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Review article

Tourist attractions of southern Poland – risk of tick infestation and exposure to tick-borne diseases

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ABSTRACT. The southern region of Poland, rich in natural and tourist attractions, encourages outdoor recreation and spending time in nature. Ongoing climate change, including global warming, has contributed to an increased abundance of ticks and an extended period of their seasonal activity. Consequently, the number of tick-borne disease cases continues to rise, and their diagnosis and treatment are often challenging and prolonged. The aim of this study is to summarize current knowledge on the occurrence of ticks in tourist areas of southern Poland and to raise public health awareness among individuals engaged in tourism and recreation, particularly regarding tick presence and the tick-borne diseases they transmit. To achieve the above goal, a review of available scientific and review articles on tick fauna and their role in the transmission of tick-borne disease pathogens in southern Poland was conducted. Electronic databases such as PubMed and Google Scholar were used in the literature analysis. The presence of ticks belonging to the family Ixodidae (*Ixodes ricinus*, *Ixodes vespertilionis*), Amblyommidae (*Dermacentor reticulatus*), and Argasidae (*Argas reflexus*, *Argas polonicus*) has been confirmed. In ticks collected from vegetation and humans in southern Poland, the presence of the following pathogens has been confirmed: *Borrelia burgdorferi* sensu lato, *Anaplasma phagocytophilum*, *Babesia microti*, *Toxoplasma gondii*, tick-borne encephalitis virus, *Ehrlichia chaffeensis*/*Ehrlichia muris*, *Rickettsia* spp., and *Coxiella burnetii*, as well as various coinfections. Knowledge of tick distribution and the pathogens they transmit plays a key role in assessing the risk of human and animal exposure to tick-borne diseases. Equally important is the dissemination of information on preventive strategies and protective measures against tick bites. The presence of ticks in recreational and tourist areas underscores the need for ongoing educational activities concerning ticks and tick-borne diseases in southern Poland.

Keywords: recreation, southern Poland, tick-borne diseases, ticks, tourist

Introduction

Southern Poland is a region rich in history, culture, and picturesque landscapes. It comprises five voivodeships (Opolskie, Silesian, Świętokrzyskie, Lesser Poland, and Subcarpathian) and offers extensive areas for hiking tourism, including routes for enthusiasts of trekking, history, and culture, as well as numerous thematic trails such as educational, architectural, papal, and cycling paths. The landscapes of southern Poland span mountainous, upland, and lowland areas. These regions provide a variety of tourist attractions: the mountains offer excellent conditions for hiking and climbing, while national and landscape parks serve as additional points of interest and places for recreation. Southern Poland attracts increasing numbers of tourists and local residents each year. The lifestyle of modern societies-active leisure, the development of tourism, growing interest in extreme sports, and the desire to explore and occupy new, previously inaccessible areas-may, however, carry negative consequences. These factors can contribute to an increased risk of developing tick-borne diseases, among other health threats. Ticks are common parasitic arthropods that feed on the blood of animals and humans. In Poland, 19 species of these arachnids are currently considered permanent components of the native fauna [1–3]. Climate changes associated with global warming-shorter winters, longer and more humid summers, and higher temperatures – have contributed to the extension of tick seasonal activity and increased survival rates. These factors may influence the rising number of tick-borne disease cases observed in Poland and across Europe. These parasites are also expanding into new geographic areas and higher altitudes, which increases the risk of human exposure to infestation [4,5]. The frequency and risk of contact with ticks infected with pathogens in areas used for recreational purposes remain insufficiently defined.

The aim of this study is to provide an overall assessment of the potential exposure of humans and animals to tick infestation and to tick-borne pathogens in selected tourist and recreational areas of southern Poland. An important goal is also to increase public health awareness among individuals participating in tourism, particularly regarding tick habitats and the tick-borne diseases they transmit.

Materials and Methods

A review of available articles concerning ticks and the tick-borne pathogens detected in them in southern Poland was conducted. The largest number of studies on the occurrence of ticks in tourist, recreational, and protected areas was recorded in the Lesser Poland Voivodeship and Silesian Voivodeship, fewer in the Subcarpathian and Opolskie regions, and only limited data are available for the Świętokrzyskie Voivodeship. Sampling locations and years were compared, and a species overview of ticks, as well as the presence of tick-borne pathogens in this region of Poland, was compiled. The literature search was conducted using PubMed and Google Scholar with the following keywords: "ticks southern Poland", "tick-borne pathogen in southern Poland", "tourist and recreational areas"; in addition, conference abstracts and specialist monographs were reviewed.

Hiking tourism and recreation in relation to tick occurrence risk in southern Poland

Southern Poland offers a wide range of hiking trails suitable for both beginners and advanced tourists. The large number of visitors, alongside individuals living or working in protected, tourist, and recreational areas, significantly increases the potential pool of hosts for ticks inhabiting these regions and raises the likelihood of human contact with these dangerous parasites.

In the area of the Silesian Voivodeship, the presence of *I. ricinus* (Linnaeus, 1758) and *Dermacentor reticulatus* (Fabricius, 1794) has been documented (Fig. 1). The occurrence of *I. ricinus*, the most widespread tick species in Poland and Europe and of the greatest medical and veterinary importance, has been repeatedly confirmed within the Silesian Voivodeship. *Ixodes ricinus* inhabits moist environments, mainly deciduous and mixed forests, humid pastures, and shrublands. It is increasingly found in urban areas as well, such as housing estate greenspaces, home gardens, and recreational areas. Its presence in the Silesian agglomeration was recorded as early as 1994–2000. Ticks were collected in mixed forests, meadows, pastures, parks, and also near picnic sites and in the vicinity of the "Barbara" coal mine in Mikołów [6–8]. Subsequent studies conducted in 2008–2009 confirmed the presence of this species near water reservoirs, lakes, retention basins, and in areas of landscape and recreational value. In the years 2010–2012, ticks were also found in the vicinity of major cities of the Silesian agglomeration: Katowice, Mikołów, Chorzów, and Sosnowiec [6,9]. Research is often conducted in recreational and tourist areas, where the risk of tick feeding on humans is higher. In the Tarnowskie Góry district, *I. ricinus* ticks were collected repeatedly; studies were conducted between 2001–2003 and again in 2015 in deciduous and mixed forests [10–12]. In 2008–2011, the presence of *I. ricinus* was confirmed during studies carried out across multiple locations throughout the Silesian Voivodeship in recreational areas situated mostly near water reservoirs and/or in forests, including campsites, trekking and cycling trails, restaurants, and entertainment sites [13]. Ticks were also found in 2010 during collections from three geographically distinct areas, including a dry forested region, an industrial and urbanized area, and forested mountain terrain. It was observed that the number of active ticks was significantly higher in spring than in summer and autumn, and their activity gradually decreased from summer to winter [5]. Research also covered the area near Piekary Śląskie, where water reservoirs of high biocenotic, landscape, and recreational value are located, and where numerous recreational facilities

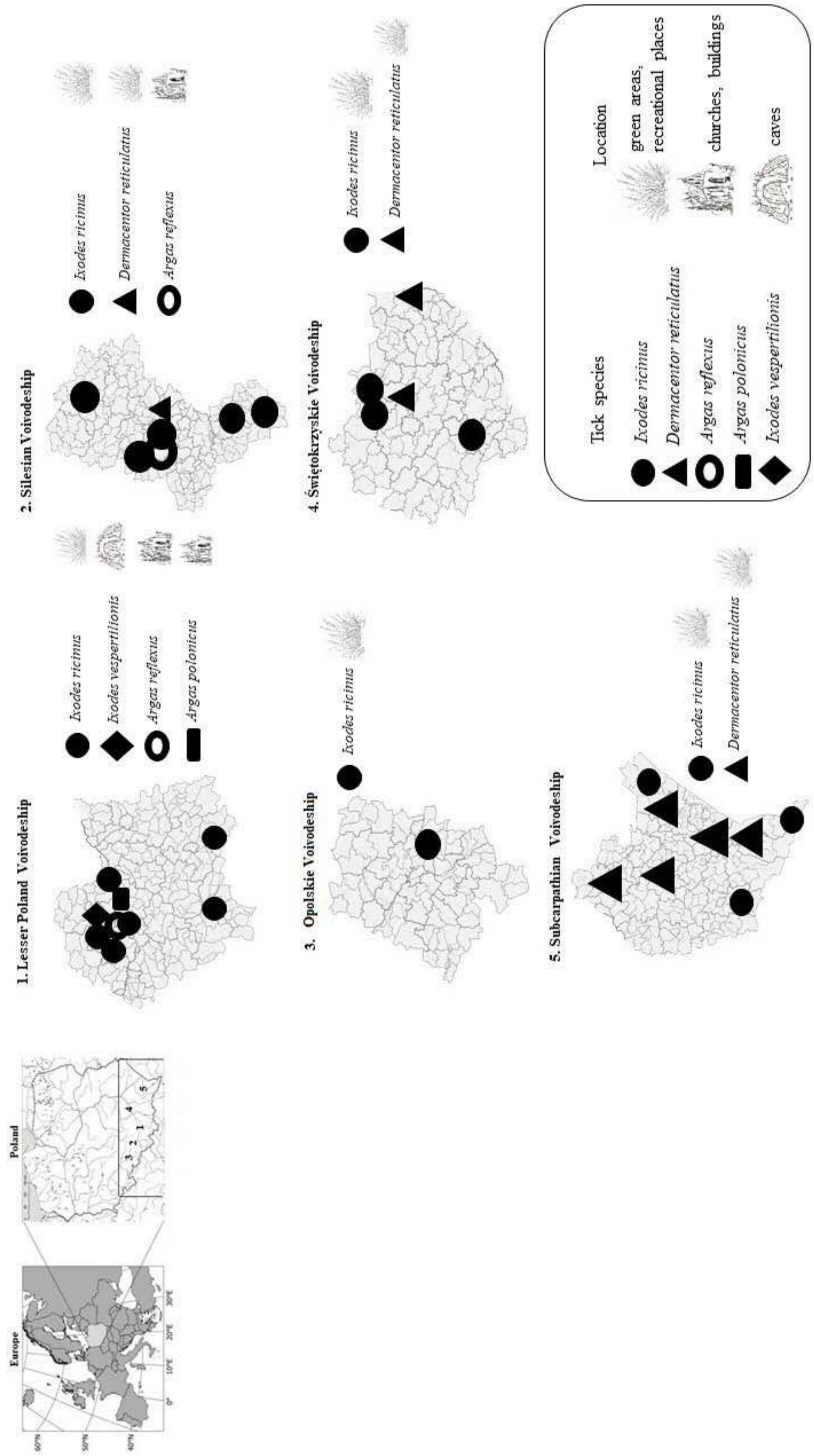

Figure 1. Occurrence of ticks in recreational, tourist, and protected areas of southern Poland

are available (campsites, leisure centers, fishing areas) [14,15]. In 2013–2014, the presence of *I. ricinus* was confirmed in the Kraków-Częstochowa Upland, one of the most attractive tourist regions in Poland. Częstochowa, a city located in the Silesian Voivodeship, is a well-known pilgrimage destination, and it also features numerous parks where tourists and residents frequently spend their free time [16].

In addition to vegetation sampling, ticks collected in 2011–2013 and in 2015 from sanitary-epidemiological stations, as well as ticks obtained in 2010 from medical facilities in Upper Silesia from patients who received assistance in removing the parasite from their bodies, were also included. The results of survey studies indicated a low percentage of individuals using repellents, which stems from low public awareness regarding the risks associated with tick attacks [17].

In the Lesser Poland Voivodeship, studies confirming the presence of *I. ricinus* in urban and forested areas have been conducted since 1994 [6,8,18] (Fig. 1). In 1999-2000, the presence of *I. ricinus* was detected during spring collections [19], and in 2011 in areas located near foresters' lodges, rural farms, and drainage ditches [20]. This species occurs with varying abundance within Kraków: Las Wolski, Kopiec Kościuszki, Lasek Mogilski, Borek Fałęcki, Tyniec, Skotniki, and in its peripheral areas, mainly in habitats containing remnants of natural forests. The castor bean tick was not found in Kraków's central city parks (Park Jordana, Park Lotników Polskich). Additionally, *I. ricinus* was collected along tourist trails in the Beskid Wyspowy and Beskid Sądecki mountain ranges [21]. In the Niepołomice Forest, a woodland area serving as a recreational site for tourists and residents of the Lesser Poland Voivodeship, as well as a location of historical significance and an important scientific base for Polish researchers studying the country's fauna and flora, the risk of exposure to *I. ricinus* ticks has also been confirmed [20]. In the case of the Kraków-Częstochowa Upland, previous studies have shown that *I. ricinus* occurs most abundantly in its southern part [16,22–26].

The Opolskie Voivodeship, despite its numerous tourist areas and picturesque landscapes, remains poorly studied in terms of tick occurrence. In 2016–2018, *I. ricinus* ticks were confirmed in the south-western part of the voivodeship [27] (Fig. 1).

In the Świętokrzyskie Voivodeship, a case of *I. ricinus* was recorded in a tick removed from the skin of a person who had previously visited the municipal cemetery in Kielce [28]. Field studies were also conducted in mixed forest areas of major cities, including Kielce, Ostrowiec Świętokrzyski, Busko, Jędrzejów, and Skarżysko-Kamienna [29] (Fig. 1).

Field studies conducted in the Subcarpathian Voivodeship also indicate that *I. ricinus* is the most widespread tick species in Poland; its presence was confirmed in the vicinity of Krosno, in areas frequently visited by tourists [30] (Fig. 1).

Dermacentor reticulatus is the second most commonly encountered tick species in Central Europe. It inhabits primarily river and stream valleys overgrown with shrubs or trees. It is also found in marshy mixed forests, on shrub-covered pastures, and in logging areas. Additionally, it occurs in open habitats such as clearings and meadows, in mixed forests, and near urban and suburban areas. It prefers moist environments [31,32]. Due to its ability to adapt to diverse habitats and climatic conditions, this species is effectively expanding its range, as confirmed by studies documenting its spread across Europe. *Dermacentor reticulatus* in the Silesian Voivodeship, collected from vegetation, was confirmed for the first time by Asman et al. [33] (Fig. 1). The collection was carried out in mid-April 2023 in the town of Sławków, located in the north-eastern part of the Silesian Voivodeship. Sampling took place in open areas that included meadow habitats and wetland sites. The area was situated near Natura 2000 protected zones. Until recently, the central-southern part of Poland, including the studied area, had been considered free of *D. reticulatus*. Previous research on the distribution of this tick species reported its absence in the Silesian Voivodeship as well as in the neighboring Opolskie and Świętokrzyskie regions [34]. In 2022–2023, *D. reticulatus* ticks were also collected in the Subcarpathian Voivodeship. The study area covered the south-eastern part of the voivodeship, focusing on grassland habitats located near forests in the Central Beskids and the Sandomierz Basin. The continuous range of this tick species is limited to foothill and lowland areas, whereas mountainous regions should be considered free of this species [35] (Fig. 1). In the Świętokrzyskie Voivodeship, the presence of *D. reticulatus* was also confirmed at designated sites characteristic of this species, and it was demonstrated that altitude above sea level, followed by humidity, were the main determinants of tick density [36].

Ticks in landscape and national parks of southern Poland

In the southern part of the Silesian Voivodeship, within the Żywiec Landscape Park in the Żywiec Beskids, a mountainous region encompassing both agricultural and recreational areas. The presence of *I. ricinus* was confirmed two times between 2011 and 2013 [37,38]. Studies by Kocoń and Nowak-Chmura conducted in the Żywiec and Silesian Beskids near tourist trails and recreational sites also demonstrated the occurrence of *I. ricinus* in this area [39] (Fig. 1).

In the Lesser Poland Voivodeship, in the Kraków-Częstochowa Upland and the Sandomierz Basin, the presence of *I. ricinus* was confirmed both within the Ojców National Park and during collections conducted along forest paths, and even in green areas of large cities [7,21,23,24,40]. The tick fauna of Poland's national parks remains poorly studied. Among the five national parks located in the Lesser Poland Voivodeship, Ojców National Park (OPN) has been the most thoroughly investigated in terms of tick occurrence and abundance [21,41,42]. In the late 1980s, the presence of *I. ricinus* was recorded throughout the entire area of OPN. The best-studied site of this species within the park is the Valley of Delight (Dolina Zachwytu) [40,44] (Fig. 1).

Ixodes ricinus was also confirmed in the Poprad Landscape Park, which is the largest landscape park in the Lesser Poland Voivodeship. In 2018–2019, *I. ricinus* was collected from paths and meadows covered mainly by deciduous forests, whereas in 2020 these ticks were collected along a nature-education trail overgrown with beech-fir-pine forest, located near drinking water sources and a quarry. Additionally, studies conducted in 2020–2021 along popular tourist routes and nature-education paths in the Poprad Landscape Park confirmed the presence of this species in selected areas [45–47] (Fig. 1).

Thanks to numerous studies on the distribution and occurrence of *I. ricinus* in the Lesser Poland Voivodeship, it was also possible to conduct observations on the seasonal activity of this species. In the Valley of Delight (Dolina Zachwytu) in OPN, it was demonstrated that during both the spring and autumn peaks of *I. ricinus* activity, tourists and local residents are exposed to the presence of ticks in this area [40,43].

In the Subcarpathian Voivodeship, in its south-western part, within the Magura National Park, the common occurrence of *I. ricinus* was confirmed in 2004–2005 during a study of the seasonal activity of ticks in the southern part of the park (Fig. 1). Collections were also carried out in the south-eastern part of the voivodeship, in the Bieszczady National Park. Ticks of this species were collected from forested areas, nature trails, mountain routes, and recreational sites located near parking areas and campgrounds. Their presence was confirmed at an altitude of 1107 m a.s.l. [48,49] (Fig. 1). In the north-eastern part of the Subcarpathian Voivodeship, ticks were found in forested areas as well [50] (Fig. 1).

Along the trail of caves and churches

In the Lesser Poland Voivodeship are located some of the most popular caves in Poland, and cave exploration is an additional attraction for tourists. Ticks of the species *Ixodes vespertilionis* (Koch, 1844) inhabit primarily places where their main hosts-the bats (Chiroptera) are found. They occur in caves, attics, and tree hollows and are active mainly at night. The presence of *I. vespertilionis* was confirmed during studies conducted in the Lesser Poland Voivodeship in 2010–2012, where they were found on the walls of caves – Zbójecka Cave in Łopień in the Beskid Wyspowy and Diabla Dziura in the Rożnów Foothills as well as in caves located in the Kraków-Częstochowa Upland [51,52] (Fig. 1).

Churches are also valuable historical monuments of the Lesser Poland Voivodeship. By visiting these sacred sites – often landmarks of architecture, art, and history – one can learn about the region's heritage and traditions. In 1978, ticks of the species *Argas polonicus* (Siuda, Hoogstraal, Clifford et Wassef, 1979) were collected and described by Professor Krzysztof Siuda from the attics and the tower of St. Mary's Basilica in Kraków (Lesser Poland Voivodeship). This species is associated with synanthropic habitats, such as house attics, historic buildings, towers of religious sites, and bird-breeding structures (pigeon lofts), where its primary hosts-rock pigeons (*Columba livia*), either wild or domesticated-are easily accessible. In Kraków, cases of *A. polonicus* attacking humans were recorded-the victims included participants of services and concerts at the Dominican Fathers' Monastery and the trumpeters playing the Hejnał on the tower of St. Mary's Basilica [53] (Fig. 1). This is a nocturnally active species that hides during the day in cracks within walls, beams, window frames, and any other places providing shelter from daylight. *Argas polonicus* does not pose a threat to humans during the day, but encounters at night are possible, and attacks on the trumpeter fire guards performing night duty in the tower of St. Mary's Basilica in Kraków have been documented [53]. It is assumed that this species may be widespread not only in Poland but also across Europe; however, insufficient research is currently being conducted to confirm this hypothesis.

The second tick species that parasitizes mainly birds and typically attacks at night, and which may be encountered in residential buildings, is *Argas reflexus* (Fabricius, 1794). The first fully documented information on the occurrence of Argasidae in Poland was provided by Rafalski (1956), who described, among others, a site of *A. reflexus* in Kraków (Lesser Poland Voivodeship). Additionally, studies by Siuda confirmed that *A. reflexus* occurs in the attics of old tenement houses in the Old Town of Kraków and the Podgórze districts [54] (Fig. 1). In the 1970s, several new localities of this tick were reported in Poland, including Zabrze (Silesian Voivodeship) [55], Ruda Śląska, and Katowice [54]. In 1994, the presence of this species was confirmed in the capital of the Silesian Voivodeship, Katowice, where three specimens belonging to this species were collected [56]. Studies by Buczek et al. [57] also confirmed the presence of this tick species in selected cities of Upper Silesia, among residents who had been repeatedly attacked by *A. reflexus* (Fig. 1).

Foci of tick-borne diseases in the provinces of southern Poland

It should be emphasized that in Europe, including Poland, ticks pose a potential threat to tourists, residents of recreational and tourist areas, forest foragers, as well as forestry workers, farmers, and individuals involved in forest exploitation and nature conservation. In southern Poland, ticks may act as vectors of, among others: Lyme borreliosis, granulocytic anaplasmosis, babesiosis, tick-borne encephalitis, ehrlichiosis, rickettsiosis, and Q fever (Table 1).

Borrelia burgdorferi sensu lato is a spiral-shaped, Gram-negative bacterium belonging to the spirochete group. In Europe, three genospecies of this bacterium occur most frequently: *Borrelia afzelii*, *Borrelia garinii*, and *Borrelia burgdorferi* sensu stricto. The primary vectors are ticks of the genus Ixodes. *Borrelia burgdorferi* s.l. is the main etiological agent of Lyme borreliosis, a widely known and the most common tick-borne disease in Poland and Europe [58,59]. Moreover, *B. burgdorferi* s.l. may persist in a latent, spherical form during a long period of dormancy, when no clinical symptoms are observed in the infected host organism. Three phases of this disease are distinguished. The first, the so-called early localized phase, is characterized by flu-like symptoms: muscle, joint, and headache, as well as fever. In this phase, some infected individuals develop erythema migrans, a hallmark of the disease. When Lyme borreliosis remains undiagnosed and untreated, it may progress to the second phase, the so-called early disseminated stage. It manifests with neurological problems, memory and speech disturbances, and may involve meningitis. The third, late phase of the disease may present with chronic arthritis, polyneuropathy, encephalopathy, and atrophic skin changes [60].

In southern Poland, over the past 10 years (2013–2023), 80,133 cases of Lyme borreliosis were reported to the National Institute of Public Health, with the highest number of cases registered in the Lesser Poland Voivodeship (38%) and Silesian (32%) Voivodeship. Fewer infections were recorded in the Subcarpathian (17%), Opolskie (8%), and Świętokrzyskie (5%) Voivodeships [61].

Borrelia burgdorferi s.l. spirochetes are the most frequently studied pathogens in collected ticks- mainly *I. ricinus* – in southern Poland, particularly in the Lesser Poland Voivodeship and Silesian Voivodeship (Fig. 2). The lowest values of *B. burgdorferi* s.l. prevalence ranged from 1.7% to 6.9% [13,38]. In many locations, detection levels ranged between 11.8% and 19.2% [46,56], while others fell between 26.9% and 37.5% [7,20,47]. The highest recorded values of this pathogen were 49.5%, 53.3%, and 75.5% [6,33] (Fig. 2). Individual results also indicate a risk in the Subcarpathian (28.57%) [35] and Opolskie (5.4%) [27] Voivodeships, with no available data from the Świętokrzyskie Voivodeship (Fig. 2, Table 1).

Anaplasma phagocytophilum is a Gram-negative bacterium that causes the disease anaplasmosis. Numerous animal species, as well as humans, can become infected. In humans, the disease is referred to as human granulocytic anaplasmosis. It may be asymptomatic or mild, and flu-like symptoms often occur, including fever, headache, muscle pain, and malaise. Severe forms of the disease are rare;

Table 1. The presence of tick-borne disease pathogens in ticks collected from vegetation and humans in southern Poland

Tick species	Location (voivodeship)	Pathogen	Coinfections
	Lesser Poland Voivodeship	*Borrelia burgdorferi* sensu lato	*Babesia* spp. + *Anaplasma phagocytophilum*
		Anaplasma phagocytophilum	
		Babesia spp	*Anaplasma phagocytophilum*, *Babesia microti* + *Borrelia burgdorferi* senu lato
	Silesian	*Borrelia burgdorferi* sensu lato	*Borrelia burgdorferi* sensu lato + *Anaplasma phagocytophilum*
		Anaplasma phagocytophilum	
		Babesia spp.	*Borrelia burgdorferi* sensu lato + *Babesia microti*
		Tick-borne encephalitis virus	*Borrelia burgdorferi* sensu lato + *Rickettsia* spp.
		Ehrlichia chaffeensis i *Ehrlichia muri*s	
		Rickettsia spp.	*Borrelia burgdorferi* sensu lato + *Ehrlichia chaffeensis/Ehrlichia muris*
		Toxoplasma gondii	*Babesia microti* + *Anaplasma phagocytophilum Babesia microt*i + *Toxoplasma gondii*
	Opolskie	*Borrelia burgdorferi* sensu lato	Not found
		Anaplasma phagocytophilum	
		Babesia spp.	
	Świętokrzyskie	*Coxiella burnetii*	Not found
	Silesian	*Rickettsia* spp.	Not found
		Borrelia burgdorferi sensu lato	
		Anaplasma phagocytophilum	
		Babesia spp.	
		Rickettsia spp.	
	Świętokrzyskie	*Rickettsia* spp.	No data
I*xodes vespertilionis*	Lesser Poland Voivodeship	No data	No data
Argas reflexus	Silesian	No data	No data
	Lesser Poland Voivodeship	No data	

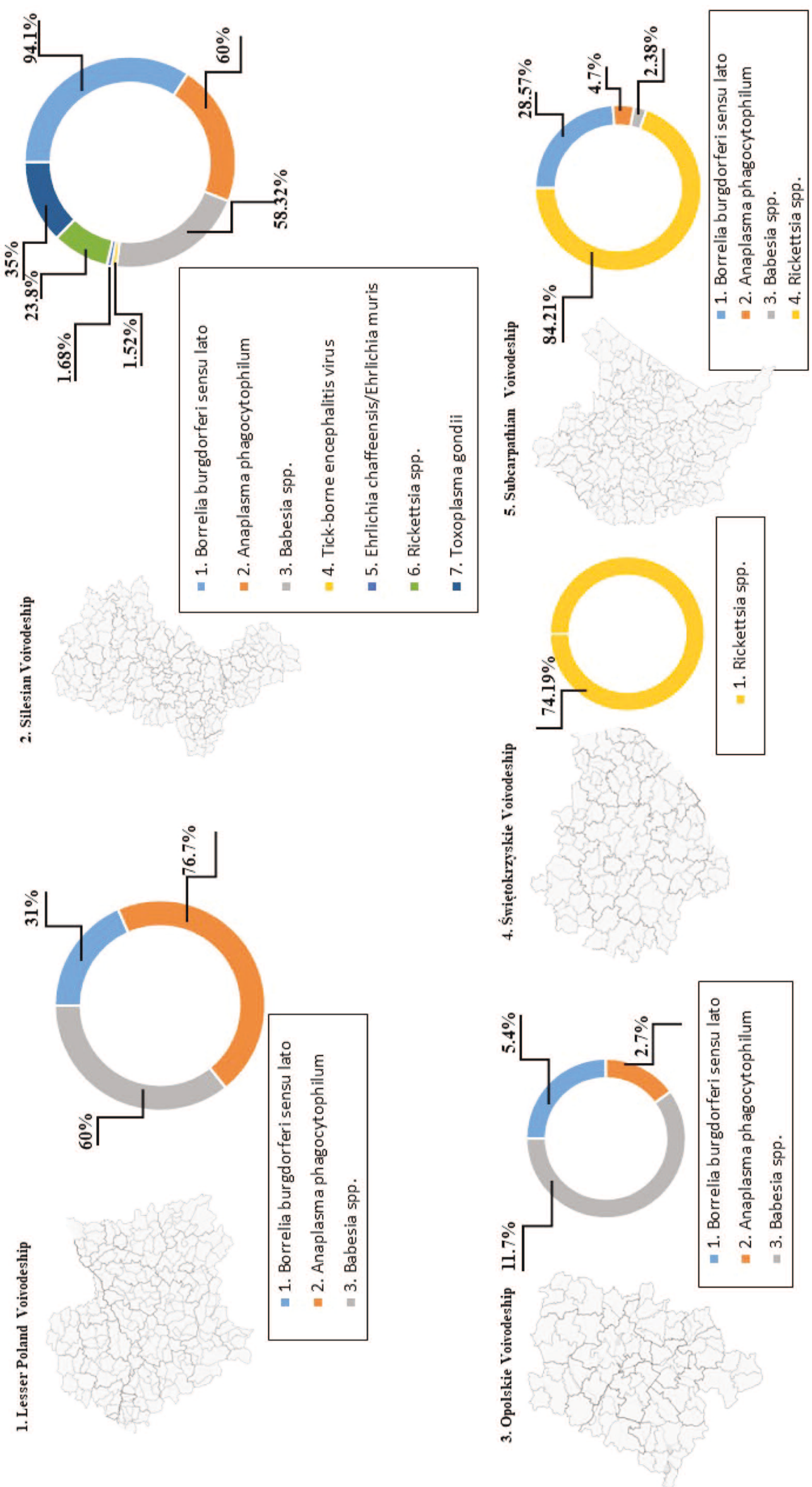

Figure 2. Prevalence of pathogens in ticks collected from vegetation in southern Poland

however, they may lead to death, particularly in patients with comorbidities. In Poland, only isolated cases of human granulocytic anaplasmosis are recorded [62,63]. According to available epidemiological data, the number of anaplasmosis cases in Poland is relatively low-only a few cases per year. However, the actual number of infections may be higher due to diagnostic challenges and nonspecific symptoms that may be confused with other diseases [61].

In southern Poland, studies on *A. phagocytophilum* are becoming increasingly common. Most reports confirming the presence of *A. phagocytophilum* in collected material concern the Silesian and Lesser Poland Voivodeship. In many locations, infection rates were low, ranging from 0.3% to 8.97% [46,64]. Higher values were confirmed in the range of 32.7% to 38.9% [15,20,37]. The highest recorded values ranged from 60% to as much as 76.7% [14,20] (Fig. 2). The tested ticks belonged to the species *I. ricinus* and *D. reticulatus*. Individual results also indicate a risk in the Subcarpathian (4.7%) [35] and Opolskie (2.7%) [27] Voivodeships, with no available data from the Świętokrzyskie Voivodeship (Fig. 2, Table 1).

Babesia microti is a protozoan belonging to the *Babesia* spp. group that causes a disease known as babesiosis. This pathogen is primarily transmitted via tick vectors; however, transmission may also occur through blood transfusion, organ transplantation, or vertically. The infection may be asymptomatic, and its symptoms often resemble malaria. Babesiosis is accompanied by fever, weakness, muscle pain, nausea, and vomiting. Enlarged lymph nodes, as well as enlargement of the liver and spleen, may occur. The disease may also take a severe course and lead to death, particularly in individuals with weakened immunity and in those infected through blood transfusion [65].

Babesia microti has been confirmed in several locations in southern Poland, mainly in the Silesian and Lesser Poland Voivodeship. The results varied widely, with a very large range – from low levels between 3.85% and 7.4% [47,65], to moderate levels ranging from 21.3% to 35% [16,38], and finally to high detection rates of *B. microti* in ticks, ranging from 58.32% to 60% [12,20] (Fig. 2). *Babesia microti* was detected in ticks of the species *I. ricinus*. Individual studies originate from the Opolskie Voivodeship (11.7%) [27] and the Subcarpathian Voivodeship (2.38%) [35] (Fig. 2, Table 1). No data are available from the Świętokrzyskie Voivodeship.

Tick-borne encephalitis virus (TBEV) is a virus of the Flaviviridae family that causes tick-borne encephalitis. It is transmitted primarily by ticks of the genus *Ixodes*. Tick-borne encephalitis (TBE) is spreading into wider geographic areas and affecting countries previously free of this disease, a trend influenced, among other factors, by climate change. Two phases of the disease are distinguished. The first phase, which occurs immediately after infection, resembles a common cold and is accompanied by fatigue, muscle and joint pain, headache, and fever; nausea and vomiting may also occur. After this stage, the patient may recover, or a second phase of the disease may develop. Characteristic symptoms of the second phase include very high fever, severe headaches, dizziness, and depressive states. Vomiting, low blood pressure, and photophobia may also occur. This phase lasts from several weeks to several months. The clinical course depends on the form of the disease: encephalitic, meningeal, or spinal. In Poland, the milder meningeal form predominates [66,67]. Vaccination against TBE should be administered to individuals at risk of tick exposure. Furthermore, people who work professionally in forested areas may, as a result of repeated tick feeding and the introduction of minimal doses of TBEV into their bodies, develop immunity to the disease through the production of specific antibodies [66].

In 2015–2019, the average incidence of tick-borne encephalitis in southern Poland was 0.28 per 100,000 inhabitants. The highest incidence of cases was recorded in the Świętokrzyskie Voivodeship – 0.51 per 100,000, followed closely by the Opolskie Voivodeship – 0.50 per 100,000, then the Lesser Poland Voivodeship – 0.30 per 100,000, only 0.08 per 100,000 in the Subcarpathian Voivodeship, and 0.03 per 100,000 in the Silesian Voivodeship [61].

Tick-borne encephalitis virus has been examined several times in southern Poland, and the current infection rate remains low. In one study conducted in the Silesian Voivodeship, the virus was not detected in the tested ticks [68]. In other locations, TBEV infection rates ranged from 0.11% to 1.28% and up to 1.52% [5,9,64] (Fig. 2, Table 1). Studies by Bartosik et al. [69] revealed the emergence of new TBE infection foci in the Świętokrzyskie Voivodeship, a region previously classified as non-endemic for TBE. Similarly, research by Zajkowska et al. [70] also documented cases of TBE in areas historically considered non-endemic, challenging the prevailing assumptions and underscoring the need for increased vigilance across the country. Through analysis of serum or cerebrospinal fluid (CSF) samples collected from patients with neuroinfections of unknown origin, it was observed that the highest positive rates were recorded in the Lesser Poland Voivodeship (31%) and the Świętokrzyskie Voivodeship (24%).

Ehrlichia chaffeensis and *Ehrlichia muris* are two distinct bacterial species of the genus *Ehrlichia* that cause a disease known as ehrlichiosis. *Ehrlichia muris* is most commonly found in rodents, whereas *E. chaffeensis* is responsible for causing disease in humans. Symptoms may be mild or severe, particularly in elderly individuals, those with weakened immune systems, and individuals infected with HIV or undergoing immunosuppressive therapy due to malignant cancers. Symptoms include malaise, muscle pain, fever, headache, and chills. Less commonly, vomiting, joint pain, and diarrhea may occur. A rash is present in some patients. Severe complications of ehrlichiosis are rare but may include pneumonia, acute respiratory distress syndrome, renal failure, and neurological disorders [71–73].

In southern Poland, testing for the presence of *E. chaffeensis* and *E. muris* was conducted twice on ticks obtained from the Provincial Sanitary-Epidemiological Station in the Silesian Voivodeship. The sample analyzed in 2011–2013 did not reveal the presence of these pathogens. In contrast, in 2015, the bacterium did not occur as a monoinfection in any tick, but was confirmed as a coinfection together with *B. burgdorferi* s.l., with a tick infection rate of 1.68% [64,68] (Fig. 2, Table 1).

Gram-negative bacteria of the genus *Rickettsia* comprise a diverse group of microorganisms transmitted mainly by arthropods (Arthropoda), including certain insects (Insecta) and arachnids (Arachnida). Bacteria transmitted by ticks are referred to as spotted fever group rickettsiae (SFGR) and may cause nonspecific fever in humans, accompanied by headaches, muscle and joint pain, respiratory problems, and, in some cases, an erythematous rash consisting of small red spots [74]. They may also lead to meningitis [75]. *Rickettsia slovaca* and *Rickettsia raoulti* in Poland are pathogens transmitted primarily by *D. reticulatus*. They can lead to tick-borne lymphadenitis syndrome and necrotizing erythema-lymphadenopathy syndrome (SENLAT- scalp eschars and neck lymphadenopathy, formerly referred to as TIBOLA-tickborne lymphadenopathy or DEBONEL), and in case *Rickettsia sibirica* subsp. mongolitimonae (lymphangitis-associated rickettsiosis, LAR) [76]. *Rickettsia* spp. has been detected in *D. reticulatus* (23.8%) and *I. ricinus* (5.8%) ticks collected in Upper Silesia (Silesian Voivodeship) [33], as well as in the Subcarpathian Voivodeship (35.71% and 84.21%) [35] and in the Świętokrzyskie Voivodeship (24.00%–74.19%) [36] (Fig. 2, Table 1).

Toxoplasma gondii is a protozoan that causes a disease known as toxoplasmosis. This disease is widespread globally. Humans are intermediate hosts, and infection occurs through ingestion of parasite oocysts from contaminated water, soil, or undercooked meat, and also congenital and iatrogenic transmission. Infection may also occur through contact with cat feces, as cats are the definitive hosts of this protozoan. It is estimated that up to one-third of the world's population may become infected with *T. gondii* during their lifetime. The mechanism of the pathogen's spread across such vast geographic areas and its broad host range is not fully understood, which may suggest a potential role of ticks in transmitting *T. gondii*, although there is no scientific evidence to support this. Toxoplasmosis may be asymptomatic in humans or resemble a mild flu-like illness. The disease is particularly dangerous for immunocompromised individuals, pregnant women, and newborns infected during the fetal period [77,78]. *Toxoplasma gondii* spreads through the bloodstream to various tissues and organs, including the brain. It may cause visual disturbances, severe headaches, seizures, or even coma. It leads to retinitis, pneumonia, and numerous neurological problems. Special care is required for newborns infected in utero, and treatment in such cases may be prolonged and challenging [77,79].

Toxoplasma gondii was detected in *I. ricinus* ticks in southern Poland in the Silesian Voivodeship by Asman et al. [12], with the pathogen identified in 35% of ticks (Fig. 2, Table 1). The role of ticks in the circulation of this pathogen in nature is not yet fully understood. Further studies on the occurrence of *T. gondii* in ticks in Poland are necessary.

Coxiella burnetii is the etiological agent of Q fever. Q fever is caused by Gram-negative bacilli belonging to the genus Coxiella and is a zoonotic disease affecting both humans and animals. In

Poland, several Q fever outbreaks have been described, with their sources attributed to imported animals and their products [80]. In most cases, the disease is asymptomatic, and infection occurs primarily through inhalation of contaminated particles of faeces or urine, consumption of animal milk, or, less commonly, through ticks, or direct contact with an infected individual [80]. According to the literature, in the Świętokrzyskie Voivodeship, a single case of an infected tick removed from human skin has been described [28].

Coinfections

Coinfection in ticks occurs when a single individual carries more than one pathogenic agent. Ticks may act as vectors for numerous bacterial, viral, and protozoan diseases. The diagnosis of tick-borne diseases has long been challenging due to a wide range of nonspecific symptoms and limited access to diagnostic tools. Coinfections, which present a significant public health concern, can further complicate the diagnostic process. Disease severity may increase, and typical symptoms may change or overlap. Diagnostic difficulties lead to delays in treatment implementation, which must be individually tailored to the co-occurring symptoms of tick-borne diseases. Infection with two or more tick-borne pathogens poses a direct threat to the health and lives of both humans and animals [81–83]. A frequently detected combination is *B. burgdorferi* s.l. with *A. phagocytophilum*. In the Silesian Voivodeship, this value ranged from 0.84% to 3.85%, and up to 6.7% [20,64,68] (Table 1). *Borrelia burgdorferi* s.l. with *B. microti* has also been confirmed in the Silesian Voivodeship at levels ranging from 1.7% to 3.85% and up to 20% [33,38,64] (Table 1). The range of coinfections involving *B. microti*/*Babesia* spp. and *A. phagocytophilum* is considerable, from 0.6% to 46.7% [16,20]. Moreover, in the location with the highest number of such cases, the coexistence of three pathogens-*A. phagocytophilum*, *Babesia* spp., and *B. burgdorferi* s.l. was confirmed at 3.3% [20] (Table 1). A case of coinfection with *B. burgdorferi* s.l. and *E. chaffeensis*/*E. muris* was also confirmed, with an infection rate of 1.68%, as well as coinfection of *B. microti* with *T. gondii*, detected in as many as 32% of ticks [12,68] (Table 1). Recent studies of *B. burgdorferi* s.l. with *Rickettsia* spp. confirmed the presence of this coinfection in 10% of ticks [33] (Table 1).

Although coinfections are usually detected at low levels, awareness of their potential impact on the human body-combined with individual studies reporting high coinfection rates-highlights the need for continued and expanded research.

Conclusions

The conducted review of the scientific literature indicates the need for further research and ongoing monitoring to better identify tick habitats and assess the potential risk of exposure to the etiological factors of tick-borne diseases transmitted by these parasites. The analysis revealed the presence of the following pathogens in ticks collected from vegetation and humans in southern Poland: *B. burgdorferi* s.l., *A. phagocytophilum*, *B. microti*, *T. gondii*, TBEV, *E. chaffeensis/E. muris*, *Rickettsia* spp., and *C. burnetii*, as well as various co-infections. The potential threat of tick attacks and tick-borne infections with one or more pathogens in the analyzed regions of southern Poland indicates the need for ongoing awareness raising among residents and tourists about the threats associated with ticks and tick-borne diseases. Therefore, further research on the distribution of these arthropods and their role as vectors, encompassing a broader spectrum of pathogens, is crucial. Furthermore, informing the public about vaccinations against tick-borne encephalitis and promoting appropriate preventive measures that reduce the risk of tick attacks – such as using repellents against these parasites, checking the body and pets after returning from a walk, and mowing lawns in home gardens – is also important from a public health perspective.

References

[1] Siuda K., Nowak M., Stanko M., Pet'ko B., Karbowiak G., Solarz K., Lencakova D. 2005. Ryzyko atakowania przez kleszcze *Ixodes ricinus* ludzi w atrakcyjnych turystycznie obszarach województwa małopolskiego. In: Streszczenia Materiałów II Konferencji „Medycyna Podróży". 12–14 Maja 2005, Białystok, Poland: 12–14.

[2] Siuda K. 2008. Kleszcze Ixodida. In: Fauna Polski – charakterystyka i wykaz gatunków. (Eds. W. Bogdanowicz, E. Chudzicka, I. Pilipiuk, E. Skibińska). Muzeum i Instytut Zoologii PAN, Warszawa, Poland: 39–44.

[3] Krantz G.W., Walter D.E. 2009. A manual of acarology, 3rd ed. Texas Tech University Press,

Lubbock, Texas.

[4] Achazi K., Ruzek D., Donoso-Mantke O., Schlegel M., Ali H.S., Wenk M., Schmidt-Chanasit J., Ohlmeyer L., Rühe F., Vor T., Kiffner C., Kallies R., Ulrich R.G., Niedrig M. 2011. Rodents as sentinels for the prevalence of tick-borne encephalitis virus. *Vector-Borne and Zoonotic Diseases* 11: 641–647. doi:10.1089/vbz.2010.0236

[5] Cuber P., Andreassen Å., Vainio K., Asman M., Dudman S., Szilman P., Szilman E., Ottesen P., Anestad G., Cieśla-Nobis S., Solarz K. 2015. Risk of exposure to ticks (Ixodidae) and the prevalence of tick-borne encephalitis virus (TBEV) in ticks in Southern Poland. *Ticks an Tick-Borne Diseases* 6: 356–363. doi:10.1016/j.ttbdis.2015.02.010

[6] Pet'ko B., Siuda K., Stanko M., Tresová G., Karbowiak G., Fricova J. 1997. *Borrelia burgdorferi* sensu lato in the *Ixodes ricinus* ticks in southern Poland. *Annals of Agricultural and Environmental Medicine* 4: 263–269.

[7] Stańczak J., Racewicz M., Kubica-Biernat B., Kruminis-Lozowska W., Dabrowski J., Adamczyk A., Markowska M. 1999. Prevalence of *Borrelia burgdorferi* sensu lato in *Ixodes ricinus* ticks (Acari, Ixodidae) in different Polish woodlands. *Annals of Agricultural and Environmental Medicine* 6: 127–132.

[8] Pet'ko B. 2002. Lyme borreliosis in Carpathian region of Central Europe – ecological aspect of diagnostics. In: Stawonogi w medycynie. (Eds. A. Buczek, C. Błaszak). Koliber, Lublin, Poland: 93–104.

[9] Drelich A., Andreassen Å., Vainio K., Kruszyński P., Wąsik T.J. 2014. Prevalence of tick-borne encephalitis virus in a highly urbanized and low risk area in Southern Poland. *Ticks and Tick-Borne Diseases* 5: 663–667. doi:10.1016/j.ttbdis.2014.04.020

[10] Strzelczyk J.K., Wiczkowski A., Spausta G., Ciarkowska J., Ziob-Zalewska M., Izdebska-Straszak G. 2006. Obecność krętków *Borrelia burgdorferi* sensu lato u kleszczy *Ixodes ricinus* na terenach rekreacyjnych okolic Tarnowskich Gór i Zabrza w latach 2001–2003. *Przegląd Epidemiologiczny* 60: 589–595.

[11] Strzelczyk J.K., Wiczkowski A., Kwaśniewski M., Strzelczyk J., Gawron K., Adamek B., Spausta G. 2006. Prevalence of *Borrelia burgdorferi* sensu lato genospecies in *Ixodes ricinus* ticks from recreational areas of Silesia. *Advances in Clinical and Experimental Medicine* 15: 1003–1008.

[12] Asman M., Solarz K., Cuber P., Gąsior T., Szilman P., Szilman E., Tondaś E., Matzullok A., Kusion N., Florek K. 2015. Detection of protozoans *Babesia microti* and *Toxoplasma gondii* and their co-existence in ticks (Acari: Ixodida) collected in Tarnogórski district (Upper Silesia, Poland). *Annals of Agricultural and Environmental Medicine* 22: 80–83. doi:10.5604/12321966.1141373

[13] Strzelczyk J.K., Gaździcka J., Cuber P., Asman M., Trapp G., Gołąbek K., Zalewska-Ziob M., Nowak-Chmura M., Siuda K., Wiczkowski A., Solarz K. 2015. Prevalence of *Borrelia burgdorferi* sensu lato in *Ixodes ricinus* ticks collected from southern Poland. *Acta Parasitologica* 60: 666–674. doi:10.1515/ap-2015-0095

[14] Cuber P., Asman M., Solarz K., Szilman E., Szilman P. 2010. Pierwsze stwierdzenia obecności wybranych patogenów chorób transmisyjnych w kleszczach *Ixodes ricinus* (Acari: Ixodidae) zebranych w okolicach zbiorników wodnych w Rogoźniku (województwo śląskie). In: Stawonogi. Ekologiczne i patologiczne aspekty układu pasożyt-żywiciel. (Eds. A. Buczek, C. Błaszak). Koliber, Lublin, Poland: 93–104.

[15] Cuber P., Asman M., Solarz K., Szilman E., Szilman P. 2011. The prevalence of *Anaplasma phagocytophilum* and *Babesia* sp. in ticks (Acari, Ixodida) collected from recreational areas of Silesian Province. In: Arthropods. Human and animal parasites. (Eds. A. Buczek, Cz. Błaszak). Akapit, Lublin, Poland: 105–114.

[16] Asman M., Solarz K., Szilman E., Szilman P., Sikora B., Jakubas-Zawalska J. 2018. The occurrence of three tick-borne pathogens in *Ixodes ricinus* ticks collected from the area of the Kraków-Częstochowa Upland (Southern Poland). *Acarologia* 58: 969–975. doi:10.24349/acarologia/20184301

[17] Asman M., Gąsior T., Jacek E., Cuber P., Solarz K. 2012. Isolation of rickettsiae *Anaplasma phagocytophilum* and protozoans *Babesia* sp. in castor bean ticks (*Ixodes ricinus*) collected from patients of public health centres on the territory of Upper Silesia. In: Arthropods. The medical and economic importance. (Eds. A. Buczek, C. Błaszak). Akapit, Lublin, Poland: 171–180.

[18] Siński E., Karbowiak G., Siuda K., Buczek A., Jongejan F. 1994. *Borrelia burgdorferi* infection of ticks in some regions of Poland. *Przegląd Epidemiologiczny* 48: 461–465.

[19] Siuda K., Pet'ko B., Stanko M., Karbowiak K. 2002. The distribution of the ticks *Ixodes ricinus* (Linnaeus, 1758) (Acari: Ixodida: Ixodidae) on the area of Kraków. In: Postępy polskiej akarologii. (Ed. S. Ignatowicz). SGGW, Warszawa, Poland: 119–130.

[20] Asman M., Nowak M., Cuber P., Strzelczyk J., Szilman E., Szilman P., Trapp G., Siuda K., Solarz K., Wiczkowski A. 2013. The risk of exposure to *Anaplasma phagocytophilum*, *Borrelia burgdorferi* sensu lato, *Babesia* sp. and co-infections in *Ixodes ricinus* ticks on the territory of Niepołomice Forest (southern Poland). *Annals of Parasitology* 59(1): 13–19.

[21] Siuda K., Nowak M. 2006. Zagrożenie atakami

kleszczy na szlakach turystycznych w województwie małopolskim. *Konspekt* 2–3: 42–48.
[22] Siuda K., Solarz K., Deryło A., Buczek A., Sadowski T., Kwiatkowski S. 1992. Studies on ticks (Acari: Ixodida) from the Krakow-Czestochowa Upland with particular consideration of the occurrence and quantity of the population of *Ixodes ricinus* (L.) (Ixodidae) on the territories affected at various stages of antropopressure. Prądnik, Prace Muzeum Szafera 5: 235–245.
[23] Siuda K., Nowak M., Urbanowicz A. 2001. Rytm sezonowej aktywności kleszcza pospolitego *Ixodes ricinus* (Linnaeus, 1758) (Acari: Ixodida) w okolicy Skały Kmity koło Krakowa. In: Materiały Konferencji Badania Naukowe w południowej części Wyżyny Krakowsko-Częstochowskiej. (Ed. J. Partyka). Ojcowski Park Narodowy, Ojców, Poland: 299–301.
[24] Siuda K., Ślusarczyk J., Nowak M. 2001. Rozprzestrzenienie kleszcza *Ixodes ricinus* (Linnaeus, 1758) (Acari: Ixodida: Ixodidae) na terenie Garbu Tenczyńskiego. In: Materiały Konferencji Badania Naukowe w południowej części Wyżyny Krakowsko-Częstochowskiej. (Ed. J. Partyka). Ojcowski Park Narodowy, Ojców, Poland: 295–298.
[25] Siuda K., Nowak M., Grycz K., Solarz K. 2004. Stan wiadomości nad rozprzestrzenieniem *Ixodes ricinus* (Linnaeus, 1758) (Acari: Ixodida: Ixodidae) na terenie województwa małopolskiego. In: Zróżnicowanie *i przemiany środowiska przyrodniczo-kulturowego Wyżyny Krakowsko-Częstochowskiej*. (Ed. J. Partyka). Ojcowski Park Narodowy, Ojców, Poland: 295–301.
[26] Nowak M., Siuda K. 2009. Kleszcze. In: Magurski Park Narodowy – Monografia przyrodnicza. (Eds. A. Górecki, B. Zemanek). Oficyna Wydawnicza Text, Kraków, Poland: 177–180.
[27] Asman M., Witecka J., Solarz K., Zwonik A., Szilman P. 2019. Occurrence of *Borrelia burgdorferi* sensu lato, *Anaplasma phagocytophilum* and *Babesia microti* in *Ixodes ricinus* ticks collected from selected areas of Opolskie Province in south-west Poland. *Annals of Agricultural and Environmental Medicine* 26: 544–547. doi:10.26444/aaem/110214.
[28] Tylewska-Wierzbanowska S., Kruszewska D., Chmielewski T., Żukowski K., Żabicka J. 1996. Kleszcze jako rezerwuar *Borrelia burgdorferi* i *Coxiella burnetii* na terenie Polski. *Przegląd Epidemiologiczny* 50: 245–251.
[29] Bartosik K., Lachowska-Kotowska P., Szymańska J., Pabis A., Buczek A. 2011. Lyme borreliosis in south-eastern Poland: relationships with environmental factors and medical attention standards. *Annals of Agricultural and Environmental Medicine* 18: 131–137.
[30] Bartosik K., Szymańska J., Buczek A. 2011. Risk to human health posed by *Ixodes ricinus* ticks in relation to diagnostic and therapeutic possibilities in south-eastern Poland. *Zdrowie Publiczne* 121: 263–266.
[31] Nowak-Chmura M. 2013. Fauna of ticks (Ixodida) of Central Europe. Wydawnictwo Naukowe Uniwersytetu Pedagogicznego, Kraków, Poland.
[32] Rubel F., Brugger K., Pfeffer M., Chitimia-Dobler L., Didyk Y.M., Leverenz S., Dautel H., Kahl O. 2016. Geographical distribution of *Dermacentor marginatus* and *Dermacentor reticulatus* in Europe. *Ticks and Tick-Borne Diseases* 7: 224–233. doi:10.1016/j.ttbdis.2015.10.015
[33] Asman M., Bartosik K., Jakubas-Zawalska J., Świętek A., Witecka J. 2024. A new endemic locality of *Dermacentor reticulatus* in central–southern Poland and its potential epidemiological implications. *Insects* 15: 580. doi:10.3390/insects15080580
[34] Mierzejewska E.J., Estrada-Peña A., Alsarraf M., Kowalec M., Bajer A. 2016. Mapping of *Dermacentor reticulatus* expansion in Poland in 2012–2014. *Ticks and Tick-Borne Diseases* 7: 94–106. doi:10.1016/j.ttbdis.2015.09.003
[35] Zając Z., Kulisz J., Woźniak A., Obregón D., Foucault-Simonin A., Bartosik K., Moutailler S., Cabezas-Cruz A. 2024. Spatial distribution and pathogen profile of *Dermacentor reticulatus* ticks in southeastern Poland: a genetic and environmental analysis. *Transboundary and Emerging Diseases* 1: 5458278. doi:10.1155/2024/5458278
[36] Zając Z., Woźniak A., Kulisz J., Foucault-Simonin A., Obregón D., Moutailler S., Bartosik K., Cabezas-Cruz A. 2025. High prevalence of *Rickettsia* spp. among moderately dense population of *Dermacentor reticulatus* ticks in south-central Poland. *Medical and Veterinary Entomology* 39. doi:10.1111/mve.12817
[37] Asman M., Gąsior T., Pająk C., Cuber P., Szilman P., Szilman E., Solarz K. 2012. Occupational risk of infections with *Borrelia burgdorferi* sensu lato, *B. burgdorferi* sensu stricto, *B. garinii* and *B. afzelii* in agricultural workers on the territory of Beskid Żywiecki (South Poland). In: Stawonogi. Znaczenie medyczne i gospodarcze. (Eds. A. Buczek, C. Błaszak). Koliber, Lublin, Poland: 163–170.
[38] Asman M., Pindel Ł., Solarz K. 2014. Ryzyko narażenia zawodowego na krętki *Borrelia burgdorferi* sensu lato, riketsje *Anaplasma phagocytophilum* i pierwotniaki *Babesia microti* na terenie Żywieckiego Parku Krajobrazowego. In: Stawonogi. Zagrożenie zdrowia człowieka i zwierząt. (Eds. A. Buczek, C. Błaszak). Koliber, Lublin, Poland: 153–162.
[39] Kocoń A., Nowak-Chmura M. 2016. The treatment of attacks by the ticks *Ixodes ricinus* in the selected areas in Żywiec and Silesian Beskids (Silesian province – southern Poland). *Annales Universitatis Paedagogicae Cracoviensis Studia Naturae* 1: 55–67.
[40] Solarz K., Piec M., Batoryna O., Kwiecień W., Szilman P. 2007. Liczebność kleszczy *Ixodes ricinus*

L. (Acari: Ixodida: Ixodidae) na terenie Ojcowskiego Parku Narodowego. *Prądnik, Prace Muzeum Szafera* 17: 113–120.
[41] Siuda K. 1990. Dotychczasowy stan badań nad kleszczami (Acari: Ixodida) Ojcowskiego Parku Narodowego. Prądnik, Prace Muzeum Szafera 1: 45–47.
[42] Siuda K., Buczek A., Solarz K., Deryło A., Sadowski T., Kwiatkowski S., Horak B., Procyk A. 1991. Wstępne badania nad występowaniem *Ixodes ricinus* (Acari: Ixodida: Ixodidae) na obszarach Jury Krakowsko-Częstochowskiej w różnym stopniu zmienionych antropopresją. *Wiadomości Parazytologiczne* 37: 17–20.
[43] Solarz K., Asman M., Cuber P., Gomółka P., Komosińska B., Nazarkiewicz M. 2009. Liczebność kleszcza *Ixodes ricinus* L. (Acari: Ixodida: Ixodidae) w dolinie Zachwytu (Ojcowski Park Narodowy) w okresie jesiennego szczytu aktywności. *Wiadomości Parazytologiczne* 55: 39–45.
[44] Siuda K. 1991. Kleszcze (Acari: Ixodida) Polski. Cz. 1. Zagadnienia ogólne. Wydawnictwo Naukowe PWN, Warszawa–Wrocław, Poland.
[45] Koczanowicz S., Nowak-Chmura M. 2021. Exposition to ticks in the Poprad Landscape Park – short faunistic note. *Annales Universitatis Paedagogicae Cracoviensis Studia Naturae* 6: 149–156.
[46] Koczanowicz S., Nowak-Chmura M., Witecka J., Rączka G., Asman M. 2024. The potential risk of human exposure to tick-borne infection by *Borrelia burgdorferi* sensu lato, *Anaplasma phagocytophilum*, and *Babesia microti* in selected recreational areas of the Poprad Landscape Park in southern Poland. *Annals of Agricultural and Environmental Medicine* 31: 345–350.
[47] Koczanowicz S., Nowak-Chmura M., Kocoń A., Rączka G., Asman M. 2025. The occurrence of *Borrelia burgdorferi* sensu lato in *Ixodes ricinus* ticks collected from nature-educational and tourist trails in the Poprad Landscape Park. *Pathogens* 14: 117. doi:10.3390/pathogens14020117
[48] Nowak M., Siuda K., Solarz K., Góra A., Cuber P. 2009. A risk of infection with ticks of *Ixodes ricinus* (Linnaeus, 1758) species (Acari: Ixodidae) in south-eastern Poland depending on the daily and seasonal rhythm. In: Arthropods. Invasions and their control. (Eds. A. Buczek, Cz. Błaszak). Akapit, Lublin, Poland: 31–44.
[49] Nowak-Chmura M., Siuda K. 2011. Rozmieszczenie *Ixodes ricinus* (Linnaeus, 1758) na terenie Bieszczadzkiego Parku Narodowego. In: Materiały Konferencyjne XXXII Sympozjum Akarologiczne. Tomaszowice k/Krakowa, Poland: 47.
[50] Siuda K., Sebesta R., Dańczak A., Ślusarczyk J., Orzechowska K., Nowak M., Urbanowicz A., Radwan E. 2000. Zagrożenie atakami kleszczy (Acari: Ixodida: Ixodidae) na szlakach turystycznych i terenach rekreacyjnych południowo-wschodniej Polski. In: Streszczenie Materiałów Konferencji Medycyna Podróży. Białystok, Poland: 98–99.
[51] Siuda K., Stanko M., Piksa K., Górz A. 2009. Ticks (Acari: Ixodida) parasitizing bats in Poland and Slovakia. *Wiadomości Parazytologiczne* 55: 39–45.
[52] Piksa K., Górz A., Nowak-Chmura M., Siuda K. 2013. Mass occurrence of *Ixodes vespertilionis* (Acari: Ixodidae) in caves, on bats roosting in caves and in nursery colony. *International Journal of Acarology* 39: 257–262. doi:10.1080/01647954.2012.762041
[53] Siuda K. 1982. Zróżnicowanie morfologiczne nimf *Argas (Argas) polonicus* Siuda, Hoogstraal, Clifford et Wassef, 1979 (Acarina: Ixodides: Argasidae). *Wiadomości Parazytologiczne* 27: 51–55.
[54] Siuda K. 1984. Stan wiadomości nad rozmieszczeniem w Polsce obrzeżków z rodzaju *Argas* (Acarina: Ixodides: Argasidae). *Wiadomości Parazytologiczne* 5–6: 595–601.
[55] Grzybek A., Dzikowski A., Stefańska E. 1973. *Argas reflexus* w Zabrzu. In: Materiały XI Zjazdu PTP. Poznań, Poland: 53.
[56] Siński E., Karbowiak G., Siuda K., Buczek A., Jongejan F. 1994. *Borrelia burgdorferi* infection of ticks in some regions of Poland. *Przegląd Epidemiologiczny* 48: 461–465.
[57] Buczek A., Bartosik K., Kulina D., Raszewska-Famielec M., Borzęcki A. 2018. Skin lesions in humans bitten by European pigeon tick *Argas reflexus* (Fab.) (Ixodida: Argasidae) massively occurring in the Upper Silesian conurbation of south-west Poland. *Annals of Agricultural and Environmental Medicine* 25: 234–240. doi:10.26444/aaem/74137
[58] Gąsiorowski J., Witecka-Knysz E., Knysz B., Gerber H., Gładysz A. 2007. Diagnostics of Lyme disease. *Medycyna Pracy* 58: 439.
[59] Steere A.C., Strle F., Wormser G.P., Hu L.T., Branda J.A., Hovius J.W., Li X., Mead P.S. 2016. Lyme borreliosis. *Nature Reviews Disease Primers* 2: 1–19. doi:10.1038/nrdp.2016.90
[60] Stanek G., Strle F. 2018. Lyme borreliosis – from tick bite to diagnosis and treatment. *FEMS Microbiology Reviews* 42: 233–258. doi:10.1093/femsre/fux047
[61] Zakład Epidemiologii Chorób Zakaźnych i Nadzoru. Pracownia Monitorowania i Analizy Sytuacji Epidemiologicznej. 2025. https://wwwold.pzh.gov.pl/oldpage/epimeld/index_p.html.
[62] Dumler J.S. 1996. Human ehrlichiosis: clinical, laboratory, epidemiologic, and pathologic considerations. In: Rickettsiae and Rickettsial Diseases. (Eds. J. Kazar, R. Toman). Veda, Bratislava, Slovakia: 287–302.
[63] Stuen S., Granquist E.G., Silaghi C. 2013.

Anaplasma phagocytophilum – a widespread multi-host pathogen with highly adaptive strategies. *Frontiers in Cellular and Infection Microbiology* 3: 31. doi:10.3389/fcimb.2013.00031

[64] Albertyńska M., Rozwadowska B., Mendera-Bożek U., Jasik K.P., Słodki A., Słodki J., Cieślik-Tarkota R. 2016. Obecność *Borrelia burgdorferi* sensu lato, *Babesia microti*, *Anaplasma phagocytophilum*, *Ehrlichia chaffeensis/Ehrlichia muris* oraz wirusa kleszczowego zapalenia mózgu i opon mózgowych (TBEV) w kleszczach z terenu woj. śląskiego. In: Stawonogi. Zależności w układzie żywiciel–ekto_pasożyt–patogen. (Eds. A. Buczek, C. Błaszak). Koliber, Lublin, Poland: 67–73.

[65] Gajda P., Rustecka A., Kalicki B. 2015. Babeszjoza człowieka – mało znana choroba odkleszczowa. *Pediatria, Medycyna Rodzinna* 11: 75–82.

[66] Kaiser R. 2016. Frühsommermeningoenzephalitis. *Der Nervenarzt* 87: 667–680. d doi:10.1007/s00115-016-0134-9

[67] Johnson N., Migné C.V., Gonzalez G. 2023. Tick-borne encephalitis. *Current Opinion in Infectious Diseases* 36: 198–202. doi:10.3390/pathogens10091168

[68] Rozwadowska B., Albertyńska M., Hudzik G., Jasik K., Okła H., Dłodki A., Słodki J. 2014. Badania nad występowaniem *Borrelia burgdorferi* sensu lato, *Anaplasma phagocytophilum*, *Ehrlichia chaffeensis/E. muris* oraz wirusa kleszczowego zapalenia mózgu i opon mózgowych (TBEV) u kleszczy z terenu województwa śląskiego. In: Stawonogi. Zagrożenie zdrowia człowieka i zwierząt. (Eds. A. Buczek, Cz. Błaszak). Koliber, Lublin, Poland: 121–128.

[69] Bartosik K., Lachowska-Kotowska P., Szymańska J., Wójcik-Fatla A., Pabis A., Buczek A. 2011. Environmental conditioning of incidence of tick-borne encephalitis in south-eastern Poland in 1996–2006. *Annals of Agricultural and Environmental Medicine* 18: 119–126.

[70] Zajkowska J., Waluk E., Świerzbińska R., Dunaj J., Zajkowska O., Wawrzuta D., Niścigorska-Olsen J., Matukiewicz M., Oczko-Grzesik B., Veltze D., Bernacka-Andrzejewska K., Burchart-Adamczyk K., Dutkiewicz E., Maciukajć J., Konieczny K., Malcher-Bober D., Dybowska D., Hapyn-Rocha M., Marsik-Styrkosz M., Kmak G., Bociaga-Jasik M., Byś-Chrzanowska M., Paradowska-Stankiewicz I. 2025. The impact of serological testing implementation on tick-borne encephalitis detection in Poland. *PLOS ONE* 20: e0323022. doi:10.1371/journal.pone.0323022

[71] Paddock C.D., Childs J.E. 2003. *Ehrlichia chaffeensis*: a prototypical emerging pathogen. *Clinical Microbiology Reviews* 16: 37–64. doi:10.1128/cmr.16.1.37-64.2003

[72] Rikihisa Y. 2015. Molecular pathogenesis of *Ehrlichia chaffeensis* infection. *Annual Review of Microbiology* 69: 283–304. doi:10.1146/annurev-micro-091014-104411

[73] Johnson D.K.H., Schiffman E.K., Davis J.P., Neitzel D.F., Sloan L.M., Nicholson W.L., Fritsche T.R., Steward C.R., Ray J.A., Miller T.K., Feist M.A., Uphoff T.S., Franson J.J., Livermore A.L., Deedon A.K., Theel E.S., Priott B.S. 2015. Human infection with *Ehrlichia muris*-like pathogen, United States, 2007–2013. *Emerging Infectious Diseases* 21: 1794. doi:10.3201/eid2110.150143

[74] Walker D.H. 2007. Rickettsiae and rickettsial infections: the current state of knowledge. *Clinical Infectious Diseases* 45 (Suppl. 1): S39–S44.

[75] Nilsson K., Elfving K., Pahlson C. 2010. *Rickettsia helvetica* in patient with meningitis, Sweden, 2006. *Emerging Infectious Diseases* 16: 490–492. doi:10.3201/eid1603.090184

[76] Buczek K., Koman-Iżko A., Buczek Alicja M., Buczek A., Bartosik K., Kulina D., Ciura D. 2020. Spotted fever group rickettsiae transmitted by *Dermacentor* ticks and determinants oftheir spread in Europe. *Annals of Agricultural and Environmental Medicine* 27(4): 505–511. doi:10.26444/aaem/120602

[77] Kochanowsky J.A., Koshy A.A. 2018. *Toxoplasma gondii*. *Current Biology* 28: R770–R771. doi:10.1016/j.cub.2018.05.035

[78] Ben-Harari R.R. 2019. Tick transmission of toxoplasmosis. *Expert Review of Anti-Infective Therapy* 17: 911–917. doi:10.1080/14787210.2019.1682550

[79] Skotarczak B. 2016. The role of ticks in transmission cycle of *Toxoplasma gondii*. *Annals of Parasitology* 62: 185–191. doi:10.17420/ap6203.52

[80] Chmielewski T., Sidi-Boumedine K., Duquesne V., Podsiadły E., Thiéry R., Tylewska-Wierzbanowska S. 2009. Molecular epidemiology of Q fever in Poland. *Polish Journal of Microbiology* 58: 9–13.

[81] Angelakis E., Raoult D. 2010. Q fever. *Veterinary Microbiology* 140: 297–309. doi:10.1016/j.vetmic.2009.07.016

[82] Moutailler S., Valiente Moro C., Vaumourin E., Michelet L., Tran F.H., Devillers E., Cosson J.F., Gasqui P., Van V.T., Mavingui P., Vourc'h G., Vayssier-Taussat M. 2016. Co-infection of ticks: the rule rather than the exception. *PLOS Neglected Tropical Diseases* 10: e0004539. doi:10.1371/journal.pntd.0004539

[83] Cutler S.J., Vayssier-Taussat M., Estrada-Peña A., Potkonjak A., Mihalca A.D., Zeller H. 2021. Tick-borne diseases and co-infection: current considerations. *Ticks and Tick-Borne Diseases* 12: 101607. doi:10.1016/j.ttbdis.2020.101607

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