

Review articles

The occurrence of the *Dermacentor reticulatus* tick – its expansion to new areas and possible causes

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ABSTRACT. The ornate dog tick (*Dermacentor reticulatus*) can be found in the temperate zones of Eurasia. Its area of occurrence is divided into east and west distributions, although the area as a whole is expanding. The initial east-west division was most probably associated with the varied climatic profile of Europe, for example, the range of specific mean winter and summer temperatures: the region where *D. reticulatus* is absent is characterized by mean winter temperatures between 0˚C and 5˚C and thin snow cover. The present expansion may be the effect of climate change. The mean temperatures in Europe have increased, the vegetation season has lengthened and positive trends in the number of wet days can be seen. Consequently, northern Europe has become warmer and wetter over the last century. Human activity can also influence the spread of *D. reticulatus*. The liquidation of habitats suitable for *D. reticulatus* and the eradication of their hosts can play a role, as can changes in agricultural land use, environmental protection and the spread of international tourism and trade. In summary, the expansion of *D. reticulatus* into new areas could be the synergistic effect of many favourable factors.

Key words: *Dermacentor reticulatus*, expansion, new areas

Introduction

In central Europe, *Dermacentor reticulatus* is the second most important hard tick species after the common tick, *Ixodes ricinus*, in terms of their number and impact on the economy. Wild and domestic ruminants, horses and dogs are the most important hosts for the adult ticks, while rodents and insectivores are infected by larvae and nymphs; humans being very seldom affected. The immediate consequences of feeding are damage to skin and stress, however, the *D. reticulatus* tick is the main vector of *Babesia canis* and other piroplasm species, and is also able to transmit tularemia, rickettsioses and other pathogens. Based on this potential to carry infection, *D. reticulatus* has great epidemiological importance in Europe.

The preferred habitats of *D. reticulatus*

D. reticulatus occurs in mild, damp open areas that are sparsely covered by trees and bushes, particularly, natural deciduous forests placed near water bodies or large stagnant waters. It is most common in the wet forest associated with river valleys and ravine systems, lake shores and meadows near forest borders. Typical biotopes are swampy mixed woods, meadows and shrub pasture communities. The most important factor for their occurrence is a combination of a high level of ground water, along with drying soil [1–3]. In the area of the former Soviet Union, it also typically occurs in marshes [4,5].

Information concerning the vertical distribution of *D. reticulatus* is sparse, but it seems to be strongly associated with lowland regions. Široký et al. [6] report the largest populations of ticks in localities situated at altitudes below 177 m above sea level and only to exist in single locations above 200 m a.s.l.

A characteristic feature of *D. reticulatus* is the ability to adapt to different habitats subject to continuous human influence, and fairly anthropogenic environments [7–9]. Their occurrence is not limited to natural plant communities, but as is the case with *Ixodes ricinus* and *Haemaphysalis* *concinna,* it has spread to urban areas: Széll et al. [10] consider this tick to be anthropophilic. In towns and urban agglomerations, it inhabits recreational areas incorporating afforestation and/or conglomerates of bushy vegetation. The parks are typically those which have been created from natural meadows and forests, with elements of primeval herbage. However, due to the small number of regular observations, it is difficult to determine the general basis for the occurrence and activity of ticks under urban conditions. Tick gathering is mainly conducted for epidemiological purposes, and the ecological data, such as the type of plant communities, the time of the study and the meteorological conditions are rarely recorded. Similarly, little indirect information is available in veterinary clinics where dogs have been treated for babesiosis.

The range of *D. reticulatus* in the last decade of the 20th century

The *D. reticulatus* tick is found in the western Palaearctic region, in forests in the Eurasian temperate climate zone, from England and France in the west to the basin of the Yenisei River in Siberia in the East. Although the northern border of the range runs along the 56–57°N latitude and the commonly sustained southern border is at 50°N [3,11], populations have been documented in Portugal, located between 39 and 50°N [12] and in Romania and Hungary between 50 and 46°N [13–15]. According to Immler [2], the occurrence of *D. reticulatus* is limited to regions with 400 to 1000 mm of spring precipitation and a summer isotherm of 20–22°C. However, it is possible that their area of occurrence was wider in the past.

Within its geographic range, *D. reticulatus* is distributed in a highly focal pattern associated with its habitat needs [16], and its area of occurrence can be divided into two separate parts, Western and Eastern Europe [2,11,17], a phenomenon not observed in other tick species. The western region covers the populations occurring from France to eastern Germany. In France, *D. reticulatus* specimens were recorded in the highlands of southern Jura, in the Rhone Valley, Northern French Alps [18] and Ardenes [19,20]. In Germany, *D. reticulatus* populations were found in the Taurus Mountains, Schwarzwald and Bayern [1], to Leipzig on the East [21]. Single, isolated foci of *D. reticulatus* have been recorded in Holland [22], south-western England [2] and Portugal [23]. There are some populations in Austria, the Czech Republic and western Slovakia; however, they can be regarded as single foci. Hubalek et al. [24] describe populations occurring in northern Austria which are associated with the populations in the Czech Republic and western Slovakia. Ticks are also present in southern Moravia and the Danube river basin, and regions along the southern Slovakian border between Bratislava and Komarno [25–27].

In the Eastern range, the *D. reticulatus* tick is common in the eastern parts of Poland, through Belarus and the European part of Russia to the Central Siberian Plateau. In Russia, large populations have been noted in the Smolensk and Moscow areas [28,29], however, in the St. Petersburg area (59°N), where the northern border of the occurrence exists, this tick is relatively rare [30].

The northern border of the Eastern range runs across from Moscow, Ivanovsky, Ryazan, Svierdlovsk, Tyumentsevsky, Omsk, Novosibirsk and Kansk to the Khemerovsky region [31,32]. To the East, the tick can be found as far as the Krasnoyarsk region. In the Asiatic part of Russia, a number of populations are present across the Northern Caucasus and eastern South Caucasus. Large populations have been noted in the southern parts of the Omsk and Nowosibirsk areas, and in Altai, where the *D. reticulatus* tick forms sympatric populations with *D. marginatus* [33,34]. The southern border of the Eastern range follows the Crimean Mountains, Northern Caucasus, eastern Kazakhstan, and western Altai [1]. However, it is difficult to establish the eastern limit of *D. reticulatus,* as it is unclear whether the Siberian records concern this species or a similar one from the same genus.

In Belarus, the *D. reticulatus* tick is commonly found in Polesie and its range extends to Vilnius, where the largest populations are recorded in the Gomel area. Smaller populations are found in the Minsk district [35–37]. These populations are conjoined with Polish populations in Podlasie and these ranges should in fact be considered as one single range. In the Ukraine, *D. reticulatus* is noted in the central part of the country. Among others, it is found in the Kiev area, in the Dnieper River Lowland and in the Samara River basin [4,38].

The populations in the eastern part of Slovakia belong to the Eastern area of occurrence of *D. reticulatus*. The foci are placed along the southern and eastern borders, in the midcourse of the Latorica River. While the tick is quite common in the northern provinces of Romania and Hungary, it is relatively rare in other parts [15,39].

D. reticulatus is absent from a region in central Europe shaped roughly like an inverted triangle. Its northern edge runs along the Baltic Sea coast, with the arms extending from central Germany at 12–13°E to western Poland at 19°E; the arms of the triangle coincide at the southern border of Hungary [8,40].

The changes in the occurrence range of *D. reticulatus* tick

The range of occurrence of *D. reticulatus* described above was relatively stable from the first species descriptions until the 1970s and 1980s. However, since the nineties, it has appeared in new localities where it was previously absent. The first comprehensive study of its presence in Poland was made by Lachmajer in 1963 [41] and later completed by Szymański (1986) [42] and Siuda in 1993–1995 [3,11]. This picture of its range was the basis for every study concerning this tick species which appeared from the end of the 20th century to the beginning of the 21st century. Their data demonstrates that this tick was found in the north-eastern parts of Poland, in Podlasie, Augustowska Forest, Knyszyńska Forest, in the Biebrza River Valley, Piska Forest and Lublin Polesie, as presented in Fig. 1. Siuda [11] and Siuda et al. [17] documented 10 new foci, representing the borders of the Eastern occurrence area, which includes regions on the east of the Vistula and San rivers. The results of a new study suggest that this should be considered a single, contiguous area connected with the main, so-called Russian, area [43].

Fig. 1. The occurrence of *D. reticulatus* in Poland according to Szymański (1986) and Siuda (1993) [3], in the last decade ([7, 8, 44, 45, 46], new foci by Kiewra and Czulowska in 2013 [48], new foci by Nowak in 2011 [49])

From the 1990s, the range of this tick species was observed to expand westward through Poland. It was found in, *inter alia*, new localities in northern Poland, in Pomerania, Kashube and in the Tuchola Woods [44,45], as well as in the central regions such as Kampinos Forest near Warsaw, and the borders of the Warsaw agglomeration [7,9,40]. In the south of the country, in Niepołomice, this tick originated from European bison in the Białowieża Primeval Forest [46]. Since 2009, newly-documented foci have been observed in Lower Silesia (south-western Poland) in Bolesławiec County [47,48] and in Lubuskie Province [49] .

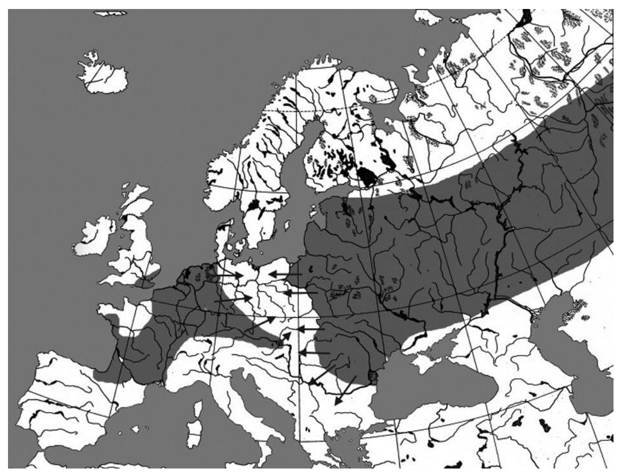

Fig. 2. The directions of *D. reticulatus* expansion in Europe

The expansion of *D. reticulatus* to new, previously free areas has been observed in all central and northern parts of Europe (Fig. 2). Until the late 1970s, this tick was relatively rare in Germany [2]. In the 1980s, it was still more common in the western part of the country and remains rare in the eastern part: only three populations were found to be present in the Leipzig district. In the nineties, some foci were found in eastern Germany in Düben-Dahlen and Annaburg, which were considered endemic [50]. *D. reticulatus* remains numerous in Saxony, Saxony-Anhalt, Brandenburg, and the previously small populations in Hessen and Bayern have recently enlarged [51].

A similar situation concerns the Czech Republic and Slovakia. Until the 1980s, this tick was rarely found, and the foci were documented around Bratislava, along the Danube and Bodrog rivers, and near the Ukraine border [27]. However, the last decade has seen the appearance of many new localities; they have spread east into the East Slovakian Upland. Simultaneously, the tick species in the Danube valley has spread to the west, and has come into contact with *D. reticulatus* ticks from the West-European and Eastern occurrence areas [52]. In addition, expansion to the north has been observed; the border of the northern range in Slovakia now reaches as far as the towns of Michalovce, Trebišov and Košice [53]. In the Czech Republic, although the distribution of *D. reticulatus* has not increased to such a degree as seen in Poland and Slovakia and has usually taken place along the main rivers, evidence of their increased abundance has still been noted [6]. In Hungary, the tick was seldom found before the 1970s, and only two separate foci were identified in the 1950s. This distribution of the species has not only been observed to expand in recent decades, and it presently occurs in the whole country, it is also more numerous [54]. The most numerous populations are recorded in the north-western and south-western parts of the country [13–15,55].

The spread of the western population to the East is evident. New populations have been found in eastern Germany in 2006, western Poland in 2010 and the Czech Republic in 2010, all correlated in time. Recently, new populations of *D. reticulatus* ticks have also been recorded in Belgium, confirming the geographical expansion in North-western Europe [56].

The possible sources of the separate East and West distributions of *D. reticulatus*

The reasons for the presence of two separate distributions of *D. reticulatus* before the end of the 20th century, as well as their present fusion, are not known. Although most hypotheses usually concern the environmental and climatic conditions, it is also possible that human activity exerts an impact.

As no geographic barrier exists between natural forest and meadow ecosystems in the Palaearctic zone along a lane running from France to the Urals between 50° and 55°N, human activity such as the melioration and the eradication of streamlets may be responsible for the absence of this tick in central Europe, as may be decreased host ranges. Elk (*Alces alces*), the most important host for adult ticks, was completely eradicated from the greater part of Europe, and deer and wild boars remain rare [27]. However, intensive human activity has always taken place within the greater part of the range of *D. reticulatus* and has not caused its elimination. Moreover, it is not possible to establish the time of the potential retirement of *D. reticulatus* from the areas of eastern Germany, western Poland and Slovakia, and any contributory factors, because the first study on their occurrence only dates from the second part of the 19th century [57].

Although there are no geographic barriers, the East-West division of *D. reticulatus* populations does in fact relate to the climatic structure of Europe. The climate in Poland is a transitional area between oceanic and continental climates, where the moist air masses from the Atlantic meet dry air masses from the continent [58]. This influences the vegetable cover and associated animals. Consequently a transitional zone exists between plant communities and fauna typical of an oceanic climate, represented by deciduous forests, and communities typical of a continental climate represented by coniferous forests. The limits of the ranges of many species of animals and plants run through the centre of Poland. It is estimated that 52% of the species occurring in Poland have a transitional character, in that they are spread throughout both the western and eastern parts of the country, while the remaining species occupy the west or the east: the centre marks the western or eastern limit of their distribution [59]. However, as the western border of their eastern range lies in both Polish territory and in Western Europe, these hypotheses are insufficient to explain the east-west division of *D. reticulatus* populations.

Another potential hypothesis is associated with the biology of *D. reticulatus* and changeable climatic influence. This tick occurs in open areas; the fluctuations in the weather in temperate zones cause large variations in temperature, humidity and insulation levels. The range of soil surface temperatures limits oviposition and egg development, and changes in humidity and susceptibility of larvae and nymphs to unfavourable factors further restricts the reproductive period to one or two months [16]. Hence it can be seen that the occurrence or local absence of the *D. reticulatus* tick is highly dependent on indigenous climatic conditions. It is possible to associate the divided occurrence area with the presence of five climatic regions of Europe established by Smolec [60]. These regions are variable with respect to the season; separate regions have been established for the whole year, for cold seasons and for the growing season. Based on this division, it is evident that the area of absence of *D. reticulatus* in eastern Germany and western Poland coincides with the C region for the cold season. It is a region with warm temperatures, with the January temperatures ranging from –5 to +5°C and a mean temperature of 0°C. The eastern part of Poland belongs to the D region, which is fairly cool.

The thermal conditions have the greatest influence on the overwintering ability of many invertebrates, including ticks. Less is known about the influence of low temperatures on various aspects of tick biology; however, many authors suggest that ticks are not freeze tolerant. Dautel and Knülle [61] estimated the supercooling points of European tick species to be between –17 and –23°C, which is the same for *D. reticulatus*: such low temperatures limit survival. Ticks spend the winter in the litter, under cover and in other safe places on the soil surface, during which time the soil surface temperature is dependent on its insulation, as well as on the thickness of snow cover. This snow cover determines the thermal conditions of the ground, and its heat-insulating attributes, such as its low thermal conductivity, protects small overwintering animals and plants from the frozen habitat. While the soil can be frozen to a great depth on frozen days when there is little or no snow cover, it only freezes to 12 cm when the snow cover is 9 cm thick, and to only 0.5 cm when the snow is 26 cm thick [62]. Another important factor is the number of days with thick snow cover. The disappearance of snow cover determines the moment at which the ground temperature rises above 0°C. Snow melting and sublimation determine the beginning of the growing season, as well as the dates of several phenological appearances of plants [63] and also the periods of activity of animals dependent on the vegetation.

The eastern part of Poland is characterised with thick snow cover, which protects the stable conditions for overwintering organisms and protects against freezing. In the western part of Poland, the snow cover is too thin to allow protection against frost. Instead, in Western Europe, the number of frozen days is low [62], and ticks can overwinter without snow cover protection. The limited ability of eggs and juvenile individuals of ticks to survive winter under conditions of central Europe is also investigated by Dautel et al [51].

The potential reasons for the expansion of *D. reticulatus*

Recently, changes in the distributions of many plant and animal species have been observed, including those of many tick species change the area, apart from *D. reticulatus*, in which such phenomena is observed in the case of *Ixodes ricinus* and *Haemaphysalis* spp. [38,64]. Although the reasons for the expansion of *D. reticulatus*, and other tick species, to new areas are currently unclear, they can be divided into two groups: the first are natural factors mainly associated with the climate, such as temperature change, wind direction and changes in precipitation, while the second group is associated with human activity, such as migration, travels and trade [65]. On this basis, other hypotheses can be rebutted.

Global warming

The majority of hypotheses refer to global warming [51]. The climatic changes observed in the last decades encompass changes in atmospheric gas composition, average climate and climate variability. The most spectacular symptoms noted in central Europe are the movement of the sub-oceanic climatic region to the east, the mean increases in winter temperature, the simultaneous decline in the number of frozen days and the earlier appearance of snow cover with shorter persistence in lowlands. Greater variation is seen in indices of daily temperature, the number of hot days is increasing and the number of frosty days is decreasing [66–68]. A 1.5–2.5°C rise of the mean temperatures has been observed in recent years in northern Europe. These changes influence the life cycles of ticks; the effects can be decreases or increases in activity, changes in population density and changes in distribution [16]. The *D. reticulatus* tick is particularly susceptible to climatic factors: the threshold temperature and humidity for their activity are relatively low, their spring activity starts only a moment after the disappearance of snow cover at 2–4°C, and it is possible to find active ticks in January and February [69–71]. This warming especially favours the overwintering of young developmental stages and elongates the activity period of adults. As a consequence, it is possible to stay the spread of ticks to new areas, where unfavourable conditions predominate [53]. For example, such a potential role was observed during the last 50 years with regard to changes in the thickness and duration of snow cover. According to Bednorz [62], the second part of the 20th century saw an increase in the number of days with snowfall, and a tendency for this snowfall to have a shorter duration. In northern Germany, winters with no snowfalls and frozen days are noticed in the areas presently expanded into by *D. reticulatus*. In Polish lowland territory a similar trend has been observed. The areas that were previously potentially unfavourable for these ticks, presently remain possible to be inhabited. Instead, on the sub-mountain areas and in the north-eastern part of Poland, a tendency for the thickness of snow cover to grow has been observed with a simultaneous decline in the number of frozen days [68]. These factors protect the eastern populations against the danger associated with the movement of the C thermal zone to the east. The impact of winter temperatures on tick distribution are also highlighted by Lindgren et al. [72], with particular reference to the density and northward expansion of *Ixodes ricinus* in Sweden.

The influence of human activities

The term “global change” describes the climatic and environmental changes encompassing changes in land use and land cover in response to increased consumption and population growth by humans. Such processes as deforestation, irrigation, grazing and urbanisation have the potential to change the dynamics and geographical distribution of species, including microbial pathogens and their vectors.

The increase and expansion of the *D. reticulatus* population are possibly also caused by human activity. Agriculture and farming have a special influence. The last two decades of the 20th century in central Europe was a time of reform in politics and the economy, which caused changes in agricultural practice, local reforestations, and a reduction in applied pesticides and the headage of cattle. Some of these factors can be favourable for the spread of *D. reticulatus*. Until the 1970s, *D. reticulatus* was most commonly found in the former Olsztyn and Białystok voivodeships (north-eastern Poland). These regions boasted the largest forest complexes and the lowest proportions of cultivated areas in the country; moreover, large areas were assigned to forestation. In addition, the greatest proportion of cultivated areas were grasslands and fallows [73].

From the beginning of the 1990s, the agricultural structure changed throughout the country, with the liquidation of great state holdings to individual smallholdings. There was an accompanying decrease of the general land area used for agrarian purposes, together with an expansion of fallow lands and fallows from 163 thousand hectares in 1990 to 230 thousand in 2002 and 140 thousand in 2006. In addition, the use of fertilisers and pesticides decreased. An essential feature of Polish agriculture is the distinct fragmentation of farming after the transformation of the system. At present, more than 60% of holdings do not exceed 5 hectares in size, the majority of which are fragmented into small lots and are divided by fallows and strands of thicket [74].

The management of protected areas and nature reserves

The changes in agriculture follow the intentional transformation of considerable agrarian grounds into meadows and wooded grounds, as well as the enlargement of the protected zones. The purpose of these actions is the restitution and enlargement of the population of wild large mammals and birds. This secures the living conditions not only for the animals which are protected, but also for hundreds of other species of plants and animals, including invertebrates, and amongst them, ticks. Although their occurrence does not directly depend on particular species of plants, ticks are relevant in plant assemblages capable of forming the specific microclimate and habitats of hosts.

The presence of dense vegetation assemblages ensures that the conditions are relatively stable and isolated from extremes of temperature, humidity and other meteorological factors, and so are essential for the survival and development of young stages of ticks. Man, in restoring the primeval phytocoenoses, also reconstitutes suitable conditions for ticks [16,51,75]. Moreover, the reconstituted populations of medium-sized and large mammals are not only a food source; they also provide the opportunity for moving to new areas. There is a rule that young mammals leave their birthplace and migrate in search of new areas in the autumn, during which time they transport ticks attached to their body. For *D. reticulatus* ticks, this can occur in the winter months, when the ticks are attached to the skin of elk, bison and possibly other large mammals [70,76].

The modern trend in environmental protection is the connection of large forest complexes and protected areas with strips of land isolated from human activity. The creation of such ecological corridors is favourable for the expansion of many animal species, among them ticks. The lines of afforestation in the agglomerations, as well as the great parks containing diverse flora, are the migration route for many wild animals. With animals, the attached ticks also migrate. Large downtown forestations constitute a local microclimate characterised by lower temperatures and higher humidity than built-up areas [77]. These conditions make the continuous presence of many animals within bordering towns possible.

The creation of recreational areas in towns

A special question concerns the presence of ticks in towns and urban agglomerations. Urban areas are a special kind of environment, which has been strongly transformed by human activities. In contrast to natural ecosystems, human activity in towns results in the degradation of animal associations: a characteristic feature being the decreasing number of species in association and one or a few species gaining a conspicuous numerical superiority. However, a number of species are included in the associations in areas transformed by anthropopressure [78]. Parks and other green terrains, with their dense vegetation, are a suitable habitat for many species of mammals, birds and invertebrates. The flora and fauna of parks are increasingly rich in accordance to the size and degree of the park's similarity to natural forest complexes. The greatest differentiations of composition have animal associations of those environments which are ecotones. They occur at the borders of towns and villages and at the borders of parks and people-inhabited areas. As the degree of forest clearing and conservation in large parks are often intentionally reduced to settle the natural plant communities and habitats of protected plant and animal species, parks remain desirable for wild animals typical of natural forests. For example, in large urban parks, there are commonly small and medium sized mammals such as rodents, foxes, mustelids and hares, and sometimes also large mammals such as red and roe deer [9,79]. An important factor is their contiguity to natural forest complexes on the outskirts of a town, which makes the migration of mammals and other animals from natural forests to city parks possible, along with any accompanying parasites and attached ticks. Also, an important role can be played by birds, as they serve as hosts of the young stages of ticks. Although city parks are often home to *Ixodes ricinus* ticks, *Dermacentor reticulatus* is also present. Their occurrence in towns has been recorded in Warsaw [7,9], Kiev [38] and Košice [80]. It is evident that *D. reticulatus* has appeared in the last decade in many cases, and often in places that were previously free of this tick [9].

Tourism and trade

The classic human influence on the spread of parasites concerns tourism, the creation of new recreation areas, the development of transport, and increased movement of people between countries. Commonly known factors include the movement of ticks by dogs while travelling with owners, and on large animals transported for trade or farming. There are many documented cases of ticks being brought into Poland from distant regions. *Rhipicephalus sanguineus*, *Dermacentor marginatus* and *Boophilus microplus* ticks were transported by dogs from Mediterranean countries to the Baltic region [81], ticks of the *Amblyomma* (*Aponomma*) genus are known to have migrated from tropical countries to Poland [82,83] and the migration of *D. reticulatus* into distant areas was documented by Daugschies [84]. Also, this phenomenon is not limited to the European continent: Keirans and Durden [85] report the presence of *D. reticulatus* in, among others, horses transported to the USA in the 1960s, 1970s and 1980s from France.

Conclusions

The spread of *D. reticulatus* is most likely a response to the combined influence of a number favourable factors for the expansion of ticks, including climate change due to global warming, changes in the landscape such as the reduction of the use of pesticides and other chemicals, the growth of the number of wild animals as a result of their protection, and the introduction of ticks into new regions through tourism and the development of transport.

A knowledge of tick distribution and monitoring its changes are both important from the medical and veterinary points of view. The *D. reticulatus* tick is known to transmit *Babesia* piroplasms, *Rickettsia* bacteriae, *Francisella tularensis* and *Coxiella burnetii*, and new records detailing an increasing trend in the infection of dogs with *Babesia canis* are evidence of the changing distribution of *D. reticulatus* ticks [16,80,86]. Although this tick species does not typically attack people, it is an important component of the zoonotic foci of rickettsiosis caused by *Rickettsia slovaca*, *R. raoultii* and *R. helvetica*. The first records of *D. reticulatus* infections with these pathogens and the first cases of human infections with TIBOLA/DEBONEL in Poland and other countries correlate with the colonisations of new areas and population growth [87–90].

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