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**ORIGINAL ARTICLE**

# Abundance and seasonal activity of adult *Dermacentor reticulatus* (Acari: Amblyommidae) in eastern Poland in relation to meteorological conditions and the photoperiod

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**Abstract**

Investigations of the abundance and seasonal activity of adult *D. reticulatus* in relation to the effect of climatic conditions (temperature, humidity) and the photoperiod on host-seeking behaviour were conducted in eastern Poland (51°25'N) in 1999-2000. *D. reticulatus* host-seeking activity was observed between the end of March at 5°C temperature and 89% humidity, and the beginning of December at 6°C temperature and 92% humidity. The peak autumn activity found between September – November was more than 2-fold higher than the spring peak, which occurred between April – May. The activity of females, males, and the total number of adult ticks was correlated with the temperature ($p<0.01$) and photoperiod ($p<0.01$); additionally, no dependency was found between adult tick activity and humidity of the environment ($p>0.05$). Females predominated throughout almost the entire activity period, but the ratios between females and males varied in the particular seasons. Males predominated only after the activity of adult ticks ceased between June – second decade of August, which was related to the reproductive processes. The investigations demonstrated that the activity dynamics in *D. reticulatus* from eastern Poland is similar to that in the southern European population, but different from that in the north-eastern Polish, Russian and West European populations. This indicates a need to monitor the threats of diseases transmitted by *D. reticulatus* within different regions of its range of geographic distribution.

**Key words**

*Dermacentor reticulatus*, seasonal activity, host-seeking activity, sex ratio, climatic conditions, photoperiod

## INTRODUCTION

The meadow tick *Dermacentor reticulatus* poses significant veterinary and epidemiological risks. Besides producing extensive skin lesions [1], it is a vector of tick-borne diseases, e.g. babesiosis, tularemia, Q-fever, zoonotic rickettsiosis, and tick encephalitis [2-17].

*D. reticulatus* is widespread in the temperate climate zone in Europe and Asia. Its western distribution range covers the area of France, Spain, UK, Central Europe, and the areas of Eastern Europe as far as the basin of the Yenisei River in Siberia to the east [18]. In Poland, the greatest numbers of *D. reticulatus* localities have been reported from the north-eastern and eastern parts, along the border with Lithuania, Belarus and Ukraine [19-22]. In recent years, the distribution range of this species has extended substantially [4, 6, 23-30], and yet, its questing behaviour in nature has rarely been described. Only in a few papers has the effect of the abiotic factors on *D. reticulatus* abundance and ecology been analysed [10, 26, 31, 32]. The current paper presents the results of studies on the abundance and activity of adult *D. reticulatus* ticks in different seasons and environmental conditions in eastern Poland. Knowledge of the seasonal activity dynamics and factors affecting *D. reticulatus* populations is crucial for assessment of the risk of transmission of tick-borne diseases in the study area, and development of effective prevention methods and tick control programs.

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## MATERIAL AND METHODS

The study was conducted in an area of approximately 8 hectares in the vicinity of Ostrów Lubelski (eastern Poland, 51°25'N) in 1999-2000. The locality was found by Lech Buczek in 1998. It is probably an extension of the Belarusian habitat of this species located in the Trzmielnica River valley, a meadow area overgrown with sedge grass characteristic for this type of ecosystem, and abundant in shrubs, coniferous and deciduous trees, mainly birch (*Betula* spp.) along the edges.

Ticks were collected using the flagging method, which involved sweeping the vegetation with a 1 × 1m white flannel cloth drag. After the cloth had been swept over the plants 5-6 times, its surface was inspected and tick specimens attached to it were transferred to tubes with forceps. The field research was conducted by one person at 11-day intervals, for 2 hours each time between 14:00–16:00, between April – November 1999, and between March – December 2000. Due to the decreasing length of days, in November and December ticks were only collected just before nightfall. The choice of the field study period was affected by weather conditions: tick collection started after the snow cover had melted and ceased when it was prevented by freezing temperatures and a snow cover on the vegetation. Ticks were not collected during and immediately after rainfall, as the wet cloth might have prevented ticks from adhering to the flag. The ticks were collected 44 times (24 in 1999 and 20 in 2000).

In each field study, the air/soil temperature were measured with an accuracy of 1°C and relative humidity with an accuracy of 1%, using electronic devices at the height of 10 cm above the ground. The length of each day of tick collection was calculated with the algorithms available on website www.calendar.k-ce.pl. The time of sunrise and sunset at the geographical position of the tick study locality followed the CEST (Central European Summer Time) in summer or CET (Central European Time) in winter.

In the laboratory, the ticks were submerged in 70% alcohol, and then viewed under a stereoscopic microscope in order to recognise the species and gender of the specimens. The key developed by Siuda [21] was used to identify the species.

**Statistical analysis.** The results were elaborated using the STATISTICA statistical package for Windows. All correlation analyses were performed by calculation of Spearman's correlation coefficients. Probability at p ≤ 0.05 was regarded as significant and as highly significant at p ≤ 0.01.

## RESULTS

**Abundance and seasonal host-seeking activity.** During the study of the seasonal activity of adult *D. reticulatus* ticks, a total of 2,873 specimens were collected in 1999-1,361 specimens (763 females and 598 males) and 1,512 (889 females and 623 males) in 2000 (Tab. 1, 2). Tick abundance in 1999 (56.7±59.4 specimens per one collection) and 2000 (75.6±47.1 specimens per one collection) and seasonal activity of the adult specimens differed in a statistically significant manner (p<0.05). However, in both study years, the seasonal number of adult ticks showed a bimodal pattern of activity. Active adult *D. reticulatus* ticks were collected from the beginning of spring. The largest number of active adult ticks during the spring activity period was observed in May in 1999, and between mid-April and the first decade of May in 2000. The questing activity of the adult specimens gradually ceased between the end of June and the beginning of August. During the autumn activity period, the greatest number of active adults was collected between the second decade of September and the end of October or mid-November, respectively in 1999 and 2000. No statistically significant differences were found between the numbers of ticks collected in the respective seasons of both study years (p>0.05).

During the 2-year long studies, the highest activity of adult *D. reticulatus* was reported in autumn (62.9±54.3 specimens per one collection), and was nearly 2-fold lower in spring (32.5±24.7 per one collection). The difference was statistically significant (p< 0.0001).

In both years of the study, the temperature and humidity fluctuated considerably (Tab. 1, 2). There were no dependencies between air humidity and female (p>0.05) and male (p>0.05) activity. However, there was a correlation between temperature and female (p<0.01) and male (p<0.01) activity, and between the length of the photoperiod and the activity of female (p<0.01) and male ticks (p<0.01).

**Table 1.** Total gender number of *Dermacentor reticulatus* ticks collected during particular collections in 1999 in context of temperature and relative humidity

| Date | Adults | Females | Males | Temp. (°C) | RH (%) | Length of day |
|---|---|---|---|---|---|---|
| 9.04 | 19 | 13 (68.4%) | 6 (31.6%) | 14 | -* | 13h07′ |
| 27.04 | 28 | 17 (60.7%) | 11 (39.3%) | 22 | 66 | 14h33′ |
| 6.05 | 75 | 54 (72%) | 21 (28%) | 10 | 72 | 15h05′ |
| 20.05 | 46 | 30 (65.2%) | 16 (34.8%) | 25 | 40 | 15h48′ |
| 27.05 | 35 | 24 (68.5%) | 11 (31.5%) | 31 | 45 | 16h05′ |
| 3.06 | 4 | 4 (100%) | 0 | 24 | 90 | 16h19′ |
| 19.06 | 0 | 0 | 0 | 24 | 100 | 16h36′ |
| 30.06 | 0 | 0 | 0 | 23 | 100 | 16h32′ |
| 13.07 | 0 | 0 | 0 | 27 | 70 | 16h14′ |
| 20.07 | 0 | 0 | 0 | 31 | 60 | 15h58′ |
| 30.07 | 0 | 0 | 0 | 21 | 70 | 15h31′ |
| 6.08 | 1 | 1 (100%) | 0 | 25 | 100 | 15h08′ |
| 18.08 | 8 | 4 (50%) | 4 (50%) | 29 | 85 | 14h28′ |
| 23.08 | 30 | 9 (30%) | 21 (70%) | 19 | 70 | 14h09′ |
| 3.09 | 66 | 36 (54.5%) | 30 (45.5%) | 22 | 65 | 13h28′ |
| 11.09 | 129 | 60 (46.5%) | 69 (53.5%) | 21 | 95 | 12h58′ |
| 18.09 | 166 | 88 (53%) | 78 (47%) | 21 | 100 | 12h31′ |
| 28.09 | 134 | 79 (58.9%) | 55 (41.1%) | 20 | 85 | 11h52′ |
| 10.10 | 131 | 70 (53.4%) | 61 (46.6%) | 12 | 100 | 11h05′ |
| 13.10 | 118 | 54 (45.7%) | 64 (54.3%) | 9 | 85 | 10h54′ |
| 19.10 | 119 | 66 (55.4%) | 53 (44.6%) | 4 | 74 | 10h31′ |
| 30.10 | 169 | 99 (58.5%) | 70 (41.5%) | 12 | 100 | 09h50′ |
| 6.11 | 83 | 55 (66.2%) | 28 (33.8%) | 13 | 100 | 09h25′ |
| 16.11 | 0 | 0 | 0 | -2 | 65 | 08h53′ |
| **Total** | **1361** | **763 (56%)** | **598 (44%)** | | | |

*- no data

**Table 2.** Total gender number of *Dermacentor reticulatus* ticks collected during particular collections in 2000 in context of temperature and relative humidity

| Date | Adults | Females | Males | Temp. (°C) | RH (%) | Length of day |
|---|---|---|---|---|---|---|
| 24.03 | 54 | 35 (64.8%) | 19 (35.2%) | 5 | 89 | 12h26′ |
| 4.04 | 54 | 29 (53.7%) | 25 (46.3%) | 14 | 58 | 13h10′ |
| 17.04 | 119 | 71 (59.6%) | 48 (40.4%) | 17 | 78 | 14h00′ |
| 30.04 | 60 | 42 (70%) | 18 (30%) | 32 | 48 | 14h48′ |
| 11.05 | 100 | 79 (79%) | 21 (21%) | 25 | 39 | 15h24′ |
| 20.05 | 38 | 31 (81.5%) | 7 (18.5%) | 22 | 58 | 15h50′ |
| 29.05 | 13 | 11 (84.6%) | 2 (15.4%) | 25 | 62 | 16h11′ |
| 9.06 | 3 | 3 (100%) | 0 | 27 | 65 | 16h29′ |
| 24.06 | 1 | 1 (100%) | 0 | 23.5 | 75 | 16h35′ |
| 13.07 | 0 | 0 | 0 | 26 | 87 | 16h12′ |
| 2.08 | 1 | 1 (100%) | 0 | 30 | 60 | 15h19′ |
| 21.08 | 11 | 5 (45.4%) | 6 (54.6%) | 37 | -* | 14h14′ |
| 7.09 | 93 | 45 (48.3%) | 48 (51.7%) | 18 | 65 | 13h10′ |
| 22.09 | 172 | 82 (47.6%) | 90 (52.4%) | 18 | 62 | 12h12′ |
| 28.09 | 155 | 84 (54.1%) | 71 (45.9%) | 18.5 | 61 | 11h49′ |
| 5.10 | 168 | 104 (61.9%) | 64 (38.1%) | 23 | 65 | 11h21′ |
| 13.10 | 125 | 65 (52%) | 60 (48%) | 22 | 79 | 10h51′ |
| 24.10 | 128 | 76 (59.3%) | 52 (40.7%) | 16.5 | 62 | 10h09′ |
| 14.11 | 168 | 93 (55.3%) | 75 (44.7%) | 16 | 90 | 08h57′ |
| 3.12 | 49 | 32 (65.3%) | 17 (34.7%) | 6 | 92 | 08h08′ |
| **Total** | **1512** | **889 (58.7%)** | **623 (41.3%)** | | | |

* – no data

**Gender ratio.** Nearly all the collections of *D. reticulatus* in 1999 and 2000 were characterised by the predominance of females over males (Fig. 1). Females constituted the highest

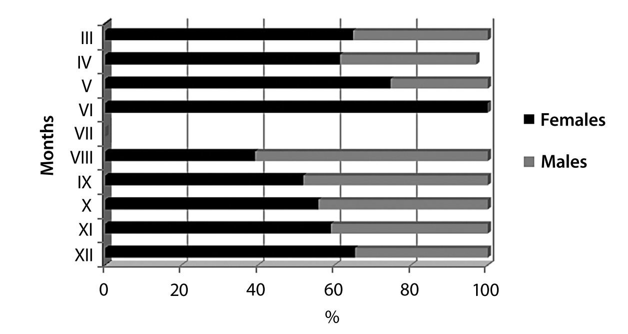


**Figure 1.** Gender percentage of *Dermacentor reticulatus* ticks collected in particular months in 1999-2000

percentage (68.5-100% and 84.6-100%, respectively, in 1999 and 2000) in the period from late May – early June. Males predominated only at the beginning of the autumn activity period, at the end of August; then female predominance was more pronounced (Tab. 3). In autumn, males were characterised by a nearly 3-fold higher activity (28.6±25.2 specimens per one collection), with its maximum in September (63±20.1 specimens per one collection), than in the spring months when the mean number of active males in one collection was 10.2±9.0, and the highest activity was observed in April (17.4±16.4 specimens). The highest activity in females was noted in autumn (34.3±30.0 specimens per one collection), with its peak from September – November (Tab. 3). In the spring months, females displayed the highest activity in April (28.7±23.3 specimens per one collection) and May (21.6±24.3 specimens per one collection). On average, 22.3±16.3 females were collected during one collection in the spring activity period. Due to the infrequent collection periods in March and December, the mean values obtained for females and males during these months was not taken into account. The differences between the numbers of active females and males collected in spring and autumn were statistically significant (p<0.0001). There were no dependencies between air humidity and female (p>0.05)

**Table 3.** Gender ratio and average number of *Dermacentor reticulatus* ticks collected during particular collections in different months in 1999-2000

| Month | Females | | | | Males | | | | Gender ratio | Total/ Adults |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Min. | Max. | SD | Mean | Min. | Max. | SD | F:M | |
| March[1] | 35 | 35 | 35 | | 19 | 19 | 19 | | 1.84 : 1 | 54 |
| April | 28.7 | 13 | 71 | 23.3 | 17.4 | 6 | 48 | 16.4 | 1.65 : 1 | 280 |
| May | 21.6 | 8 | 79 | 24.3 | 8.2 | 0 | 21 | 7.7 | 2.64 : 1 | 307 |
| June | 1.6 | 0 | 4 | 1.8 | 0 | 0 | 0 | 0 | | 8 |
| July | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| August | 4 | 1 | 9 | 3.3 | 6.2 | 0 | 21 | 8.6 | 0.64 : 1 | 51 |
| September | 87.7 | 36 | 88 | 20.7 | 63 | 30 | 90 | 20.1 | 1.07 : 1 | 915 |
| October | 76.2 | 54 | 104 | 18.4 | 60.5 | 52 | 70 | 6.3 | 1.27 : 1 | 958 |
| November | 49.3 | 0 | 93 | 46.7 | 34.3 | 0 | 75 | 37.8 | 1.43 : 1 | 251 |
| December [1,2] | 32 | 32 | 32 | | 17 | 17 | 17 | | 1 : 1 | 49 |

[1]- only 1 tick collection
[2]-regard only to year 2000

and male (p>0.05) activity. However, there was a correlation between temperature and female (p<0.01) and male (p<0.01) activity, and between the length of the photoperiod and activity of male (p<0.01) and female ticks (p<0.01).

## DISCUSSION

The activity of adult *D. reticulatus* varies in the particular seasons of the year. Our results indicate that the stimulation and dynamics of this tick activity are affected by various environmental factors. Higher activity was recorded in the autumn period during the short 8h57'-12h58' day, at a large range of temperatures (4-21°C) and humidity (61-100%). In previous studies conducted in the same habitat, active *D. reticulatus* adults were observed attacking dogs as late as December, after the appearance of the snow cover (L. Buczek, unpublished). Adult ticks were collected even at low daily mean temperatures in December, January and February (7.5, 7.7 and 6.6°C, respectively) around Berlin (Germany) in 2006 [33]. Nosek [34] and Bogdaszewska [35] reported the highest activity of adult *D. reticulatus* at daily mean temperatures ranging from 4 -13°C. These authors found that the lower and upper range of the threshold temperature for tick activity is +1°C and 39°C, respectively.

The high questing activity of adult *D. reticulatus* in open-type habitats in eastern Poland was stimulated by various combinations of temperature and humidity, which indicates high ecological plasticity of this developmental stage. The results of our field observations are consistent with laboratory investigations, which confirmed the ability of *D. reticulatus* to develop in a wide range of humidity and temperature [36, 37, our unpublished data]. However, throughout the seasonal activity period and during the spring and autumn peaks, the only abiotic factors that significantly affected the questing *D. reticulatus* adults in eastern Poland were temperature and photoperiod. The absence of correlation between the number of active ticks and humidity renders our findings different from the results obtained by Bogdaszewska [35] in her study of *D. reticulatus* population in north-eastern Poland (Mazury region), who reported an effect of humidity on *D. reticulatus* activity. The low relative air humidity in that habitat strongly limited the activity of the meadow tick adults, and humidity lower than 65% resulted in their disappearance. No correlation between rainfall and tick dynamics was found in a field study of a French tick population carried out in 1982-1983 [10]. Ambient humidity, however, exerts an effect on the tick survival period, which was demonstrated by studies of adult stages in *D. reticulatus* [38], *Amblyomma cajennense* [39], *Hyalomma truncatum* [40], *A. americanum*, *A. maculatum*, *Dermacentor albipictus* and *Boophilus annulatus* [41].

Our results showed certain differences in the activity dynamics in various tick populations in Poland and other countries. In eastern Poland, the spring activity lasted from March to the end of May, with a peak from late April to May, and it disappeared at the beginning of June. The second period of seasonal activity began in August and lasted until December, with the peak at the end of September – mid-November.

In the north-eastern population, the spring activity lasted from mid-March to mid-June, with a peak in April, and the autumn activity began in mid-August and lasted until mid-November, with a peak in October [35, 42]. In southern Jura

(France), *D. reticulatus* are active from mid-April – mid-June, and from September – October [10]. The shifts of tick activity periods may be related to different climatic conditions and different biotopes of the populations studied and host behaviour, as well as biological differences between these populations. Comparative studies conducted in Slovakia (southern Moravia) and in north-eastern Poland showed differences in the length of the development cycle and development of *D. reticulatus* stages depending on the biotope [31]. A delayed activity peak in *Dermacentor* spp. in cool mountain conditions compared to warmer conditions of dry pastures, which can be explained by temperature-dependent developmental rate of ticks, was observed by Hornok and Farkas [43] in Hungary. Honzáková *et al.* [44] confirmed the dependence of the length and effectiveness of feeding on the host on the age and origin of the population of ticks and on the biotope.

Despite some differences in the dynamics of male and female activity, the autumn activity of tick adults was higher than that in spring in both our study periods. In contrast, the *D. reticulatus* ticks from a north-eastern Polish population (Warmia and Mazury, 55°45'N) [35, 42], a Russian population (Moscow Oblast, 53°45'-54°10'N) [32] and a French population (southern Jura, 47°12'N) [10] exhibited greater activity in spring. In that season, twice as many adult ticks were collected in populations inhabiting the continental climate zone than during the autumn activity period [35, 42]. In southern Jura, France, the spring populations were even 9-fold greater than in the autumn [10]. On the other hand, as in our study, the peak of spring tick activity in Hungary in April was lower than the peak of autumn activity, September – November, with intensification in October [30].

It seems that the *D. reticulatus* population under study is similar to the populations inhabiting the warmer regions of Europe. In fact, our research area is situated in the warmest bioclimatic zone in Poland. The temperate climate in eastern Poland has a transitional oceanic-continental character. The atmospheric circulation has a great impact on the weather and climate conditions (wandering cyclones with frontal systems and anti-cyclones), which causes significant day-to-day, daily, or year-to-year changeability of the weather elements. Most frequently, the highest monthly mean temperatures are reported in July (18.2°C) and the lowest (-3.8°C) in January [45]. The winter months are characterized by considerable temperature changeability. The annual rainfall varies substantially in the different months, ranging from 0.4 mm - 148 mm (data from the Polish Institute of Meteorology and Water Management, 2009) The year-to-year temperature variability and changeable rainfall rates may explain the shifts of the periods of male and female activity observed during our field observations.

The impact of environmental factors such as the photoperiod, the length of photophase and scotophase [46, 47], and other abiotic factors, e.g. temperature, humidity and solar radiation on the tick questing behaviour was also found in other studies of species from the genus *Dermacentor* [48-53]. The behaviour of *D. reticulatus* males and females, similar to other ixodid ticks [54], is dependent upon their biological traits and requirements for humidity and temperature [36, 37]. Tick adults overwinter in the soil or sometimes in hay stacks left in the meadows [22]. They can also overwinter on the host [55]. In the Białowieża Forest (eastern Poland), the incidence of infection of the bison (*Bison bonasus*) in this period ranges between 43 - 100% (mean 68-71%) [56-58]; after the winter diapause, *D. reticulatus* males remain on the host longer than females, which may explain their lower numbers found on vegetation. The enhanced female activity is also related to the need to find a host for ingestion of blood, which is essential for egg development. Copulation of males with females also occurs on the host. Under natural conditions in Poland, the pre-oviposition and oviposition period lasts from June – July (our data, unpublished). Loss, or a sharp decline in adult *D. reticulatus* behavioural activity observed between June – August is also related to the processes of feeding and reproduction of this species, rather than to the effects of the photoperiod, temperature or humidity only, as suggested by Bogdaszewska [35]. On the other hand, the more pronounced activity of males and the smaller difference in the gender ratio at the beginning of the autumn activity period may result from the biological differences between female and male ticks.

A larger proportion of active females was also detected in *Dermacentor marginatus* (Sulz.) [34], *D. silvarum* Ol. [59] and *D. niveus* Neum. [60]. A different gender ratio was found in *D. reticulatus* adults collected on hosts. Females dominated in spring (61-64%) and males in the autumn period (64%) in cattle grazing in habitats of the tick in the Biebrza Valley [42, 61, 62]. A similar phenomenon was observed by Olsuf'ev [63] in cattle, and by Kadulski [64] in the elk.

The differences in the dynamics of the behavioural activity of this species within different regions of its geographic distribution range encourage further field studies and monitoring of tick-borne diseases.

## REFERENCES


1. Buczek A, Kuśmierz A, Olszewski K, Buczek L, Czerny K, Łańcut M. Comparison of rabbit skin changes after feeding of Ixodes ricinus (L.) and Dermacentor reticulatus (Fabr.). In: Berini F, Nannelli R, Nuzzaci G, de Lillo E. Acarid Phylogeny and Evolution: Adaptation in Mites and Ticks. Kluwer Acadmic Publishers, Dortrecht 2000.p.419-424.
2. Barutzki D, Reule M, Scheunemann R, Heide C, Schein E. Die Babesiose des Hundes. Dtsch Tierärzteblatt 2007; 3, 284-293.
3. Chmielewski T, Podsiadły E, Karbowiak G, Tylewska-Wierzbanowska S. Rickettsia spp. in ticks. Poland. Emerg Infect Dis 2009; 15, 486–488.
4. Dautel H, Dippel C, Oehme R, Hartelt K, Schettler E. Evidence for an increased geographical distribution of Dermacentor reticulatus in Germany and detection of Rickettsia sp. RpA4. Inter J Med Microbiol 2006; 296, 149-156.
5. Dobec M, Golubic D, Punda-Polic V, Kaeppeli F, Sievers M. Rickettsia helvetica in Dermacentor reticulatus ticks. Emerg Infect Dis 2009; 15, 98-100.
6. Duh D, Slovák M, Saksida A, Strašek K, Petrovec M, Avšič-Županc T. Molecular detection of Babesia canis in Dermacentor reticulatus ticks collected in Slovakia. Biologia 2006; 61, 231-233.
7. Heide C, Heydorn AO, Schein E. Dermacentor reticulatus (Fabricius, 1794) – Vebreitung, Biologie und Vektor von Babesia canis in Deutschland. Berl Munch Tierarztl Wochenschr 2006; 119, 330-334.
8. Hubalek Z, Sixl W, Halouzka J. Francisella tularensis in Dermacentor reticulatus ticks from the Czech Republic and Austria. Wien Klin Wochenschr 1998; 23, 909-910.
9. Hubálek Z, Treml F, Halouzka J, Jucicová Z, Huóady M, Janik V. Frequent isolation of Francisella tularensis from Dermacentor reticulatus ticks in an enzootic focus of tularemia. Med Vet Entomol 1996; 10, 241-246.
10. Martinod S, Gilot B. Epidemiology of canine babesiosis in relation to the activity of Dermacentor reticulatus in southern Jura (France). Exp Appl Acarol 1991; 11, 215-222.
11. Nijhof AM, Bodaan C, Postigo M, Nieuwenhuijs H, Opsteegh M, Franssen L, Jebbink F, Jongejan F. Ticks and associated pathogens collected from domestic animals in the Netherlands. Vector Borne Zoonotic Dis 2007; 7, 585-595.
12. Porchet MJ, Sager H, Muggli L, Oppliger A, Müller N, Frey C, Gottstein B. A descriptive epidemiological study on canine babesiosis in the Lake Geneva region. Schweiz Arch Tierheilkd 2007; 149, 457-465.

13. Rar VA, Maksimova TG, Zakharenko LP, Bolykhina SA, Dobrotvorsky AK, Morozova OV. Babesia DNA detection in canine blood and Dermacentor reticulatus ticks in southwestern Siberia, Russia. Vector Borne Zoonotic Dis 2005; 5, 285-287.
14. Špitalská E, Kocianová E. Detection of Coxiella burnetii in ticks collected in Slovakia and Hungary. Eur J Epidemiol 2003; 18, 263-266.
15. Sréter T, Széll Z, Varga I. Spatial distribution of Dermacentor reticulatus and Ixodes ricinus in Hungary: evidence for change? Vet Parasitol 2005; 128, 347-351.
16. Stańczak J. Detection of spotted fever group (SFG) rickettsiae in Dermacentor reticulatus (Acari: Ixodidae) in Poland. Int J Med Microbiol 2006; 296, 144–148.
17. Wójcik-Fatla A, Cisak E, Zając V, Zwoliński J, Dutkiewicz J. Prevalence of tick-borne encephalitis virus in Ixodes ricinus and Dermacentor reticulatus ticks collected from the Lublin region (eastern Poland). Ticks Tick Borne Dis 2011; 2, 16-19.
18. Kolonin GV. Fauna of ixodid ticks of the world (Acari, Ixodidae). 2009 (http://www.kolonin.org/)
19. Dróżdż J, Szymański S. Additional data on the occurrence and ecology of Dermacentor pictus Herm. in the Rajgród-Kobylany region. Wiad Parazytol 1965; 11, 493-495 (In Polish).
20. Dutkiewicz J, Siuda K. New focus of Dermacentor pictus ticks in the south of Lublin region. Medycyna Weter 1969; 25, 44-47 (in Polish).
21. Siuda K. Ticks (Acari: Ixodida) of Poland. Part II Taxonomy and Distribution. Polskie Towarzystwo Parazytologiczne, Warsaw 1993 (in Polish).
22. Szymański S. Distribution of the tick Dermacentor reticulatus (Fabricius, 1794) (Ixodidae) in Poland. Acta Parasitol Pol 1986; 31, 143-154 (in Polish).
23. Bogdaszewska Z. Range and ecology of Dermacentor reticulatus (Fabricius, 1794) in Mazuria focus. I. Defining current range. Wiad Parazytol 2004a; 50, 727-730 (in Polish).
24. Bullova E, Lukan M, Stanko M, Pet'ko B. Spatial distribution of Dermacentor reticulatus tick in Slovakia at the beginning of the 21st century. Vet Parasitol 2009; 165, 357–360.
25. Gray JS, Dautel H, Estrada-Peña A, Kahl O, Lindgren E. Effects of climate change on ticks and tick-borne diseases in Europe. Interdiscip Perspect Infect Dis 2009; 593232, 1-12.
26. Karbowiak G. Kleszcz łąkowy Dermacentor reticulatus – distribution, biology and role as a vector of numerous tick borne diseases pathogens. Postdoctoral degree. The Witold Stefański Institute of Parasitology, Polish Academy of Sciences, Warsaw 2009 (in Polish).
27. Medlock JM, Jameson LJ, Phipps LP. Status of Dermacentor reticulatus in the UK. Vet Rec 2011; 168, 386-387.
28. Nowak M. Discovery of Dermacentor reticulatus (Acari: Amblyommidae) populations in the Lubuskie Province (Western Poland). Exp Appl Acarol 2011; 54, 191-197.
29. Smith FD, Ballantyne R, Morgan ER, Wall R. Prevalence, distribution and risk associated with tick infestation of dogs in Great Britain. Med Vet Entomol 2011; doi: 10.1111/j.1365-2915.2011.00954.x.
30. Széll Z, Sréter-Lancz Z, Márialigeti K, Sréter T. Temporal distribution of Ixodes ricinus, Dermacentor reticulatus and Haemaphysalis concina in Hungary. Vet Parasitol 2006; 141, 377-379.
31. Daniel M, Szymański S, Černý V, Dusbábek F, Honzákowá E, Olejniĉek J. A comparison of developmental dynamics of Dermacentor reticulatus (Fabr.) of different geographic origins and their affection by different microclimate. Folia Parasitol 1980; 27, 63-69.
32. Razumova IV. The activity of Dermacentor reticulatus Fabr. (Ixodidae) ticks in nature. Med Parasitol 1998; 4, 8-14.
33. Dautel H, Dippel C, Kämmer D, Werkhausen A, Kahl O. Winter activity of Ixodes ricinus in a Berlin forest. Inter J Med Microbiol 2008;294,50-54.
34. Nosek J. The ecology and public health importance of Dermacentor marginatus and D. reticulatus ticks in Central Europe. Folia Parasitol 1972; 19, 93-102.
35. Bogdaszewska Z. Range and ecology of Dermacentor reticulatus (Fabricius, 1794) in Mazuria focus. III. The influence of temperature and day length on the activity of hungry adult ticks in laboratory conditions. Wiad Parazytol 2004b; 50, 739-745 (in Polish).
36. Zähler M, Gothe R. Effect of temperature and humidity on longevity of unfed adults and on oviposition of engorged females of Dermacentor reticulatus (Ixodidae). Appl Parasitol 1995b; 36, 200-211.
37. Zähler M, Gothe R. Effect of temperature and humidity on egg hatch, moulting and longevity of larvae and nymphs of Dermacentor reticulatus (Ixodidae). Appl Parasitol 1995a; 36, 53-65.
38. Meyer-König A, Zähler M, Gothe R. Studies an survival and water balance of unfed adult Dermacentor marginatus and D. reticulatus ticks (Acari: Ixodidae). Exp Appl Acarol 2001; 25, 993-1004.
39. Strey OF, Teel PD, Longnecker MT, Needham GR. Survival and water-balance characteristics of unfed adult Amblyomma cajennense (Acari: Ixodidae). J Med Entomol 1996; 33, 63-73.
40. Wilson ML, Dykstra EA, Schmidt BA. Temperature- and humidity-dependent in biological research. Ecology 1993; 41, 232-237.
41. Needham GR, Teel PD. Off-host physiological ecology of ixodid ticks. Annu Rev Entomol 1991; 36, 659-681.
42. Szymański S. Seasonal activity of Dermacentor reticulatus (Fabricius, 1794) (Acarina, Ixodidae) in Poland. I. Adults. Acta Parasitol Pol 1987a; 31, 247-255 (in Polish).
43. Hornok S, Farkas R. Influence of biotope on the distribution and peak activity of questing ixodid ticks in Hungary. Med Vet Entomol 2009; 23, 41-46.
44. Honzáková E, Daniel M, Černý V, Dusbábek F. Feeding of Dermacentor reticulatus (Fabr.) females depending on their age, origins and biotope of survival. Folia Parasitol 1980; 27, 353-358.
45. Kaszewski BM. Climatic conditions in Lublin region. Academic Press UMCS, Lublin 2008 (in Polish).
46. Atwood EL, Sonenshine DE. Activity of American dog tick, Dermacentor variabilis (Acarina: Ixodidae), in relation to solar energy changes. Ann Entomol Soc Am 1967; 60, 354-362.
47. Belozerov VN. Diapause and biological rhythms in ticks. In: Obenchain FD, Galun R. Physiology of Ticks. Pergamon Press, Oxford 1982. p.469–500.
48. Burg JG. Seasonal activity and spartal distribution of host-seeking adults of the tick Dermacentor variabilis. Med Vet Entomol 2001; 15, 413-421.
49. Eisen L, Meyer AM, Eisen RJ. Climate-based model predicting acarological risk of encountering the human-biting adult life stage of Demacentor andersoni (Acari: Ixodidae) in a key habitat type in Colorado. J Med Entomol 2007; 44, 694-704.
50. Harlan HJ, Foster WA. Micrometeorologic factors affecting field host-seeking activity of adult Dermacentor variabilis (Acari: Ixodidae). J Med Entomol 1990; 27, 471-479.
51. Hubálek Z, Halouzka J, Jucicová Z. Host-seeking activity of ixodid ticks in relation to weather variables. J Vector Ecol 2003; 28, 159-165.
52. McEnroe WD. Stability of Dermacentor variabilis populations (Acari: Ixodidae). Folia Parasitol 1990; 37, 340-342.
53. McPherson M, Shostak AW, Samuel WM. Climbing simulated vegetation to heights of ungulate hosts by larvae of Dermacentor albipictus (Acari: Ixodidae). J Med Entomol 2000; 37, 114-120.
54. Sonenshine DE. Biology of ticks, vol. 1. Oxford University Press, Oxford 1991.
55. Nosek J. Overwintering cycles in Dermacentor ticks. Angew Parasitol 1979; 20, 34-37.
56. Izdebska JN. Observations on the presence of ticks (Acari: Ixodidae) in European bison (Bison bonasus) in Poland. In: Buczek A, Błaszak C. Parasite-Host Relationships. Liber, Lublin 2004.p.45-51 (in Polish).
57. Izdebska JN. The occurrence of Dermacentor reticulatus (Fabricius, 1794) (Acari, Ixodidae) on the bison (Bison bonasus) from the Białowieża Primaeval Forest. Przegl Zool 1998; 42, 219-221 (in Polish).
58. Karbowiak G. Izdebska JN, Czaplińska U, Wita I. Cases of survival of the winter by Ixodidae ticks on the hosts in the Białowieża primeval forest. In: Buczek A, Błaszak C. Arthropods and hosts. Liber, Lublin 2003.p.77-82.
59. Kolonin GV. Gender relations in natural pasture populations of ixodid ticks in the littoral region. Ekologiya 1978; 3, 104-105 (in Russian).
60. Burenkova LA. The seasonal activity rhythm in D. nivens Neum., 1897 specimens and the gender relation in the natural population in the northernpart of the Turkmenian USSR. Medskaya Parazit 1983; 61, 55-59 (in Russian).
61. Szymański S. Seasonal activity of Dermacentor reticulatus (Fabricius, 1794) (Acarina, Ixodidae) in Poland. II. Sex ratio in the adult population. Acta Parasitol Pol 1987b; 31, 257-264 (in Polish).
62. Szymański S. Seasonal activity of Dermacentor reticulatus (Fabricius, 1794) (Acarina, Ixodidae) in Poland. Larvae and nymphs. Acta Parasitol Pol 1987c; 31, 265-280 (in Polish).
63. Olsuf'ev NG. External parasites of the common vole Microtus arvalis Pall. and other wild-living mammals in the southern part of the Moscow district. In: Pawlovski EN. Problems in home, foreign and experimental parasitology. Academy of Medical Sciences of the USSR, 1949.p.130-144 (in Russian).
64. Kadulski S. Ectoparasites of Polish arthrodactylous game animals. Acta Parasitol Pol 1975; 23, 493-535 (in Polish).