (*B. divergens*, *B. venatorum*, and *B. microti*) causing human babesiosis (Hildebrandt et al., 2013). *B. divergens* is the most widespread and pathogenic *Babesia* species infecting cattle in northern temperate areas. *D. reticulatus* has been recognized as the most important vector of *B. canis*, the causative agent of canine babesiosis for dogs in Europe (Schaarschmidt et al., 2013; Solano-Gallego et al., 2016). Over the last decades, spread of canine babesiosis due to *B. canis* to the previously non-endemic areas has been reported in Europe (Solano-Gallego, Baneth, 2011). Previous studies conducted in different European countries showed that the prevalence of *B. canis* in adult *D. reticulatus* varies from 0% to 14.8%. Thus, any urban or suburban area where cattle, dogs, and *I. ricinus* and

*D. reticulatus* ticks are found is potentially at risk. The reservoir hosts of *Babesia* spp. varied from small mammals (*B. microti*) to medium and large mammals, such as dogs (*B. canis*), cattles, and cervids (*B. divergens* and *B. capreoli*) (Yabsley, Shock, 2012; Overzier et al., 2013a; Andersson et al., 2016). The prevalence of *Babesia* spp. in ticks from urban and suburban habitats has been reported in several European countries. In eastern Germany, the prevalence of *Babesia* spp. in *I. ricinus* ticks collected in an urban park was found to be 0.4–0.7%. Moreover, most of *Babesia*-positive ticks were found on sampling sites with permanent population of large mammals (Schorn et al., 2011). In south Germany, *I. ricinus* infection rate with *Babesia* spp. in urbanised areas ranged from 0.3% to 3.4% (Silaghi et al., 2012; Overzier et al., 2013). The dominant *Babesia* species found in *I. ricinus* ticks was *B. venatorum* and *B. microti*; however, single cases of *B. capreoli*, *B. divergens* and *B. gibsoni* were detected. Studies conducted in Belgium, Slovakia, and Finland found similarly low prevalence of *Babesia* spp. in ticks from urban and suburban areas: 0.2% (Heylen et al., 2019), 1.2% (Hamšíková et al., 2016), and 0.4%, respectively (Sormunen et al., 2020). The highest *Babesia* spp. infection rate of 4.5% in urban areas was reported in Poland, and it exceeded the rate in rural areas (2.5%). *B. venatorum* (detected in *I. ricinus*) and *B. canis* (detected in *D. reticulatus*) (Stanczak et al., 2015) were the dominant *Babesia* species in both areas.

In Lithuania, different *Babesia* spp. have been detected in *I. ricinus* and *D. reticulatus* ticks from various natural habitat types and in city dogs (Paulauskas et al., 2014; Radzijevskaja et al., 2018; Radzijevskaja et al., 2020). *Babesia* spp. were detected in 1.2% (26/2259) of questing *D. reticulatus* (mostly *B. canis*, and one case of *B. venatorum*) and in 9.5% (35/370) of *I. ricinus* ticks (represented by *B. venatorum*, and *B. microtii*). Although previously uncommon, canine babesiosis has become quite frequent in Lithuania during the past decade and an increasing number of cases with a wide variety of clinical symptoms have been recorded throughout the country. *Babesia* spp. could be endemic to urban and suburban parks in Lithuania, especially those adjoining more natural or semi-natural areas such as forests or rural areas, and public health risk during recreational activities should be emphasised.

## CONCLUSIONS

This short review surveys studies on the prevalence of tick-borne pathogens *Borrelia burgdorferi* s. l. complex, *Rickettsia* spp., *Anaplasma phagocytophilum*, *Candidatus N. mikurensis* and *Babesia* spp. in urbanised areas conducted in Europe during the last 15 years (2005–2020). The presence of these pathogens found in ixodid ticks with the same or higher infection rates than in natural habitats demonstrates that tick-borne diseases are endemic to urban and suburban areas and the potential health risk to humans and domestic animals in these areas should not be underestimated. Variation in the abundance and diversity of tick hosts – medium-sized and small size mammals, ground-foraging birds (especially in parks and small urban forests) – has been suggested as a crucial determinant of the prevalence and density of tick-borne pathogens. In urban habitats, humans and their companion animals (mainly dogs), small mammals and birds probably play a significant role as tick hosts and sources of tick-borne pathogens. The presence of large vertebrates (like cervids), which serve as hosts for ticks and as reservoirs of a number of zoonotic pathogens in suburban and rural areas, allows long-term maintenance of the tick population. Urban and suburban areas should be included in surveillance for tick-borne diseases, because the variation of tick density in urbanised areas is clearly unexplained and the risk of pathogens in urban environment needs to be understood. Due to changing environmental conditions, rising abundance of ticks, and diversity of tick-borne pathogens , priority should be given to more comprehensive research on ticks and their pathogens in urban areas.

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## ERKIŲ PERNEŠAMŲ PATOGENŲ PAPLITIMAS MIESTUOSE IR PRIEMIESČIUOSE: TRUMPA APŽVALGA

*Santrauka*

Erkės yra plačiai paplitę kraują siurbiantys ektoparazitai ir daugelio zoonozinių patogenų, sukeliančių žmonių ir gyvūnų infekcines ligas, pernešėjai. Erkių platinamų ligų išplitimas siejamas su klimato pokyčiais – trumpesnėmis ir šiltesnėmis žiemomis, užsitęsusia vegetacija bei didėjančia urbanizacija. Pastaraisiais dešimtmečiais daugelyje Europos regionų erkių populiacijos didėja miestų ir priemiesčių teritorijose, pvz., miestų parkuose ar priemiesčių miškuose. Natūralių ekosistemų transformacija į miesto teritorijas gali paveikti erkių platinamų patogenų cirkuliaciją ir padidinti infekcijos riziką žmonėms bei naminiams gyvūnams. Erkių platinami patogenai, įskaitant *Borrelia burgdorferi* s. l., *Rickettsia* spp., *Anaplasma phagocytophilum*, *Candidatus* Neoehrlichia *mikurensis* ir *Babesia* spp., buvo aptikti miesto erkių populiacijose Europoje. Tokios vietos kaip parkai, laisvalaikio praleidimo zonos, žaliosios erdvės, sodai tampa endeminėmis erkių platinamų ligų sukėlėjų zonomis. Šioje apžvalgoje aprašomi erkių platinamų patogenų urbanizuotose vietovėse tyrimai, atlikti Europoje per pastaruosius penkiolika metų (2005–2020 m.).

**Raktažodžiai:** erkės, erkių pernešami patogenai, miesto ir priemiesčio buveinės