

Review articles

Ticks of Poland. Review of contemporary issues and latest research.

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ABSTRACT. The paper presents current knowledge of ticks occurring in Poland, their medical importance, and a review of recent studies implemented in the Polish research centres on ticks and their significance in the epidemiology of transmissible diseases. In the Polish fauna there are 19 species of ticks (Ixodida) recognized as existing permanently in our country: *Argas reflexus, Argas polonicus, Carios vespertilionis, Ixodes trianguliceps, Ixodes arboricola, Ixodes crenulatus, Ixodes hexagonus, Ixodes lividus, Ixodes rugicollis, Ixodes caledonicus, Ixodes frontalis, Ixodes simplex, Ixodes vespertilionis, Ixodes apronophorus, Ixodes persulcatus, Ixodes ricinus, Haemaphysalis punctata, Haemaphysalis concinna, Dermacentor reticulatus.* Occasionally, alien species of ticks transferred to the territory of Poland are recorded: *Amblyomma sphenodonti, Amblyomma exornatum, Amblyomma flavomaculatum, Amblyomma latum, Amblyomma nuttalli, Amblyomma quadricavum, Amblyomma transversale, Amblyomma varanensis, Amblyomma* spp., *Dermacentor marginatus, Hyalomma aegyptium, Hyalomma marginatum, Ixodes eldaricus, Ixodes festai, Rhipicephalus rossicus, Rhipicephalus sanguineus.* The most common species of the highest medical and veterinary importance in Poland is invariably *Ixodes ricinus*. The review also sets out information on the risks of tick-borne diseases in recreational areas of large cities in Poland, ticks as the cause of occupational diseases and dangerous species of ticks attacking people outside the Polish borders. Selected problems of the biology of ticks, the spread of alien species transferred on hosts and prevention of tick attacks have also been presented. The Polish studies on ticks are a valuable contribution to global research on the Ixodida.

Key words: tick, Ixodida, Poland, epidemiology

The aim of this paper is to present up-to-date state of knowledge about the fauna of ticks in Poland and their ability to transmit pathogens. The latest release of the full list of ticks occurring in Poland was published as a monograph 19 years ago [1]. The fauna of ticks does not change remarkably fast, and in the zoological and parasitological literature there is still relatively little work in the field of taxonomy, systematics and faunistics of ticks. However, noteworthy information is continually collected about the biology and ecology, the transfer of alien species of these parasites into the Polish territory and the epidemiological importance of ticks occurring in Poland.

Because ticks are obligate, external and temporary parasites of terrestrial vertebrates, and their numerous species attack also humans, their parasitizing can cause very serious negative medical, veterinary and economic consequences. Two life phases are distinguished in the development of each active stage of ticks: the parasitic phase, in which the tick embedded in the host gets the food, especially blood from the body of the host, and the non-parasitic phase in which the tick usually lives in nature without close association with the host. Adaptation to external and temporary parasitic lifestyle of ticks is clearly marked in the formation of sensory organs, the structure of the integument and digestive system, as well as feeding strategy and association of the habitat with the host.

An invariably important aspect increasingly promoted in Poland is prophylaxis against ticks and

dissemination of information to society groups who, for professional, tourist or other reasons, stay in areas of occurrence and feeding grounds of ticks. Enhancing public awareness about the dangers posed by tick attacks and disease transmission is increasingly being promoted by various media, which is beneficial and essential in prophylaxis. However, the main responsibility lies with academic lecturers who prepare teachers of biology and nature to work in schools with children and adolescents, as well as doctors of medical and veterinary sciences.

Systematic classification of ticks and representatives in the world fauna

Ticks are classified in a separate order Ixodida, superorder Parasitiformes, class Arachnida, subphylum Chelicerata, phylum Arthropoda. Currently, the order Ixodida is divided into two suborders: Argasina and Ixodina. Suborder Argasina with one family Argasidae and two subfamilies: Argasinae with one genus *Argas* (57 species) and Ornithodorinae with genera *Carios* (88 species), *Ornithodoros* (37 species) and *Otobius* (3 species); suborder Ixodina with three families; Nuttalliellidae with subfamily Nuttalliellinae including a single genus and species *Nuttalliella namaqua* Bedford, 1931; Ixodidae with subfamily Ixodinae and one genus *Ixodes* (249 species); Amblyommidae with subfamilies and genera: Amblyomminae: *Amblyomma* (142 species), *Cornupalpatum* (1 species *Cornupalpatum burmanicum* Poinar et Bron, 2003), Bothriocrotoninae: *Bothriocroton* (5 species), Haemaphysalinae: *Haemaphysalis* (166 species), Hyalomminae: *Hyalomma* (25 species) and *Nosomma* (1 species – *Nosomma monstrosum* (Nuttall et Warburton, 1908)), Rhipicephalinae with genera: *Anomalohimalaya* (3 species), *Cosmiomma* (1 species – *Cosmiomma hippopotamensis* (Denny, 1843)), *Dermacentor* (36 species), *Margaropus* (3 species), *Rhipicentor* (2 species) and *Rhipicephalus* (79 species).

There are also other monographs on world's tick fauna in which researchers generally agree on the actual existence of 896 species of ticks, while still debatable is the taxonomic division into genera and higher systematic units of the Ixodida order [2].

Worldwide tick fauna comprises about 900 recognized species, of which 77 belong to the European fauna. Currently, the Polish fauna includes 19 species of ticks (Ixodida) identified as permanent residents in our country, and the species occasionally recorded as transferred to the Polish territory are entered into the database „Alien species in Poland" (www.iop.krakow.pl/ias). The most common species of the highest medical and veterinary importance in Poland and almost all over Europe is still *Ixodes ricinus* (Linnaeus, 1756).

Distribution of ticks on Earth and in Poland

Ticks inhabit all types of terrestrial environments, from tropical to sub-polar regions, from the sea level to high mountain ice zone, in highly humid habitats, but also on the steppes, semi-deserts and deserts where few other haematophagous arthropods survive. In tropical countries tick species representation is richer, but in our latitudes with a small number of species they can also reach very high abundance. An example would be the size of the Polish common tick population. Cases were recorded when propitious for ticks microclimatic conditions in the habitat and host availability resulted in abundance of *I. ricinus* exceeding 100 specimens per 100 square meters.

Argasidae are more thermophilic. It is generally accepted that the northern border of their range in Europe extends along the 50°N, but in Poland two species expand further to the north: *Argas reflexus* Fabricius, 1794 and *Carios vespertilionis* Latreille, 1802. Ixodidae have a more global range reaching beyond the polar circles, where exists widespread *Ixodes* (*Ceratixodes*) *uriae* White, 1852, a nidicolous parasite of marine birds.

All species of ticks occurring in Poland have probably been already identified, but knowledge of their distribution in our country is inadequate. Most information is available on *I. ricinus* – the most common and most easily collected species in Poland. Likewise, distribution of *Dermacentor reticulatus* (Fabricius, 1794) in Poland is relatively well-known, and recent studies have shown that its range of occurrence is much more extended in western Poland than expected [3,4].

Specific microclimatic conditions of the habitat have an effect on selection of living space by ticks. Consequently, in case of many species their presence in the area of coverage is restricted to a number of „islands" and „islets". An example is dispersion of *I. ricinus* ticks, which are usually not evenly distributed within the habitat and their number may change even at intervals of a few meters – the so called „mosaic distribution".

Fauna of ticks in Poland and their ability to transmit pathogens

Family Argasidae

***Argas* (*Argas*) *polonicus* Siuda, Hoogstraal, Clifford et Wassef, 1979**. In Poland the localities of this species have been found in Cracow (in the Śródmieście and Podgórze district). The attic of St. Mary's Church is *locus typicus* of this species [5]. Several foci have been registered in the Czech Republic and Slovakia [6]. *A. polonicus* is a nests- and burrows-dwelling parasite. It exists mainly in synanthropic habitats in towers and attics of buildings, where its main hosts are rock pigeons (*Columba livia*) [5,6], but incidents of attacks on humans have also been recorded [7,8]. In Cracow, the one peak annual activity cycle of *A. polonicus* begins in early April and lasts until the end of October. Maximum abundance falls in July and August and during warmer summers to early September. Throughout the entire period of activity all developmental stages are observed in various states of repletion. The larvae are more numerous in late summer (predominantly unfed specimens) and spring (most replete specimens). *A. polonicus* is a parasite of nocturnal activity. It feeds in a manner typical of ticks, i.e. the larvae slowly for about 6 days, nymphs and adults quickly, from several minutes to about 2 hours. They spend the day hiding in cracks in beams and walls; usually in one crevice a few specimens in different developmental stages and different repletion states are gathered. Predominantly nocturnal activities of these ticks and their absence at the ground level of St. Mary's Church do not pose the risk of attacking people who visit the church during the day. However, tick attacks on trumpeters performing night shifts on the church tower have been reported [1,8]. Studies to date on the role of *A. polonicus* as a vector of transmission of disease pathogens have been negative. Direct adverse effects of attacks by soft ticks of the genus *Argas* are shown in the table (Table 1).

***Argas* (*Argas*) *reflexus* (Fabricius, 1794).** On the Polish territory most localities of *A. reflexus* are found to the west of the Vistula River, it is probably a common tick in the western part of Poland. *A. reflexus* is a nests- and burrows-dwelling parasite. All the known Polish localities are found in synanthropic habitats (attics, church attics, houses and lofts), in all places where pigeons nest, the main hosts of these ticks [1,68]. Outside Poland sporadic cases of attacking other bird species by *A. reflexus* have been reported. It often attacks people, especially in cases where there is no access to pigeons. Behaviour and activities (annual rhythm, circadian rhythm) of *A. reflexus* are similar to those of *A. polonicus*. Parasitizing ticks cause in infested humans stress, allergic reactions and toxicoses (oedema and erythema, itching, pain, fever, weakness, nausea, diarrhoea, dizziness, headaches, anxiety, increased heart and breathing rate, fainting with varying degrees of severity), which may pose threat to health and even lives of victims [69–71] (Table 1). Large populations of *A. reflexus* threaten farms of pigeons which die when attacked en masse. Pigeons abandoning nests with nestlings have also been observed [72].

***Carios vespertilionis* Latreille, 1802.** In Poland localities of this species are recorded across the country [1,73]. *C. vespertilionis* belongs to a nests- and burrows-dwelling type of species, parasitizing bats in natural, synanthropic and semi-synanthropic habitats where it hides in the cracks of walls of buildings and caves, also under piles of guano. Moreover, it is found in tree hollows inhabited by bats. The annual rhythm of activity in the acquisition of hosts in Central Europe is not fully understood; in the circadian rhythm ticks are active during the day. The argasids can attack humans [17,74] (Table 1), but in Poland no such case has been reported.

Family Ixodidae

***Ixodes* (*Exopalpiger*) *trianguliceps* Birula, 1895.** In Poland *I. trianguliceps* occurs across the country (from the subalpine zone of the Tatra mountains to the coast of the Baltic Sea) and is one of the most common parasites of small mammals [1,75,76]. Most of localities of *I. trianguliceps* in Poland are found in the foothills and mountain areas. It lives in moderately humid habitats, mostly in shady mixed and deciduous forests. There is no evidence of existence of these ticks in the swamp forests with heavily watered ground and in dry woods, on sandy soil with a thin layer of litter and bare grassland sites. It is out of nest dwelling parasite and polyphagous species of a three-host development cycle. It feeds mainly on small mammals (about 50 species); among its hosts several species of birds and a viviparous lizard (*Lacerta vivipara*) have been reported [1]. Adult ticks are active from April to October, nymphs from April to September, and the larvae for the whole

year [77]. It is believed that *I. trianguliceps* is the main vector and the reservoir of tick-borne encephalitis virus (Togaviridae: *Flavivirus*) among populations of small mammals (Table 1).

***Ixodes* (*Pholeoixodes*) *arboricola* Schulze et Schlottke**. *I. arboricola* probably occurs across the whole of Poland, but most of the localities of the ticks have been recorded in the western part of the country. *I. arboricola* is a nests- and burrows-dwelling parasite, strictly ornithophilic, associated with birds nesting in tree hollows and bird booths, rarely in burrows carved in the ground. In Central and Western Europe *I. arboricola* attacks hosts throughout the year, its abundance falls in the winter, the maximum activity of females is in the spring, in other seasons there is preponderance of larvae and nymphs, adult males do not feed [78]. There is little data about the medical, veterinary and economic importance of *I. arboricola* (Table 1).

***Ixodes* (*Pholeoixodes*) *crenulatus* Koch, 1844**. In Poland over a dozen localities have been recorded across the country. This is a nests- and burrows-dwelling parasite, dwelling in burrows of rodents and predatory mammals, also found in caves. The hosts of immature stages and females are insectivorous mammals, rodents, predatory mammals and birds in contact with mammal burrows. Adult males do not attack a host. These ticks may attack humans, domestic animals and livestock: dogs, cats, horses, sheep. In annual rhythm the highest intensity of invasion of females and immature stages of *I. crenulatus* is recorded in spring (April), followed by reduction in the intensity of invasion in summer, and its increase again in autumn. Medical and veterinary importance of this species is little known (Table 1).

***Ixodes* (*Pholeoixodes*) *hexagonus* Leach, 1815**. In Poland it is likely to occur across the whole country, but most of the known foci are situated in the southern Poland. The largest concentration of these ticks has been observed at a beaver farm in Popielno in Masuria [1,79,80]. This nests- and burrows-dwelling parasite inhabits different types of hollows, also in buildings, in caves, rock shelters and dog kennels [1,81]. There is no precise data on the course of the seasonal rhythm of activity of *I. hexagonus* on the Polish territory. In the United Kingdom these ticks are active throughout the year with increased activity of the attacks on hosts in April and May, and from August to October [78]. *I. hexagonus* is counted among the species causing tick paralysis [82], and is important in the epidemiology of transmissible diseases in Europe (Table 1).

***Ixodes lividus* Koch, 1844**. *I. lividus* occurs across the whole of Poland. It is a nidicolous parasite, specifically ornithophillic, closely related to the *Riparia riparia*. It nests in burrows carved in the ground by these birds. In Poland it is most frequently recorded in the central and northern parts. *I. lividus* has a one-year life cycle involving three hosts and is time-dependent on the nesting and development rhythm of *R. riparia*. It may be important in transmission of pathogens (Table 1).

***Ixodes* (*Pholeoixodes*) *rugicollis* Schulze et Schlottke, 1929**. Geographical borders of *I. rugicollis* are not fully known. In Poland its prevalence has been found near Wroclaw [83] and Przemyśl [84]. *I. rugicollis* is a nests- and burrows-dwelling parasite of a three-host development cycle. It lives in burrows and shelters, mostly of predatory mammals of the family Mustelidae. In Poland cases of *I. rugicollis* parasitism have been detected on dogs and cats. No data on the epidemiological importance of *I. rugicollis* is available.

***Ixodes* (*Scaphixodes*) *caledonicus* Nuttall, 1910**. Localities of *I. caledonicus* are rarely recorded, in Poland found in Pomerania, a parasite of *Apus* spp. [85]. *I. caledonicus* is a nests- and burrows-dwelling parasite, absolutely ornithophillic. It attacks birds nesting and living in the rocky hideouts. Biology of this species and its medical and veterinary importance are poorly known.

***Ixodes* (*Trichotoixodes*) *frontalis* (Panzer, 1798)**. In Poland the occurrence of *I. frontal*is has been identified on the Vistula Spit [86] and on birds during their spring migration (own unpublished studies). *I. frontalis* is an absolutely ornithophillic, out of nest dwelling parasite with a three-host development cycle. It attacks ground feeding birds that nest in trees. The importance of this species in the epidemiology has been demonstrated (Table 1).

***Ixodes* (*Pomerantzevella*) *simplex* Neumann, 1906**. In Poland one location in Bukowiec near Nowy Sącz is known [87] Subsequent studies on ticks parasitizing bats have not shown the increase in the number of localities of *I. simplex* in Poland [73]. It is a nests- and burrows-dwelling tick, a parasite of bats, living in caves and grottos, and its main host is considered to be the bat *Miniopterus schreibersi*. In Poland it has been collected from *Myotis myotis* [87]. There is no data of medical and veterinary importance.

***Ixodes* (*Eschatocephalus*) *vespertilionis* Koch, 1844.** In Poland 22 sites have been registered, one in Samogoszcz in Mazovia, others in caves in the Polish Jura Krakowsko-Częstochowska and in the Carpathians [73]. *I. vespertilionis* is a nests- and burrows-dwelling oligoxenous parasite of bats with three-host development cycle. The course of the seasonal cycle of activity is closely associated with the rhythm of activity and hibernation of bats. Females and immature forms attack hosts from November to May, adult males do not feed. There is no data on their medical and veterinary importance.

***Ixodes* (*Ixodes*) *apronophorus* Schulze, 1924**. The distribution of this species in Poland is little known, several localities have been registered in Pomerania, Masuria, in the Białowieża Forest and in the Lublin region [80,85,88–90]. *I. apronophorus* is a three-host, nests- and burrows-dwelling, hygrophilous parasite occurring in wetlands, overgrown banks of water reservoirs, muddy rivers and streams, islands and islets, marshes and swamps with sedge clumps in which it lives in the nests and burrows of small mammals and birds [1]. Adult males probably do not feed. The ability of this species to transmit pathogens has been demonstrated (Table 1).

***Ixodes* (*Ixodes*) *persulcatus* Schulce, 1930**. Poland is outside the compact range of *I. persulcatus*, a few records of the tick have been reported from the Białowieża Forest [85,91]. *I. persulcatus* is out of nest dwelling parasite of a three-host development cycle. It is a species with a broad food specificity and can attack all species of terrestrial vertebrates, including humans. The species is of great medical and veterinary importance (Table 1).

***Ixodes* (*Ixodes*) *ricinus* (Linnaeus, 1758).** In Poland it exists throughout the country, hundreds of locations have been recorded [92]. It occurs in damp habitats (about 80-100% relative humidity), mainly in deciduous and mixed forests, or bushy thickets. These ticks are not usually found in dry pine forests on sandy soils and coniferous forests without undergrowth. It does not occur in swamps and bogs. *I. ricinus* ticks are unevenly distributed in habitats, and their number may change every few meters. They tend to gather along narrow roads and forest paths overgrown with grass vegetation along animal trails where they have a greater chance of contact with the host. *I. ricinus* is out of nest dwelling parasite of three-host development cycle with broad food specificity. It attacks terrestrial animals, mammals, birds and reptiles. It prefers warm-blooded animal hosts, all active stages attack humans, mostly nymphs and females. *I. ricinus* is counted among the arthropods of the greatest significance in the epidemiology of transmissible diseases (Table 1).

Family Amblyommidae

***Haemaphysalis* (*Aboimisalis*) *punctata* Canestrini et Fanzago, 1877.** In Poland two localities have been registered in West Pomerania province [93,94]. *H. punctata* is a polixenic, out of nest dwelling parasite of a three-host development cycle. Larvae and nymphs attack mainly small-sized animals (mammals, birds, domestic fowls among others), hosts of the adult forms are mainly domestic and wild ungulates, in Poland it has been collected from cows [93]. *H. punctata* attacks also humans and can cause tick paralysis in the host [82] (Table 1).

***Haemaphysalis* (*Haemaphysalis*) *concinna* Koch, 1844.** In Poland one locality of *H. concinna* has been recorded in Troszyn in West Pomerania [93]. *H. concinna* lives in well-lit, thin, moist deciduous and mixed forests with rich bushy undergrowth, forest steppes and wet steppe habitats, overgrown lake districts and river valleys. It is also found in thickets of reeds on the banks of lakes [95]. *H. concinna* is a polixenic, exophilic parasite of three-host development cycle. Its hosts are numerous species of reptiles, birds, mammals and, among others, domestic cattle, goats and sheep. Humans are attacked by nymphs and adult ticks. In Slovakia adult *H. concinna* are active from mid-April to mid-August with maximum activity in June, nymphs from mid-April to mid-October, larvae from late May to mid-October [95]. All active development stages are active day and night. High epidemiological importance of these ticks has been demonstrated (Table 1).

***Dermacentor* (*Dermacentor*) *reticulatus* (Fabricius, 1794).** In Poland most of the known locations are found in the north-eastern and eastern parts of the country [1,44,96], but also in the western Poland natural occurrence of *D. reticulatus* has been recorded [3,4,97]. In Poland *D. reticulatus* exists mainly in wooded or bushy valleys of rivers, streams and drainage channels, in mixed swamp forests, mid-forest glades and meadows, clearings and bushy pastures on small hills among marshes covered with gray willow [98]. *D. reticulatus* is a polygenic, nests- and burrows-dwelling parasite of three-host development cycle. Immatures live in

burrows and corridors of burrows of small mammals. The hosts of adult *D. reticulatus* are medium-sized and large mammals. It rarely attacks humans, but is important in the epidemiology of transmissible diseases (Table 1).

Migration of ticks beyond their natural range

In Poland sporadic cases of natural and unnatural transfer of alien tick species whose natural range of

Table 1. Medical significance of ticks occurring in the Polish fauna

Species	Medical significance	References
Argas reflexus	localized allergic skin reactions, systemic allergic reactions manifesting as generalized urticaria and asthma; transmission: tick-borne encephalitis virus, Grand Arbaud virus and Ponteves virus, Crimean-Congo hemorrhagic fever, *Coxiella burnetii*, *Salmonella enteritidis*; it can cause tick paralysis in the host	[9–12]
Argas polonicus	local allergic skin reactions similar to the effects of *A. reflexus* attack, no data on transmission of pathogens	[10]
Carios vespertilionis	in humans local mild itching lasting several weeks, transmission: tick-borne encephalitis virus, Sokuluk virus, Issyk-Kul virus, *Borrelia burgdorferi* s. l., *Coxiella burnetii*, *Wolbachia* sp.	[13-18]
Argas spp.	transmission: *Borrelia anserina, Anaplasma* (*Aegyptianella*) *pullorum*	[19]
Ixodes trianguliceps	transmission: tick-borne encephalitis virus, *Borrelia burgdorferi* s. l., *B. afzelii, B. garinii, Coxiella burnetii*, *Anaplasma phagocytophilum, Babesia microti*	[10, 19-23]
Ixodes arboricola	transmission: *Borrelia burgdorferi* s. l., *Rickettsia* spp., involved in the spread of ornithosis in birds	[24,25]
Ixodes crenulatus	transmission: *Coxiella burnetii, Yersinia pestis;* it can cause tick paralysis in the host	[26]
Ixodes hexagonus	transmission: tick-borne encephalitis virus, *Borrelia burgdorferi* s.l., *Anaplasma phagocytophilum*, *Rickettsia helvetica*, *R. conorii*, *Babesia canis, B. divergens, B. microti;* it can cause tick paralysis in the host	[10,19,27]
Ixodes lividus	transmission: the virus of Russian spring-summer encephalitis, Kama virus, *Coxiella burnetii*, *Rickettsia sibirica*, *Rickettsia* spp.	[26,28,29]
Ixodes rugicollis	no data	
Ixodes caledonicus	no data	
Ixodes frontalis	transmission: tick-borne encephalitis virus, Chizè virus, Bahig virus, Kemerovo virus, *Coxiella burnetii*	[19,26,30]
Ixodes simplex	no data	
Ixodes vespertilionis	no data	
Ixodes apronophorus	transmission: Omsk hemorrhagic fever virus, *Rickettsia sibirica*, *Coxiella burnetii, Francisella tularensis*	[1,26]
Ixodes persulcatus	transmission: spring-summer tick-borne encephalitis virus, Powassan virus, Omsk hemorrhagic fever virus, West Nile virus, Langat virus, Uukuniemi virus, Kemerovo virus, Sichote-Alin virus, *Borrelia burgdorferi*, *B. garinii, B. afzelii*, *B. valaisiana*, *B. miyamotoi, Rickettsia tarasevichiae*, *R. sibirica, R. helvetica, Anaplasma phagocytophilum, A. marginale, A. centrale, Coxiella burnetii, Francisella tularensis, Erysipelothrix rhusiopathiae, Yersinia pseudotuberculosis, Salmonella* sp., *Theileria sergenti, Babesia divergens, B. ovis, Babesia* sp., *Bartonella henselae*, *Bartonella* spp.	[10,19,31-40]

Ixodes ricinus	transmission: tick-borne encephalitis virus, Shetland encephalitis virus, Crimean-Congo haemorrhagic fever virus, Uukuniemi virus, Kemerovo virus (Koliba, Lipovnik, Tribec), Louping ill virus, *Borrelia burgdorferi* s.l., *B. garinii*, *B. afzelii*, *B. valaisiana, B. lusitaniae, B. bissettii, B. spielmani*, *Rickettsia slovaca*, *R. helvetica*, *R. monacensis*, *R. conorii, R. aeschilmannii, Anaplasma phagocytophilum, A. marginale, A. centrale, Coxiella burnetii*, *Ehrlichia chaffeensis*, *Salmonella enteritidis*, *Francisella tularensis, Listeria monocytogenes, Pasteurella, Erysipelothrix rhusiopathiae, Brucella melitensis, Theileria mutans, T. sergenti, Bartonella vinsonii, B. henselae*, *Babesia divergens, B. microti, B. caballi, B. bigemina, B. ovis, B. bovis, B. major, B. canis, B. capreoli, B. motasi, B. venatorum, Toxoplasma gondii*; can cause tick paralysis in the host	[10,19,31,41-59]
Haemaphysalis punctata	transmission: tick-borne encephalitis virus (Western subtype), Crimean-Congo haemorrhagic fever virus, Bhanja virus, Tribec virus, *Rickettsia sibirica*, *R. aeschlimannii*, *Coxiella burnetii*, *Anaplasma phagocytophilum, Francisella tularensis*, *Salmonella pullorum*, *S. enteritidis*, *Brucella* sp., *Theileria mutans*, *T. buffeli/orientalia, Babesia motasi*, *B. bovis*, *B. bigeminia*, *B. major* ; it can cause tick paralysis in the host	[1,19,60,61]
Haemaphysalis concinna	transmission: tick-borne encephalitis virus (Western and Eastern subtypes), *Borrelia burgdorferi* s.l., *Rickettsia hulinii, R. sibirica*, *Coxiella burnetii*, *Francisella tularensis*, *Salmonella pullorum*, *Brucella* sp.	[1,19,62-64]
Dermacentor reticulatus	transmission: tick-borne encephalitis virus, Omsk hemorrhagic fever virus, *Rickettsia conori*, *R. slovaca*, *R. sibirica, R. honei, R. raoulti, Rickettsia* spp., *Coxiella burnetii*, *Francisella tularensis, Salmonella* sp., *Brucella abortus, B. melitensis*, *Erysipelothrix rhusiopathiae*, *Listeria monocytogenes, Theileria rossica, T.equi, Nicollia equi, N. ninense, Clostridium* sp., *Brucella* sp., *Babesia canis, B. microti, B. caballi, B. divergens, Hepatozoon canis*	[10,19,44,65-67]

occurrence is remote from the Polish territory have been recorded. Geographical transference of ticks on migrating hosts, referred to as natural transfer, occurs in nature and is independent of human activity. Cases of unnatural tick transfer are associated with deliberate or accidental human activity (Table 2). Each described case of ticks transfer into new territory is valuable information for faunists and epidemiologists, because expansion of ticks is epizootiologically and epidemiologically important.

Migratory birds are the most common group of hosts which can easily introduce alien species of ticks into the Polish fauna. Probably every year, during bird migrations to the southern part of Central Europe and further north, alien species of ticks are imported to Poland. During the study of birds in the Hel Peninsula (the Baltic coast in Poland), four specimens of *Ixodes eldaricus* were recorded for the first time in Poland [99].

It is assumed that species brought for climatic reasons cannot acclimatize in natural conditions of our country, but their transfer may cause increased risk of tick-borne diseases. The general tendency of climate warming in Poland, well-conducted breeding of terrarium animals, potential hosts for ticks, and formation of new parasite-host systems, create greater opportunities for acclimatization of tick species brought from warmer areas of the Earth, and therefore open up new vectors of disease transmission. Reported cases of tick feeding on host indicate numerous direct consequences of parasitism. These are local, systemic changes causing disturbances in normal development of the host.

In the course of studies conducted on reptiles [100], isolated cases of lizards and pythons infested with exceptionally large number of ticks were found (from 1 to 68 specimens of ticks on 1 host). Apathetic and slow behaviour of the reptiles and observable weakened life activity showed the direct consequences of high number of ticks parasitizing them. It was noted that ticks parasitizing in clusters obstructed nasal and ear openings of *Varanus*

Table 2. Registered cases of ticks transfer to Poland

Species	Host	Cite of collection from host in Poland	Country from which animals were imported * refers to reptiles
Amblyomma exornatum (Koch, 1844)	*Varanus exanthematicus*	Świętochłowice (Silesia province)	Ghana
Amblyomma flavomaculatum (Lucas,1846)	*Iguana iguana* *Varanus exanthematicus*	Świętochłowice (Silesia province) Świętochłowice (Silesia province)	El Salvador Ghana
Amblyomma latum (Koch, 1844)	*Varanus exanthematicus* *Python regius*	Świętochłowice (Silesia province) Świętochłowice (Silesia province)	Ghana Ghana
Amblyomma nuttalli Dőnitz, 1909	*Varanus exanthematicus*	Świętochłowice (Silesia province)	Ghana
Amblyomma quadricavum Schulze, 1941	*Iguana iguana*	Świętochłowice (Silesia province)	El Salvador
Amblyomma sphenodonti Dumbleton, 1943	*Sphenodon punctatus*	Cracow	New Zealand
Amblyomma transversale (Lucas, 1845)	*Python regius*	Świętochłowice (Silesia province)	Ghana
Amblyomma varanensis (Supino,1897)	*Varanus salvator*	Świętochłowice (Silesia province)	Indonesia
Amblyomma spp. Koch, 1844	*Varanus exanthematicus* *Python regius*	Świętochłowice (Silesia province) Świętochłowice (Silesia province)	Ghana Ghana
Dermacentor marginatus (Sulzer, 1776)	*Sus scrofta*	The Kłodzko Valley	
Hyalomma aegyptium (Linnaeus,1758)	*Testudo* sp. *Testudo graeca* *Testudo marginata*	Wieliczka, Chorzów Świętochłowice (Silesia province)	Greece
Hyalomma marginatum Koch, 1844	*Motacilla flava* *Acrocephalus schoenobaenus*	Popielno (Warmia-Masuria province) Umianowice, Pińczów region, (Świętokrzyskie province)	
Ixodes eldaricus Djaparidze, 1950	*Prunella modularis,* *Erithacus rubecula*	The Hel Peninsula	
Ixodes festai Rondelli, 1926	*Turdus merula*	The Hel Peninsula	
Rhipicephalus rossicus Jakimov et Kohl-Jakimova, 1911	?	Machnów (Lublin province)	
Rhipicephalus sanguineus (Latreille, 1806)	*Canis familiaris*	Warsaw	

Table 3. Tick-host specificity of Ixodida species recorded in Poland

Species	Hosts				
	Amphibia	Reptilia	Aves	Mammalia	Homo
Argas reflexus			+ + +		+ +
Argas polonicus			+ + +		+ +
Argas vespertilionis				+ + + +	+
Ixodes trianguliceps		+	+	+ + +	
Ixodes arboricola			+ + + +		
Ixodes crenulatus			+	+ + +	+
Ixodes hexagonus			+	+ + +	+
Ixodes lividus			+ + + +		
Ixodes rugicollis				+ + + +	
Ixodes caledonicus			+ + + +		
Ixodes frontalis			+ + + +		
Ixodes simplex				+ + + +	
Ixodes vespertilionis				+ + + +	
Ixodes apronophorus			+	+ + +	
Ixodes persulcatus	NS	NS	NS	NS	NS
Ixodes ricinus	NS	NS	NS	NS	NS
Haemaphysalis punctata		+	+ +	+ +	+
Haemaphysalis concinna		+	+ +	+ +	+
Dermacentor reticulatus		+	+	+ + +	+

Explanations:
+ + + + strictly specific host group
+ + + moderately specific host group
+ + relatively specific host group
+ accidental host group
NS non-specific host group attacking all available hosts

exanthematicus. In the eye and its close vicinity a few replete tick specimens restricted the field of view. The overall prevalence of ticks infestation was 77.6%, 81.2% thereof for the host group of snakes (pythons) and 78.7% for lizards (monitor lizards). Therefore, breeders of exotic animals are warned to purchase animals from licensed brokers and not from casual sellers, and an animal examined by a veterinarian and an experienced breeder reduces the risk of introducing a host with parasites into the terrarium. Moreover, ticks transfer into home herpetoculture may detach unnoticed from the body of the host and move around the terrarium or the room in which they are held. In consequence, it might result in a tick transmission to an accidental host. Such an incident occurred in a breeding room, where the African tick *Amblyomma flavomaculatum* was collected from *Iguana iguana* imported from Central America [101].

Polish research on infection caused by pathogenic micro-organisms in humans and animals conducted on ticks imported on reptiles confirmed in two *Amblyomma flavomaculatum* specimens the presence of *Anaplasma phagocytophilum*, and hence indicated a new epidemiological problem in our country – the problem of transmissible diseases pathogens in ticks brought on imported reptiles. The findings also suggest that *A. flavomaculatum* ticks may participate in the natural circulation of *A. phagocytophilum* in Africa. No bacteria of *Rickettsia* spp. causing spotted fevers were found in the examined ticks [102].

Selected aspects of the biology of ticks

Host specificity. The relationship between a tick species and a vertebrate species – the host, which is essential for the development and survival of

populations of a given species of ticks, is known as host specificity. Out of approximately 900 species of ticks in the world only a few have very strict host specificity, feeding solely on one host species. In the Polish fauna it is *I. lividus* – the parasite of Sand Martin (*R. riparia*). Ticks characterized by strict host specificity seek their hosts within a group of closely related species of vertebrates. For instance, in the Polish fauna these are such parasites of bats as *C. vespertilionis*, *I. vespertilionis*, *I. simplex*, or species ecologically associated with habitat, e.g. ticks dwelling and feeding in tree hollows of birds. Moderate host specificity is exhibited mainly by ticks from ecological group of nidicolous species that choose for hosts related host groups, but also feed on vertebrates which accidently occur at the site and are not related, for example, representatives of the genus *Argas*, or subgenus *Pholeoixodes*. It has been shown that about 100 species of ticks of the world fauna are host nonspecific. These are mainly exophilic species, such as in the Polish fauna *I. ricinus* which feeds on all terrestrial vertebrates. Until now no species of ticks (Ixodida) has been recognized as specific for humans. Among the ticks found in Poland we can distinguish several groups as regards the types of host specificity or lack thereof (Table 3). Most of these species of ticks feed on atypical and accidental hosts, such as *A. reflexus* and *A. polonicus* regarded as specific parasites of pigeons willing to attack distantly related humans. Feeding on species atypical for the parasite may in host-specialized ticks cause disturbances in development or incomplete engorgement. In the Polish fauna no ticks specific for amphibians (Amphibia) and reptiles (Reptilia) have been recognized.

Host specificity of ticks is in natural conditions one of biological factors limiting the geographic distribution and population density of ticks. Modern man-made changes in the environment, as well as transport of animals over longer distances, facilitate the spread of ticks to new areas and questing for new hosts.

Morphological characteristics of active stages of development of ticks. In the life cycle of ticks there are three active developmental stages: larva, nymph and adult (male or female). In the development of argasids (Argasina) there are two to eight nymphal instars, their number may be different in individuals of the same species. In the development of ixodid ticks (Ixodina) there is only one nymphal instar. Ticks are dioecious, but in Argasidae sexual dimorphism is poorly marked, the differences are visible in the construction of genital aperture positioned at the rear edge of the coxae of the first pair of legs.

In Ixodidae and Amblyommidae larva, nymph and female have a very similar structure. Their gnathosoma is mounted on the anterior edge of idiosoma, dorsal scutum is adjacent to the base of the gnathosoma, in unfed specimens it covers the anterior dorsal part of the idiosoma. Their idiosoma greatly increases their body size in the course of feeding. Differentiating characteristics of these developmental stages are as follows: larva has three pairs of legs, there are no developed spiracular and genital orifices; nymph has four pairs of legs, spiracles and beginnings of future genital aperture; the female has four pairs of legs, spiracles, developed genital aperture and on the dorsal surface of the base of gnathosoma the so called porose areas, i.e. two clusters of glands outlets. Sexual dimorphism is evident. In males the entire dorsal surface of idiosoma is covered with dorsal scutum. Besides, in males of the Ixodidae family practically the entire ventral surface of idiosoma is covered with abdominal scuta; in males of the Amblyommidae they cover the rear of the ventral surface of idiosoma, or there are no abdominal scuta and then coxae of legs are more strongly developed.

Development cycles of ticks. Life cycle includes egg, larva, nymph and adult stage. A common feature of all development cycles of ticks is that females of nearly all the species lay their eggs outside the body of the host, on the ground, in the litter, walls, cracks in buildings, etc., and the fact of a single long-term, from a few to several days, larvae feeding. Notable exceptions are the larvae of *Ornithodoros* s.s (Argasidae) which transform into stage I nymphs without feeding.

Hosts of ticks may belong to the same or different species of vertebrates. Active developmental stages are present on the body of the host usually only during feeding. Oviposition, embryonic development and moulting of each life stage take place outside the body of the host. There are four main types of development cycles of ticks (multi-host, three-host, two-host, one-host), the division of which is based on differences in the relationships between developing ticks and the host.

Multi-host development cycle of Argasidae. Argasidae can attack practically all vertebrates nesting or staying temporarily in their hideout. Life cycle: egg – larva – nymph (usually 2–4 stages, but

may be up to eight nymphal instars) – an adult form (male or female). Larva after hatching from eggs and growing attaches to the first host and feeds from a few to several days. Nymphs and adults feed for a short time, from several minutes to two hours. Adults can feed several times and after each feeding the females lay new batches of eggs. This is an example of gonotrophic harmony, which is an expression of compatibility between the processes of digestion of food and the development of the ovaries – the adoption of one blood meal from the host secures maturation of one portion of eggs in the female tick. After engorgement the nymphs and adults detach from the host and hide in the host's nest.

Development cycles of ticks from the families Ixodidae and Amblyommidae. Life cycle: egg – larva – nymph – adult (male or female). Each active stage of development feeds once from a few to several days, and feeding time is usually longer in each further life stage. In the development there is a close harmony between feeding and subsequent moulting in immature stages as well as between feeding, development and oviposition by females (gonotrophic cycle). Taking into account the number of hosts, the following development cycles are distinguished in Ixodidae and Amblyommidae:

Development cycle of three-host ticks. In this type of life cycle each growing tick has three hosts, one for each active stage of development. Three-host development is the oldest and most common form of the development of ixodid ticks, including all the species of Ixodidae and Amblyommidae in the Polish fauna.

Development cycle of two-host ticks. Each tick has two hosts in its development. Larvae and nymphs feed on one host, and adults feed on another. An example of this type of development is the life cycle of *H. marginatum* which is brought into Poland by migratory birds.

Life cycle of one-host ticks. The entire life cycle of the tick is associated with one individual vertebrate host. The subgenus *Boophilus* ticks of the genus *Rhipicephalus* parasitizing large grass-eating mammals in tropical countries reproduce in this way.

Ecological groups of ticks acquiring hosts. Ticks attack their hosts in conditions of natural occurrence in a variety of habitats. These are often diversified environmental conditions, e.g. altered by human activity, or dictated by the current climate. There are several ecological groups of tick as regards the habitat of host acquisition:

Nests- and burrows-dwelling ticks. Natural conditions of existence of Argasidae are burrows, pits, caves, bird nests, hollows, crevices in the rock in warm and hot countries. In the biotopes altered by human activity, especially in the temperate climate, Argasidae find their hiding places in synanthropic environment. Some Ixodina have also specialized as nidicolous parasites. In the Polish fauna, species of the subgenus *Pholeoixodes* (Ixodidae) which, like nidicolous Argasidae, spend their whole lives in burrows, caves, hollows and other hiding places where they can feed on the host that lives there, sleeps, reproduces and overwinters, or finds temporary shelter. These tick species usually exhibit varying degrees of host specificity (e.g. monophagous *I. lividus* tick or oligophagous *I. arboricola* tick parasitizing titmice). Additional factors favouring survival of ticks adapted to life in such hidden habitats are usually little fluctuations of climatic conditions such as temperature, humidity or light.

Out of nest dwelling ticks. Most ixodid ticks (Ixodidae and Amblyommidae) living today are out of nest dwelling parasites that have adapted to living in exposed habitats and feeding on motile hosts that migrate and are not strictly associated with definite places of residence and reproduction. These ticks are usually moderately host-specific or host-nonspecific (e.g. poliphagous *I. ricinus* in the Polish fauna). In this ecological group of ticks host acquisition is associated with high risk of failure to get the host in time and, consequently, with death from exhaustion after using energy reserves accumulated in the previous stage of development, or on account of the occurrence of environmental conditions preventing the tick survival. Survival of a hungry tick is highly dependent, especially in such conditions, on its tolerance to temperature and light changes, and relative humidity. In the case of open habitats many ticks die before they manage to find their host and feed. Especially high mortality rate, depending on environmental conditions, occurs among the larvae. Most species of nonnidicolous ticks cling to plants passively waiting for a host. When ticks locate approaching host, they extend the first pair of legs with Haller's sensory organ positioned on feet and, if contact is made, catch the host with legs and pass on to his body. These ticks have little mobility and do not move further than a few meters away. A chance to find a host is created by narrow forest tracks and paths that are often

movement trails of animals and humans. There is a group of species, e.g. of the genus *Hyalomma*, inhabiting steppe and desert environments that can actively seek their host. They are more mobile and can move within several hundred meters.

Out of nest- and burrows-dwelling ticks. Adult forms of certain species of ixodid ticks are exophilic parasites and immature forms adapted to nidicolous parasitism. In such cases, only adult forms and larvae are exposed to severe climatic changes and the difficulties associated with obtaining a suitable host. In the Polish fauna such species is *D. reticulatus*.

Out of nest dwelling-stationary ticks. There are a small number of tick species which develop a close and more durable relationship with the host. These ticks tend to move from nonnidicolous type of parasitism to a permanent existence on the body of the host. Larvae hatched on the ground after obtaining host spend entire life cycle on it until engorged and fertilized females detach from the host to lay eggs on the ground. In such form of parasitism only the hungry larva is exposed to dangers associated with finding a host. Ticks of this type of parasitism are not found in the Polish fauna. A typical example is the species of subgenus *Boophilus* of the genus *Rhipicephalus*.

Seasonal and circadian rhythms of host acquisition by hungry ticks. There are two groups of ecological rhythms of ticks: seasonal rhythms related to annual changes in the external environment and the circadian (daily) rhythms associated with the rhythms of daily changes in the external environment.

In Ixodida seasonal rhythms are manifested by interweaving of periods of active life: host acquisition, feeding, growth, metamorphosis, reproduction, with periods of „biological rest": diapause synchronized with specific seasons of the annual climate rhythm of the external environment. The model of seasonal rhythms of life activity of ticks may be different depending on the geographical location of population within the range of a given species.

Argasidae found in Poland residing in synanthropic and semi-synanthropic habitats, medium wet or dry, about 50–70% of relative humidity, have the peak of activity in the middle of summer.

In Poland *I. ricinus* is active from early spring to late autumn, but has two seasons of peak activity of hungry specimens – spring (spring peak) and in late summer and fall (autumn peak). During the spring peak the abundance of hungry ticks is definitely the highest, the autumn peak may occur in the years in which there are very hot and dry summer months. Very characteristic is the pattern of activity of hungry *D. reticulatus* ticks, adults have two clearly separated periods of activity during the year. Spring activity falls in the second half of March (in some years from February) to the first decade of June, with the peak of activity in the third decade of April. Autumn activity occurs from mid-August to mid-November, with the peak of activity at the end of the first and second decade of October. In spring the number of active ticks is much greater. Immature forms of *D. reticulatus* are active in the summer, from June to September. The daily rhythms of hungry ticks' activity in host acquisition are associated with circadian rhythms of activity of their hosts and microclimatic changes in the habitat at certain times of the day.

Argasidae, nidicolous parasites of birds, are usually characterized by strictly nocturnal pattern of locomotor activity, e.g. *A. polonicus*. However, Argasidae, nidicolous parasites of mammals active at night, are generally parasites of diurnal locomotor activity of unfed specimens, e.g. *C. vespertilionis*. Their rhythm of activity is adapted to the circadian rhythm of activities of their hosts.

In case of ixodid ticks (Ixodidae and Amblyommidae) circadian rhythm of activity is endogenously generated and the main exogenous factors are diel microclimatic changes in the habitat of ticks: the degree of solar radiation and lighting, humidity and temperature. An example is the pattern of circadian activity of *I. ricinus.* They are active all day and night but are most active in the morning (about 8–9) and at night (about 23–24). Increased tick activity is also observed in the evening (about 18–19), especially during autumn activity of these parasites. The lowest activity of all developmental stages is recorded during midday hours [103].

Ticks attacking humans in Poland

It has not been found that any tick species inhabiting the Polish and world fauna is a specific human parasite. On the Polish territory people can be attacked by ticks of the family Argasidae: *A. reflexus* and *A. polonicus*. From the family Ixodidae, to which most ticks occurring in Poland belong, humans are mainly attacked by *I. ricinus*, a

non-host-specific species. Therefore, it is the most important tick in the epidemiology of transmissible diseases in our country (Table 1). In Poland there is a risk of attacking humans by a taiga tick *I. persulcatus* which, like *I. ricinus*, is of utmost importance in the epidemiology of transmissible diseases (Table 1). The tick species with high epidemiological significance which can also feed on man in Poland is *I. hexagonus* (Table 1). It can inhabit dog kennels and even human quarters where there are permanent beddings for dogs and cats. Incidents of infesting people in Poland by *D. reticulatus* from the family Amblyommidae have also been recorded.

Outside Polish borders isolated cases of people attacked by ticks *C. vespertilionis*, *I. crenulatus*, *H. concinna* and *H. punctata* have been reported.

Ticks as the cause of occupational disease

While intruding into tick habitat, man can become an accidental host of any specimen, and hence a genuine risk of being infected with tick-borne diseases. Particularly vulnerable are social groups whose work or interests require constant or seasonal stay outdoors. Foresters, farmers, gardeners, orchard men, enthusiasts of hunting, hunters, border guards, seasonal collectors of forest fruits, tourists, naturalists, people resting in parks and forests are particularly exposed to attacks by ticks, and noteworthy is the fact that in Poland there are no safe areas in this respect.

According to the National Institute of Hygiene, tick-borne diseases in Poland constitute an increasingly growing problem, and each year the incidence of infection in humans, especially with borreliosis, is consistently high. For instance, 8 225 persons contracted borreliosis in 2008, 10 333 people in 2009, 9 011 persons in 2010 and 6 775 individuals in 2011 (until November 15th). 351 humans were infected with tick-borne encephalitis virus in 2009, 292 persons in 2010 and 172 people in 2011 (up to November 15th).

For some occupational groups (forestry, agriculture, hunting) borreliosis is regarded as a work-related disease, but the diagnosis is difficult owing to cumbersome procedures, lack of full documentation of the disease and relevant legal regulations. Forest workers need to be screened with serological tests, which are the only reliable method to detect infection, and the results from different areas of Poland confirm high proportion of infected individuals, which is validated by studies carried out in various research centres in Poland. Only some of them are presented below.

The presence of antibodies against the antigens of *Borrelia burgdorferi* was detected in 23.8% of foresters from areas of the north-eastern Poland, in 40.7% from the south-eastern Poland, in 66.67% of the workers from forestry of Lower Silesia, in 35–61.9% of foresters from the area of the West Pomerania province [104]. The forestry staff of Roztocze National Park in south-eastern Poland is often exposed to attacks of *I. ricinus* infected with *B. burgdorferi* and *A. phagocytophilum*. In 40.7% of forestry workers the presence of specific IgG and / or IgM antibodies against *B. burgdorferi* s.1. was detected. The prevalence of IgG antibodies against *A. phagocytophilum* was 17.7% [105].

In the woods near Bialystok the presence of *A. phagocytophilum* infections in *I. ricinus* ticks (14.5%) was found, and the prevalence of IgG antibodies against *A. phagocytophilum* (3.9%) in the forest guards from the same region was determined, as well as IgM anti-*B. burgdorferi* antibodies (26.4%) and IgG (18.6%) [106].

The presence of antibodies against *A. phagocytophilum* and *B. burgdorferi* was also tested among forestry workers from the Lublin region [107].

Detection and diagnostics of borreliosis is still associated with interpretation difficulties frequently complicated by coinfections with other pathogens, as well as high costs and longevity of treatment. Understanding the principles of personal protection against ticks is the cheapest and most certain way recommended for all professional groups residing in habitats and feeding grounds of ticks.

Rules of hygiene and safety at work should be applied especially in cases where the material with which people work is blood and tissues of animals – a potentially infectious material. This may be important for those involved in meat processing (hunters, butchers, game meat harvesters).

Risk of tick-borne diseases in recreational areas of large cities in Poland

The expansion of ticks into cities, especially urban green areas, is considered to be a natural phenomenon of the spread of parasites in search of hosts. The presence of urban vacancies, illegal waste dumps, small crops in home gardens and urban allotments leads to enhancement and

maintenance of the population of small rodents within the small and large cities. Small rodents, large population of domestic animals and urban birds are the intermediate hosts of ticks and natural nutritional base for these parasites in each city. Noticeable is a close relationship between the development of gardening, horticulture, agro tourism, urbanization and the occurrence of ticks.

Studies carried out in the Polish urban areas have shown that ticks are present in cities, and that they are infected with morbific pathogens [41,48,67,68, 108–114].

It is necessary to pay special attention to familiarize the urban population, especially children and adolescents, with areas of occurrence of ticks and the principles of individual protection against their attacks. Notice-boards informing about the presence of ticks in parks and city squares would be advisable. High-risk territories are places with tall grass and undergrowth (up to 120 cm in height), but also paths and lawns in parks. Private gardens covered with autumn leaves and withered forest litter also create habitat for *I. ricinus*. Urban green zone and its permanent residents protect the population of ticks in cities from extinction. The risk is also in close contact of humans with pets, which may serve as periodical hosts of ticks subsequently dropping off in the home environment. Ticks can get to all parts of the body crawling on the skin under clothing, and the bite can occur anywhere.

Examples of risks to human health caused by ticks outside Polish borders

Selected examples of ticks endangering people in different parts of the world have been presented. Most of the species live in warm and tropical countries, those that threaten human health are represented on all continents.

People travelling to work, especially where there is contact with soil, e.g. working in quarries or mineshafts, digging canals or ditches, building mounds of earth or stone, performing agricultural and archaeological jobs, etc., as well as tourists and holidaymakers in hot and warm areas, are exposed to attack by ticks of the genus *Ornithodoros* Koch, 1844 from family Argasidae, which are reservoirs and vectors of spirochetes of different species of the genus *Borrelia* – pathogens of tick-borne relapsing fever. Ticks of the genus *Ornithodoros* exist on all continents in the tropical and warm countries. In southern Europe there are 7 species [72,115].

In the wild these ticks live in the burrows and nests of mammals, birds and reptiles, in caves, crevices and cavities in rocks, in cracks in the soil, in clusters of stones. Most of the species exist on the steppes and semi-deserts, some live high in the mountains (e.g. *Ornithodoros tholozani* (Laboulbène and Megnin, 1882) (syn. *O. papillipes*) at an altitude of 2000–2800 meters above the sea level [72]). In the areas exploited by humans *Ornithodoros* ticks use as habitat huts of the natives, especially the old clay ones, less often brick apartment buildings, in which they live in the crevices of walls, under floors and in the cracks of furniture, as well as in synanthropic burrows of rodents. They use similar shelters in farm buildings and animal pens, ruins of old buildings as well as cracks, crevices and holes in clay and stone walls surrounding human domiciles [116,117].

O. tholozani is a reservoir and a vector of *Borrelia sogdianum* in the countries of western and central Asia. It is a polyxenic parasite whose hosts are various species of mammals, birds and reptiles, and it often attacks people. It is widespread from Kazakhstan, the Middle East, through the central and western Asian countries to Libya in the Mediterranean. This species causes outbreaks of tick-borne relapsing fever within human settlements [72].

Most *Ornithodoros* are parasites of night activity in host acquisition, but they are classified as anthropophilic species attacking people during daytime in glowing sunlight. One such species is *Ornithodoros asperus* Warburton, 1918 (syn. *O. verrucosus*) occurring from Iraq via Transcaucasia, the Caucasus to the south of Ukraine and Moldova. A case has been described [72] of a group, probably of tourists who during a very sunny day sheltered from strong sunlight in the shadow of the rocks where they were massively attacked by ticks transmitting *Borrelia caucasica*.

The countries of the western Mediterranean region are inhabited by *Ornithodoros erraticus* (Lucas, 1849), a tick attacking mainly small rodents and carrying *Borrelia hispanica,* the pathogen of Hispano-African relapsing fever in Spain, Portugal, Morocco, Algeria, Tunisia [118].

In the south of the Sahara in Africa there exists a dangerous species *Ornithodoros moubata* (Murray, 1877). It frequently inhabits homes of the natives

and is a reservoir and a vector of *Borrelia duttoni*. People can be exposed to these ticks during safari trips to Africa.

From the *Ornithodoros* species inhabiting North America, most of the concerns raise in humans the attacks of *Ornithodoros coriaceus* Koch, 1844 occurring frequently in the mountainous coastal area of California (USA) and Mexico. [119] In California it is known as „Pajaroello", and the tick's attack is believed to be more dangerous than a rattlesnake bite.

In Eastern Europe and Asia (Russia, Mongolia, China, Japan) there is *I. persulcatus* [120]. Outside its compact range of distribution, its presence has been found in the Bialowieża Primeval Forest in Poland [85]. It exists in a variety of woods along the middle and southern taiga, and in forest steppes. It is very aggressive, more frequently than any other Ixodidae attacks man. In sparsely populated taiga *I. persulcatus* is most numerous in clearings, forest edges, on the outskirts of animal trails, resting and grazing areas of animals, and watering places of large mammals. It is one of the species of the genus Ixodes of major importance in the epidemiology of transmissible diseases (Table 1). Amongst its victims were probably exiles working in the taiga in the nineteenth and twentieth centuries.

Travelling to North America humans can come in contact with two species of ticks from the group of *I. ricinus*, i.e. *Ixodes scapularis* Say, 1821 and *Ixodes pacyficus* Cooley et Kohls, 1943, considered as some of the most important vectors of tick-borne diseases in North America.

Ticks can endanger people not only epidemiologically. The consequence of infestation with certain ticks can be poisoning of the host organism and generalized allergic and stress reactions, but the most dangerous direct consequence of tick parasitism to humans is the disease defined as tick paralysis. Approximately 43 species of ticks of the world fauna have been considered capable of inducing tick-borne paralysis with toxins contained in the saliva of ticks. Six of those tick species exist or are transferred into the Polish territory (Table 1), but in Poland there have not been officially recorded cases of tick paralysis. However, its incidence cannot be ruled out in people returning from areas of natural occurrence of the most important species of ticks in this respect. The ease and speed with which people move around the world, the fact that an attached tick cannot be seen (especially the American *Dermacentor)*, and that the first signs of tick paralysis usually occur five days after tick invasion, increase the likelihood of the disease in localities where nobody expects it.

Incubation period of tick paralysis usually lasts 5–7 days. The paralysis symptoms begin in the lower limbs, initially slight to increasing problems with coordination, ataxia, and muscle weakness. Within hours the symptoms of paralysis become more severe and gradually affect the trunk, upper limbs, neck, throat and face. The attacked person cannot move arms, legs, stand upright or sit. Descending, symmetrical, flaccid paralysis of the limbs follows with the weakening of tendon reflexes, and Romberg sign. There is also nystagmus, difficulty in speaking, breathing, chewing and swallowing, and reduced sensitivity. The body temperature is normal and the blood picture does not deviate from the norm. In the final phase of the disease (usually the second, third day) coma and death follow. The most vulnerable to the disease are young children (up to 2 years). The primary therapeutic procedure is to remove the tick in time prior to the patient's critical condition. The venom causing paralysis is likely to be quickly eliminated or metabolized in a short time and then the patient recovers quickly.

In the world fauna the most important role in causing tick paralysis in humans is played in North America by *Dermacentor andersoni* Stiles, 1908 and *Dermacentor variabilis* (Say, 1812), in Australia by *Ixodes holocyclus* Neumann, 1899 [118]. There is a known case of a group of Polish mountaineers from Cracow, who in Banff (Canada) in the Rocky Mountains collected *D. andersoni* from the clothing of one of the members of the expedition. It is known that just one feeding *D. andersoni* female may induce full paralysis and cause human death.

An overview of the latest Polish research on ticks

In the latest Polish literature on tick issues much space is devoted to research into the epidemiology and significance of ticks in the transmission of tick-borne diseases. Publications referring to the classic faunistics are relatively few, most of them contain information about *I. ricinus* – commonly occurring tick species in Poland. The research base on the biology and ecology of ticks is also increasing. The first report on Polish ticks data was presented by Lachmajer [85], an update and complete

descriptions were made by Siuda [1]. Research pursued in this field by the national centres at the turn of the century is presented in this study (Table 4).

Epidemiological research

Studies on the role of ticks in the epidemiology of transmissible diseases are broadly represented by the Polish researchers [56,121–132], and the published works are often pioneering not only in Poland, but also in Europe and in the world [49,51,65,102,133–135].

Because the most important role in the biology and epidemiology of developing infectious and invasive diseases in Poland is played by *I. ricinus*, its role in epidemiology is most frequently studied and the prevalence of pathogens in the system vector–zoonotic reservoir is determined. The second most frequently studied epidemiologically tick is *D. reticulatus* [42–45,48,52,58,67,127, 136– 145], and on this occasion its foci are being discovered throughout Poland.

Monitoring public health risk of tick-borne diseases and recording the frequency of occurrence of tick attacks, especially on humans occupationally exposed to ticks, as well as determination of endemic sites are becoming increasingly important owing to high incidence rate and diagnostic difficulties [11,105,107,146–160].

Essential research trends in the twenty-first century parasitology are studies using methods of molecular genetics, whose aim is application of molecular methods for the detection of DNA of pathogens transmitted to humans by ticks [47,50,121,161–163].

An important issue in research is co-occurrence of micro-organisms not only within the populations of ticks from various regions in Poland, but mainly within the body of a single tick [59,164–167], and in patients bitten by ticks treated for meningitis [168] and with a diagnosis of borreliosis [169].

Several centres in Poland conduct research on the role of vertebrates as a reservoir of tick-borne pathogens: game [170–173] bison [174], dogs [175,176], rodents [126,177,178], birds [179], and testing animal products such as milk for the presence of tick-borne pathogens [151].

Extremely important studies are performed on epidemiological, clinical and molecular aspects of tick-borne diseases in humans [180–186].

Studies on the morphology and biology of ticks

The database of world literature in the field of biology is enriched by the Polish insightful research on the anatomy and morphology of ticks [187,188], with particular emphasis on sense organs, pheromones and teratological changes [189–192], as well as research on the development of ticks [193,194], tick behaviour in natural and laboratory conditions associated with host acquisition and feeding [195].

Circadian and seasonal activity of Polish ticks is still not sufficiently understood. Many species are difficult to observe in the wild. Consequently, most researchers examine tick life cycles for the species easiest to obtain for study: *I. ricinus*, *D. reticulatus* [44,103].

Research on the relationship between parasite species and vertebrate host species, a necessary relationship for the development and survival of the parasite population, is a common topic of studies of Polish parasitologists. It is also reflected in the study of tick-host specificity [44,100,196–198].

Faunistic studies

Faunistic studies are conducted only by a few research centres and are focused on the occurrence, distribution and abundance of ticks in habitats in various Polish regions, both in urban areas and in natural biotopes [4,97,110,113,114,199– 204].

Studies on biodiversity of ticks feeding on hosts, large and small vertebrates, have their long tradition dating back to the early twentieth century [89,205,206]. They are successful insofar as they in progress and bring a lot of new findings on, among others, infestation of different hosts by ticks, location of ticks on the body of the host and consequences of their feeding [73,76,84,196,207–216].

There are research centres regularly monitoring distribution of ticks in Poland, expansion of their ranges and discovery of new localities of species. The following areas in Poland are best known in terms of the presence of ticks: West-Pomeranian and Pomeranian provinces [68,76,97, 217], north-eastern Poland and Masovia [3,88,111,218–221], Lower Silesia province [222,223], areas of the south-eastern Poland, especially the Lublin region [224–226], and the provinces of southern Poland: Silesia, Świętokrzyskie, Lesser Poland, Subcar-

Table 4. List of scientific centres in Poland conducting research on ticks and their medical significance

Research centre in Poland*	Current research interests
Department of Tropical Parasitology, Chair of Tropical Medicine and Parasitology, National Centre of Tropical Medicine, Medical University of Gdańsk	- studies on haematophagous arthropods and their role in the transmission of zoonoses in Poland, - research on the role of Ixodidae in the epidemiology of transmissible diseases: tularemia, tick-borne encephalitis, and since the 90s of the last century, mainly the so-called „emerging infectious diseases" - newly diagnosed infectious and invasive zoonoses in the world: Lyme disease, human granulocyte anaplasmosis, spotted fever group (SFG) rickettsiosis, babesiosis and their natural foci, - research on prevalence of infections in ticks with pathogens and their spread in the areas under study, - research on co-infections with several tick-borne pathogens, - studies on prevalence level of pathogens in tick populations and host density of these parasites, - molecular detection and genotyping of pathogens in ticks and their natural hosts, - identifying areas of occurrence of natural tick-borne disease foci in Poland with special reference to northern and north-eastern part of the country, - research on the prevalence of infection in people exposed to tick attacks
Department of Invertebrate Zoology, University of Gdańsk	- study of ticks feeding on deer and bison, analysis of causes of location on the host body, - analysis of feeding traces and histopathological changes caused by ticks in bison, - research on variability of *Ixodes ricinus* in ungulates, - studies of ticks feeding on wild boar, determination of dynamics and seasonal occurrence, parameters of infection and location, - study of ticks feeding on small mammals, - research on the occurrence of ticks in Poland, especially in the northern part of the country
Chair and Department of Biology and Parasitology, Medical University of Lublin	- research on morphology of ticks with a special focus on sense organs and teratological changes, - study on the development of embryonic and extra-embryonic stages, and factors affecting the development of ticks *Argas reflexus, Ixodes ricinus, Dermacentor reticulatus, Dermacentor marginatus,* - research on tick-host system, - study on the behaviour of ticks associated with the search for the host and feeding in natural and laboratory conditions, - research on tick distribution and ecology, especially in the south-eastern part of the country, - studies on the role of ticks in epidemiology of transmissible diseases, transfer of tick-borne pathogens in south-eastern Poland, - monitoring public health risks of tick-borne diseases through serological testing and recording the frequency of tick attacks, - study of chemical and biological surveillance of tick abundance
Department of Parasitology, Faculty of Biology, University of Warsaw, Warsaw	- research towards identifying the prevalence of pathogens (*Borrelia burgdorferi* s.l., *Anaplasma phagocytophilum*, *Bartonella* sp., *Babesia* sp.) in the vector - zoonotic reservoir system taking into account variability amongst and within species of pathogens and their phylogenetics, - studies on the effects of various environmental factors on the prevalence of pathogens in *Ixodes ricinus* tick populations in different biotopes (urban biotopes with strong anthropopression and natural biotopes of mixed forests with little anthropopression)

Research centre in Poland*	Current research interests
Department of Microbial Ecology and Environmental Protection, Institute of Genetics and Microbiology, University of Wrocław	- monitoring the occurrence of ticks in selected districts of Lower Silesia in forest and urban areas Wrocław, - structures of tick populations, seasonal activity, ecological relationships of tick activity, - mapping the results of environmental and laboratory studies using geographic information systems (Arc View), - determination of the degree of tick infection with *Borrelia burgdorferi* s.l. (DFM method and nested PCR)
Department of Invertebrate Zoology and Parasitology, Institute of Biology, Pedagogical University of Cracow	- research on fauna and taxonomy of ticks (Ixodida) in Poland and Central Europe, - studies on the occurrence, distribution and abundance of ticks in urban recreational areas and natural biotopes (landscape and national parks), especially in the southern Poland, - research on daily and annual cycles of ticks, - studies on ecology, host specificity and epidemiological significance of ticks, - research on migration of alien species of ticks (*Ixodes*, *Amblyomma*, *Hyalomma*) to Poland on different hosts and spread of ticks beyond their natural ranges of occurrence
Department of Parasitology, Medical University of Silesia in Katowice, Sosnowiec	- studies on the occurrence of ticks, especially in the Silesia province, - epidemiological studies on human and animal exposure to tick-borne pathogens such as, among others, spirochetes of *Borrelia burgdorferi* s. l., *Anaplasma phagocytophilum*, *Babesia* sp., tick-borne encephalitis virus, *Toxoplasma gondii*, rickettsiae
Department of Genetics, Faculty of Biology, University of Szczecin, Szczecin	- studies using molecular genetics methods, the aim of which is application of molecular methods for the detection of DNA of human disease pathogens transmitted by ticks (*Borrelia*, *Babesia*, *Ehrlichia/Anaplasma, Rickettsia*, *Bartonella*), - research on delimitation of areas endemic for *Ixodes ricinus* and borreliosis, babesiosis, anaplasmosis in forested areas of Szczecin and West Pomeranian province, - research on coexistence of DNA of various pathogens in *Ixodes ricinus*, - study on participation of forest birds and rodents in Greater Poland in the spread of borreliosis, babesiosis, anaplasmosis, ehrlichiosis, *Bartonella* genus, - studies on the role of wild game and forest vertebrates as reservoir of tick-borne pathogens, - study of bacteria of the genus *Bartonella* in the tissues of game animals (roe deer, red deer) and *Ixodes ricinus* infesting these animals in areas of West Pomeranian province
Division of Parasitology and Parasitic Diseases, Department of Preclinical Sciences, Faculty of Veterinary Medicine, Warsaw University of Life Sciences – SGGW, Warsaw	- epidemiology of canine diseases transmitted by ticks, especially babesiosis in dogs
Department of Applied Entomology, Faculty of Horticulture and Landscape Architecture, Warsaw University of Life Sciences - SGGW, Warsaw	- research on anatomy and role of *Ixodes scapularis* synganglion, - popularization of knowledge about ticks, methods of protection against ticks
Department of Biology and Medical Parasitology, Pomeranian Medical University, Szczecin	- the role of *Ixodes ricinus* in the epidemiology of transmissible diseases, including Lyme disease and piroplasmosis in the areas of north-western Poland, especially Szczecin and vicinity

Research centre in Poland*	Current research interests
W. Stefański Institute of Parasitology of Polish Academy of Sciences, Warsaw	- studies on the occurrence, distribution, activity, annual cycle and range of tick hosts in Poland and their role as a reservoir and vector of tick-borne diseases, - research on the role of ticks and mammals in the spread of micro-organisms (*Borrelia burgdorferi* s.l., *Babesia microti*, *Babesia canis*, *Babesia divergens, Bartonella* sp., *Rickettsia* sp., *Hepatozoon canis, Anaplasma phagocytophilum*) in selected Polish regions, - research on prevalence of tick-borne infection of small mammals in Poland, - studies on the occurrence and distribution of ticks in urban recreational areas and natural biotopes, - occurrence, biology and epidemiological significance of *Dermacentor reticulatus* in Poland
Unit of Zoonoses, Institute of Rural Health, Lublin	- the role of ticks in the epidemiology of disease transmission (Lyme disease, anaplasmosis, babesiosis, bartonellosis, tick-borne encephalitis), - frequency of occurrence of specific pathogens in ticks *Ixodes ricinus* and *Dermacentor reticulatus*, - tick activity in the foci of specific tick-borne diseases, - occurrence of tick-borne encephalitis virus in milk, - prevalence of antibodies against specific pathogens in occupationally exposed populations, foresters and farmers, - tick-borne disease prevention
Laboratory of Rickettsiae, Chlamydiae and Enzootic Spirochetes National Institute of Public Health, National Institute of Hygiene, Warsaw	- research on microorganisms that are etiological agents of zoonoses transmitted by ticks, -performance of full range of diagnostic testing (in humans, animal reservoirs, vectors) allowing detection of infections with bacteria *Borrelia burgdorferi* s.l., *Coxiella burnetii*, and the genera of *Rickettsia*, *Bartonella*, *Anaplasma* (serological, molecular, bacteriological testing, culture of etiological agent)
High School of Civil Sciences, Lublin	- expansion of *Dermacentor reticulatus* and *Ixodes ricinus* in urban environments of southeastern Poland, especially the Lublin region, - assessment of the risks of tick attacks in environments with varying degrees of anthropopression
Department of Infectious Diseases and Hepatology, Medical University of Białystok	- the study of ticks as vectors of human and animal diseases (bison, northern vole), - selected epidemiological, clinical and molecular aspects of *Anaplasma phagocytophilum* - the agent of human granulocyte anaplasmosis, - diagnostic and therapeutic testing of tick-borne diseases: tick-borne encephalitis and Lyme disease, - vaccination against tick-borne encephalitis
Department of Infectious Diseases and Neuroinfections, Medical University of Bialystok	- diagnosis, epidemiology and treatment of tick-borne diseases
Department of Biochemistry and Molecular Biology, University of Natural Sciences and Humanities in Siedlce	- molecular testing for the role of *Ixodes ricinus* in the transmission of human and animal pathogens (*Babesia* sp., *Anaplasma phagocytophilum*, *Borrelia burgdorferi* s.l.) in the area of central and eastern Poland

* The review presents achievements of research institutions from which full information about their studies has been obtained

pathia [81,92,227–229].

Research is also in progress on migration of alien species of ticks (Ixodes, Amblyomma, Hyalomma) to Poland on different hosts and aspects of expansion of ticks outside their natural ranges of occurrence, hence the knowledge of importing alien

tick species to the territory of Poland is systematically increasing [99–101,230,231].

Extremely important are comprehensive publications popularizing knowledge of ticks and tick-borne diseases which should be available primarily for family doctors, naturalists, forests and national parks employees, teachers, tourists, schoolchildren and students. Especially in the spring, when ticks activity in host acquisition is increasing, there is a need for publications on methods of protection against ticks and widely understood prophylaxis [185,232–239].

Prevention of tick attacks in Poland

Ixodid ticks from families: Ixodidae: *I. ricinus*, Amblyommidae: *D. reticulatus*. Broadly defined recreational places in Poland are areas of high risk of exposure to ticks and tick-borne diseases. There are no safe places in Poland in this respect. People spending their free time in the city in recreational settings (private gardens, allotments, parks, walking paths for animals), and outside the city (places of summer recreation for children and adults, forest and parts of the forest immediately adjacent to areas inhabited by humans, pastures, meadows, hiking trails, river banks and others) should be aware of prophylaxis against tick attacks.

The easiest protection is appropriate clothing, preferably in bright colours, preventing parasites from moving to bare skin, e.g. long pants tucked into socks, boots, a long-sleeved sweatshirt tightly inserted into trousers, a hat or cap on the head, neck protected with a scarf. Additional and recommended protective measures are repellents which should be sprayed on the skin and clothing. The aim is to prevent tick transfer to bare skin, but effectiveness of such measures is limited to a few hours, therefore it is recommended to repeat repellent application several times a day. In order to limit contact with ticks, walking trails overgrown with tall grass, shrubs and wildlife trails should be avoided as well as lying down on the grass without spreading a blanket. After spending time outdoors, especially during the spring and autumn periods of ticks activity, the entire body, hair and clothes should be searched for ticks; light coloured clothing will help detect moving parasites. The smallest developmental forms of ticks (larvae and nymphs), owing to very small size (about 1–2 mm), may be difficult to notice. Each tick embedded in the skin must be removed immediately with a firm, fast motion using fine tweezers, or with a tissue or instruments available in pharmacies to remove ticks. Strict hygiene measures should be observed while pulling a tick. Ticks must not be removed with bare fingers, nor should any grease or lubricant fluid be applied. After removal of the parasite the site should be disinfected. The removed tick may be sent for examination to an appropriate laboratory. In case of less accessible places assistance in removing the tick should be sought from an experienced nurse or a doctor at the health clinic. The place after tick removal should be monitored and, if feeling unwell in the next few weeks, going to a doctor and informing him about tick infestation is recommended. People residing in forests or for other reasons staying in the areas of constant exposure to ticks may, after consulting a doctor, undergo vaccination against viral encephalitis transmitted by ticks. One possibility of infection with tick-borne encephalitis virus is also eating raw goat's milk and dairy products from goats infected with the virus by parasitizing ticks.

The simplest procedures performed in the immediate environment of humans aiming at reduction of tick population are removing shrubby thickets, regular mowing, restricting access of small rodents and other wild animals to human buildings, and inspection of the skin and fur of farm animals.

Argasids of genus *Argas* (Argasidae) in Poland and Europe

Effective protection against argasids is getting rid of pigeons, hosts of these ticks, which nest near human dwellings and windows in attics, lofts, in wild nests built on balconies and other constructions, in order to prevent ticks from entering the human living quarters. Argasids of the subgenus *Argas* spend the day hidden in the frames of window cracks, crevices and fissures in walls, behind paintings, folds of curtains, and during the night they quest for host, who can often be accidental sleeping man. Therefore, the neighbourhood of pigeon lofts with resting place for the night should be avoided. Flats once converted from lofts or attics where pigeons had lived, or flats on the top floors bordering bird nests should undergo disinfection with specialist chemicals to eradicate ticks. Incompetently chosen methods to control the ticks, or unprofessionally secured cracks in the walls and adjacent windows can allow ticks to survive even a few years without access to the host.

One way to detect the presence of ticks in the room is observation of walls and cracks in walls where ticks can leave their droppings in the form of off-whitish lumps, or sticking double-sided adhesive tape in places adjacent to openings, on the windowsills, and wherever their movement is expected. While attempting to move, ticks will stick to the tape. [11] In the absence of possibility of isolating lofts from human domiciles, walls should to be adequately protected in order to eliminate cracks, holes and hideouts, which will prevent tick migration between two adjacent compartments.

Parasitizing ticks can cause serious human health problems [11], therefore noticing on the human body blisters, itching and rashes and recurrent dyspnoea should be consulted with a physician.

Bat argasids *C. vespertilionis* are active during the day, therefore people intruding into hiding places of bats, such as caves, must be protected from argasids attacks with suitable tight clothing. Appropriate repellents can be applied, which should be sprayed on the skin and clothes.

Argasidae (Ornitodorinae): a possibility of contact during trips to warm and tropical countries

Tourists travelling to warm and tropical countries may be attacked by ticks of the subfamily Ornithodorinae. It is difficult to determine the presence of ticks in the room. The easiest way is to collect the dry content from cracks, or the ground level parts of walls and floors, and leave in the sun. Under the influence of heat, ticks will demonstrate activity and will be easier to observe. Staying overnight or hiding from the sun in mud huts, ruins of buildings, caves, rocks, etc. should be avoided, as well as setting up tents or sleeping outdoors in a place where there are many rodent burrows. In cases when the aforementioned places cannot be avoided, protective insect repellents should be sprayed on the skin, clothes and a sleeping bag. Impenetrable mosquito nets, sleeping bags and clothing are recommended. While staying overnight in such room the bed should be moved away from walls. Inserting bed legs in water and paraffin oil can also act as a deterrent.

From the twenties of the 20th century attempts have been made at biological control of ticks, but without much success. Ticks have many natural enemies (such as arthropods, amphibians, birds, mammals, nematodes, protozoa, entomopathogenic fungi, viruses, bacteria), which have also been used in fight against ticks. Combating ticks by chemical means is prohibited in order to protect the environment, and the European Union restricts the use of pesticides that were once exploited to fight ticks [240]. There are several techniques to control ticks in their natural environment, i.e. influencing changes in microclimatic habitat conditions which impede their development cycle, land drainage, melioration, removal of shrubs and grasses from habitats, chemical and biological procedures [71]. In Poland no techniques to combat ticks in their natural environment are used.

Polish scientists conducting research on ticks greatly contribute to ever-increasing recognition of parasitism of this group, identification of species, diagnosis and treatment of diseases, i.e. utilizing all possible means offered by the twenty-first century to save human health and life.

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Received 20 January 2012
Accepted 5 March 2012