Biometrical analysis of the common tick, *Ixodes ricinus*, in the Ślęża Massif (Lower Silesia, Poland)

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ABSTRACT: The aim of this study was to biometrically analyze the behavioral activity of *Ixodes ricinus* ticks as influenced by season and trend in numbers, based on material collected during three years in the Ślęża Landscape Park within the Ślęża Massif (Lower Silesia, Poland) using a time series decomposition method. The effects of the abiotic factors of air temperature and humidity on this activity were also determined. A total of 2,745 nymphs and adults of *I. ricinus* was observed and collected from 2001 through 2003. It was the only collected species from the 17 representatives of the family Ixodidae recorded from Poland. The abundance of the common tick in the Ślęża Landscape Park confirms the risk of tick-borne diseases in these nature areas that are under legal protection. The chance of being bitten by ticks increases in the spring and autumn when the behavioral activity of these arthropods reaches their highest levels. Predictions concerning the level of tick behavioral activity should take into account not only seasonality but also the effects of random components, which accounted for about half of the tick activity in our study. The method of time series decomposition employed in our research appears to be useful in making such prognoses. Humidity is particularly significant as it can determine the activity of *I. ricinus* to a large extent. ***Journal of Vector Ecology* 31 (2): 239-244. 2006.**

Keyword Index: Tick activity, *Ixodes ricinus*, time series decomposition method, Poland.

INTRODUCTION

The common tick, *Ixodes ricinus* L., is the most frequently recorded tick species in Central Europe, including Poland (Siuda 1996). It occurs mainly in deciduous and mixed forests but also in urban parks (Siuda et al. 1991, Nowosad et al. 1999, Humiczewska 2001, Kiewra et al. 2002, Michalik et al. 2003). Due to its direct parasitic effect as well as its contribution to the maintenance and transmission of infectious pathogens, particularly the bacterium *Borrelia burgdorferi* sensu lato, *I. ricinus* poses a threat to public health (Kahl 1991, Prokopowicz 1995, Bennett 1995, Hubalek and Halouzka 1998, Stañczak et al. 2004). In Poland, Lyme boreliosis is largely an occupational disease, as the people particularly endangered are those whose professions involve exposure to tick bites, such as forest service workers, foresters, woodcutters, undergrowth berry-pickers, mushroom gatherers, and farmers (Dobracki and Dobracka 1997, Cisak et al. 2001, 2005, Niścigorska et al. 2003). The first cases of Lyme disease were noted in the late 1980s (Januszkiewicz and Kieda 1987), and *I. ricinus* infected with *B. burgdorferi* s. l. were found in the early 1990s (Dąbrowski et al. 1993/1994). The reporting of all boreliosis infections was made obligatory in Poland in 1996 and there has been a persistent growth documented in the incidence of tick-borne boreliosis by the State Hygiene Institute to approximately ten cases per 100,000 in 2004.

The risk of infection is related to high activity of ticks, which in Poland, including Lower Silesia, occurs in the period from April to November, with peaks in spring and autumn (Siuda 1993, Lonc et al. 2001, Kiewra et al. 2002, Humiczewska et al. 2003).

The aim of this research was the biometrical analysis of behavioral activity with regard to the influence of season and trend on the abundance of *I. ricinus* collected during a three-year study conducted in the Ślęża Landscape Park within the Ślęża Massif (Lower Silesia, Poland) using the time series decomposition method. The effects of abiotic factors, including air temperature and humidity, on this activity were also determined.

MATERIALS AND METHODS

Study area

The Ślęża Massif, stretching ca. 35 km south-west of Wrocław (Figure 1), is the highest elevation of the Sudetes Foothills. The greatest peak, Mt. Ślęża, is situated at 718 m a.s.l. at latitude 50°52' N and longitude 16°43' E, which rises above the surrounding plains by about 500 m (Kondracki 1994). The region has a unique climate, similar to that of the mountains, characterized by heavy cloudiness and ample precipitation (Błaś and Sobik 1998). The predominant habitats of the Massif are mixed deciduous and coniferous forests of the mountainous and upland type. The stands are dominated by the Norway spruce *Picea abies* with European beech *Fagus sylvatica*, Scots pine *Pinus sylvestris*, silver birch *Betula pendula,* and common oak *Quercus robur* (Radziejowski 1996). The diversified sculpture of the terrain along with interesting communities of fauna and flora compose a habitat endowed with extraordinary natural, landscape, and historical values. One such area has been placed under legal protection. The Ślęża Landscape Park,

Figure 1. Location of the tick collection sites at Ślęża Massif within the Sudetes Foothills.

established in 1988, is an important recreational ground for the inhabitants of Wrocław and its environs. Two sites located in the central section of the Ślęża Massif at an altitude of 350 to 400 m a.s.l., frequented by tourists and holiday-makers, were selected for ecological studies.

Tick collecting

Ticks were collected by the standard flagging method twice a month from May 2001 to November 2003 during the season of tick activity, which occurs between May and November. Each collection day, ticks were sampled three times for 30 min from each site. The analyses took into account only nymphs and adults; larvae were omitted due to their mass occurrence at a single site and consequent collection of several hundred specimens at a time. During the tick collections, air temperature and humidity were recorded at a height of ca 1 m from the ground using a portable electronic thermohygrometer.

Statistical analysis

Decomposition of the tick activity time series (*Y*), understood as a succession of observations of this variable in consecutive periods (months), was performed by distinguishing the components of the time series, i.e. trend (**T**), cyclical (**C**), and seasonal (**S**) fluctuations as well as random fluctuations (ε). A trend characterizes a long-term tendency of changes in a time series, which means a growth/drop of the value of variable *Y* or lack of distinct tendency for a change, indicating stagnation in the development of this variable. The remaining three component parts of a time series are the different types of deviations from the trend. Cyclical fluctuations are recurring oscillations of duration exceeding a year, which were not analyzed in the present paper ($C_t = 0$). Seasonal oscillations represent such deviations from the trend which recur in time in a regular manner and whose full cycle completes within a year. Random fluctuations (ε) include all oscillations from the trend that result from the influence on a studied variable of unrepeated events that are impossible to predict or foresee. Based on the components mentioned, an additive model of tick activity was formulated, in accordance with the way in which the effect of particular components of the time series on the shaping of the variable *Y* value in time is summarized to assume the following form:

$$Y_t = T_t + C_t + S_t + \varepsilon_t$$

In an additive model, the deviations S_t can take both positive and negative values. In order to determine the seasonality indices S_t, the trend that describes a long-term tendency of changes of the variable *Y* was assessed, and then for each observation *t* the result of the subtraction $S'_t = Y_t - T_t$ was obtained to measure the deviation of this observation from the assessed trend. Such deviations are caused both by seasonal and random factors and bear the name of the raw indices of seasonality. For each season *i,* the seasonal adjustment factor S_i was established, the value of which is obtained through removal of the effect of random fluctuations from raw indices. To estimate the corresponding seasonality factor, we used the mean value of raw seasonality factors for the observations made during a given season. The trend equation having been arrived at, for each observation *t* the relative deviation from the trend line, defined as a quotient $S^*_t = Y_t / T_t$ was calculated. Such quotients constitute raw

Table 1. Number of collected ticks *I. ricinus* in consecutive months of a three-year study (2001–2003).

Year	Month	Study periods in sequence (t)	Numer of collected ticks (Y_t)
2001	May	1	175
	June	2	260
	July	3	152
	August	4	46
	September	5	163
	October	6	107
	November	7	17
2002	May	8	301
	June	9	70
	July	10	86
	August	11	107
	September	12	57
	October	13	139
	November	14	0
2003	May	15	478
	June	16	214
	July	17	85
	August	18	49
	September	19	73
	October	20	154
	November	21	12
Total			2745

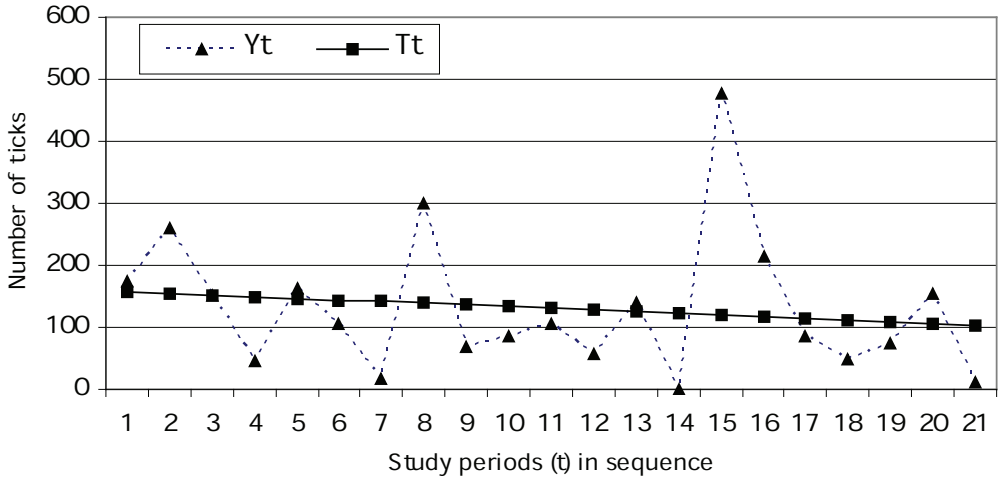

Figure 2. Empirical series of tick activity in particular study periods (Y_t) and the estimated trend line (T_t).

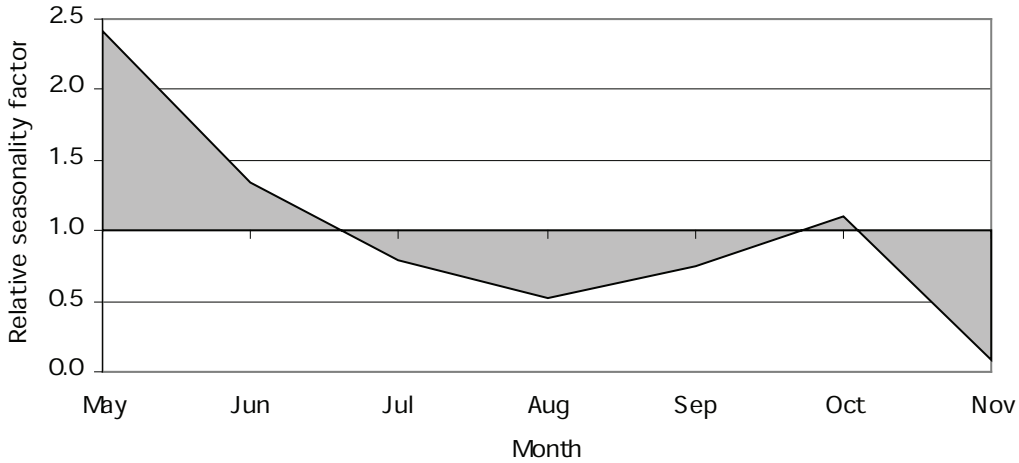

Figure 3. Relative seasonality factors for particular months.

Table 2. Relationship between the number of collected ticks *I. ricinus* and abiotic factors.

Developmental form	Temperature		Humidity	
	Spearman's correlation coefficient **R**[*]	p-value	Spearman's correlation coefficient **R**[*]	p-value
Nymphs	0.019	0.787	-0.191	0.006
Males	0.202	0.003	0.013	0.85
Females	0.292	0	-0.073	0.292

[*]The number of analyzed cases (n) equalled 210.

Table 3. Seasonality factors S_i for particular study months.

Month	Absolute factor	Relative factor
May	179.19	2.422
June	45.222	1.34
July	-25.746	0.796
August	-63.381	0.522
September	-30.349	0.742
October	8.016	1.1
November	-112.952	0.079

relative seasonality factors. The proper seasonality factor S_i was determined as the averaged value of raw seasonality factors for observations made during a given season.

To determine the correlation between air humidity and temperature measured during the collection of ticks and the number of specimens gathered, Spearman's rank correlation coefficient was applied as the distributions were not normal.

RESULTS

In the course of the three-year study of tick activity, a total of 2,745 nymphs and adults of *I. ricinus* was collected (Table 1). Active forms of ticks were collected at a temperature ranging from 4.4°C to 30.6°C and humidity of 24.5–94.7%. The largest number of specimens was collected at a humidity exceeding 60% and temperature of 15°C–20°C. A weak positive correlation was identified between temperature measured during the collection and the number of females and males collected, and a weak negative correlation was identified for nymphs relative to humidity (Table 2).

Using an analytic function, the linear trend of tick activity $T_t = 160.4–2.6987t$ was determined (Figure 2). In 2001–2003, the total number of ticks decreased monthly by an average of three specimens. However, the statistically insignificant slope of the straight line (P=0.52) does not allow a generalization for the whole population, which indicates that the activity of ticks was stable, on average 160 specimens per month (P=0.006). In May, probably as a consequence of the influence of seasonal factors, the activity of ticks was on average 142% higher than might be inferred based on the linear trend (Table 3, Figure 3). Increased activity of ticks was also observed in June and October, whereas a decline in their activity was recorded in the summer (July–September) and late autumn (November) months.

In the discussed model, the irregular component of the analyzed series is represented by residual constituents (ε_i), which have been calculated according to the formula (Table 4): $\varepsilon_i = Y_t - T_t - S_t$.

Residual components describe the effects of random fluctuations on the abundance and activity of ticks. The measure of random fluctuations is the standard deviation

Table 4. Residual values ε_i for each period along with the remaining constituents of the series (number of ticks observed [*Yt*] and following from: *Ti* - trend, *Si* - seasonal fluctuations, ε_i - irregular, random fluctuations).

Year	Month	*Yt*	*Ti*	*Si*	ε_i
2001	May	175	157.7	179.19	-161.89
	June	260	155	45.22	59.78
	July	152	152.31	-25.75	25.44
	August	46	149.6	-63.38	-40.22
	September	163	146.91	-30.35	46.44
	October	107	144.2	8.02	-45.22
	November	17	141.51	-112.95	-11.56
2002	May	301	138.81	179.19	-17
	June	70	136.11	45.22	-111.33
	July	86	133.42	-25.75	-21.67
	August	107	130.71	-63.38	39.67
	September	57	128.02	-30.35	-40.67
	October	139	125.31	8.02	5.67
	November	0	122.62	-112.95	-9.67
2003	May	478	119.92	179.19	178.89
	June	214	117.22	45.22	51.56
	July	85	114.53	-25.75	-3.78
	August	49	111.82	-63.38	0.56
	September	73	109.13	-30.35	-5.78
	October	154	106.42	8.02	39.56
	November	12	103.73	-112.95	21.22

Table 5. Proportions of particular months in the pool of total number of ticks collected in a given year.

Year \ Month	May	June	July	August	September	October	November	Total
2001	0.19	0.28	0.17	0.05	0.18	0.12	0.02	1
2002	0.40	0.09	0.11	0.14	0.08	0.18	0.00	1
2003	0.45	0.20	0.08	0.05	0.07	0.14	0.01	1

(ε_i) of a residual component. In the analyzed series s (ε_i), this deviation equals 66.9374, which means that average intensity of influence of random fluctuations in the whole series amounts to +/- 67 individuals per month. The obtained coefficient of residual variation $V = s(\varepsilon_i) / mean(Y_t)$, which in the analyzed case equals 51.2089, and indicates that on average, random deviations account for 51% of the average number of observed ticks. Fluctuations in temperature and humidity can affect the correspondence of results for particular years (2001, 2002, 2003) with regard to the structure of tick abundance in particular months (Table 5). The correspondence in this respect between particular years of investigations was assessed by applying the mean rank correlation coefficient, which amounted to 0.976 and 0.12 for temperature and humidity, respectively.

DISCUSSION

The common tick, *I. ricinus,* was the only species of the 17 representatives of the family *Ixodidae* known to occur in Poland that was collected in the Ślęża Massif. The results of the present study, as well as ones published by other authors (Siuda 1993, Bennett 1995, Estrada-Pena et al. 2004, Pietzsch et al. 2005), indicate that the common tick is widespread in Europe. The species finds more favorable conditions in areas of low human population, particularly ones under protection, the creation of which is conducive to the maintenance and restoration of ecological relationships (Kiewra and Lonc 2005). The abundance of *I. ricinus* in the Ślęża Landscape Park confirms the risk of tick-borne diseases faced by people who stay within naturally attractive areas that are under legal protection. The danger of being bitten by ticks increases in spring and autumn when the behavioral activity of these arthropods is the greatest. However, when making predictions about this activity, it is essential to take into consideration not only the seasonality factor but also the influence of random factors, since the performed study revealed that as much as 50% of the tick activity resulted from random deviations. As irregular factors, air humidity and temperature can be of great importance, which is indicated by the observed correlation. The relation between the behavioral activity of ticks and air temperature and humidity is also observed in other territories, such as the Czech Republic (Hubálek et al. 2003).

The discrepancies in the data of tick activity between particular years could stem from the influence of weather conditions in a given year. In the course of nine years of research carried out in Spain, a substantial increase in the autumn activity of *I. ricinus* in years of wet summers was recorded (Estrada-Pena et al. 2004). The high value of the mean rank correlation coefficient for temperatures in particular years, which was found in our analyses, shows that average temperatures of particular months in consecutive years were almost identical, whereas the low value of the coefficient for humidity points to the lack of a correlation in humidity for particular months of the three consecutive years of study. Thus, humidity appears to be the abiotic factor with the greatest effect on the random component in the estimated time model. This conclusion agrees with the fact that humidity is significantly correlated with the activity of nymphs, which predominated in the total number of collected ticks. Such a correlation has also been found in other studies, including Perret et al. (2000) for the territory of Switzerland. The influence of humidity and temperature on random fluctuations in tick abundance has also been observed by Vail and Smith (1998). These authors have demonstrated that the two factors jointly account for 51% of random variation, the seasonal fluctuations having been eliminated. Also our own research conducted in Poland indicates that humidity has a greater effect on tick numbers than does temperature. On the other hand, Hubalek et al. (2003) have shown that air temperature and humidity jointly account for only 32% of the active ticks in the model of linear regression. Nevertheless, such substantial influence of air humidity and temperature on the number of active ticks corresponds to higher correlation coefficients of these variables. In our investigation, these coefficients corresponded to lower values, which means that temperature and humidity measured at the moment of collection account for a smaller percentage of random variation after elimination of the trend and seasonal fluctuations. This suggests an essential role of the remaining constituents of the habitat, including the biotic ones. The risk of attack by *I. ricinus* may extend over the whole season, as active forms of these ticks were collected at a wide range of temperatures and humidities, confirming the high ecological plasticity of these hematophagous arthropods.

In Poland, people and animals are most threatened with the bites of ticks in the spring and autumn. However, it is of paramount importance that any predictions concerning the level of tick behavioral activity take into account not only the seasonality factor but also the effect of random components, which accounted for about half of the tick activity in our own study. The method of time series decomposition employed in our research appears to be useful in making such predictions. Humidity is a particularly significant

factor as it can determine the activity of *I. ricinus* to a great extent.

REFERENCES CITED

Bennett, C.E. 1995. Ticks and Lyme disease. Adv. Parasitol. 36: 343-405.

Błaś, M. and M. Sobik. 1998. [Selected characteristics of the climate of the Mt. Ślęża on the background of the climate of the Sudetes and Silesian Lowlands in the light of materials available.] Acta Universitatis Wratislaviensis 2022. Prace Instytutu Geograficznego. Seria C. Meteorologia i Klimatologia. V: 55-68.

Cisak, E., J. Chmielewska-Badora, J. Dutkiewicz, and J. Zwolinski. 2001. Preliminary studies on the relationship between *Ixodes ricinus* activity and tick-borne infection among occupationally-exposed inhabitants of eastern Poland. Ann. Agric. Environ. Med. 8: 293-295.

Cisak, E, J. Chmielewska-Badora, J. Zwolinski, A. Wojcik-Fatla, J. Polak, and J. Dutkiewicz. 2005. Risk of tick-borne bacterial diseases among workers of Roztocze National Park (south-eastern Poland). Ann. Agric. Envir. Med. 12: 127-132.

Dąbrowski, J., A. Schönberg, Z. Wegner, J. Stańczak, and W. Kruminis-Łozowska. 1993/1994. The first isolation of *Borrelia burgdorferi* from *Ixodes ricinus* (*Acari, Ixodidae*) ticks in Poland. Bull. Inst. Marit. Trop. Med. Gdynia. 44/45: 61-64.

Estrada-Pena, A., J.M. Martinez, C. Sanchez Acedo, J. Quilez, and E. Del Cacho. 2004. Phenology of the tick, *Ixodes ricinus*, in its southern distribution range (central Spain). Med. Vet. Entomol. 18: 387-397.

Hubálek, Z. and J. Halouzka. 1998. Prevalence rates of *Borrelia burgdorferi* sensu lato on host-seeking *Ixodes ricinus* ticks in Europe. Parasitol. Res. 84: 167-172.

Hubálek, Z., J. Halouzka, and Z. Juřicová. 2003. Host-seeking activity of ixodid ticks in relation to weather variables. J. Vector Ecol. 28: 159-165.

Humiczewska, M. 2001. [Seasonal activity of the ticks *Ixodes ricinus* in the lakesides and forests habitats of Szczecin and environs and its infestation with the spirochete *Borrelia burgdorferi*.] Wiad. Parazytol. 47: 389-393.

Humiczewska, M., W. Kuźna-Grygiel, L. Kołodziejczyk, S. Białek, A. Kozłowska, W. Rozen, and Z. Sych. 2003. [Prevalence of *Borrelia burgdorferi* sensu lato in *Ixodes ricinus* population in forests of north-western Poland.] Wiad. Parazytol. 49: 255-271.

Januszkiewicz, J. and A. Kieda. 1987. [Cases of borreliosis (Lyme disease) in Western Pomerania.] Przegl. Epidemiol. 41: 324-329.

Kahl, O. 1991. Lyme borreliosis – an ecological perspective of a tick-borne human disease. Anz. Schädlingskde., Pflanzenschutz, Umweltschutz 64: 45-55.

Kiewra, D. and E. Lonc. 2005. [Parasitological risk for ecotourism In Lower Silesia.] Medycyna Podróży. 41.

Kiewra, D., E. Lonc, M. Głuszkowski, and A. Malinowska. 2002. [Geo-climatic conditions of ticks – *Ixodes ricinus* (L.) - prevalence.] W: Buczek A. Błaszak C. (red.). Stawonogi w medycynie. Wyd. Drukarnia LIBER. Lublin. 115-126.

Kondracki, J. 1994. [Geography of Poland. Physical-geographic mesoregions.] PWN. Warszawa.

Lonc, E., A. Buczek, D. Kiewra, and K. Ciosek. 2001. [Occurrence of ticks *Ixodes ricinus* (L.) on Sleza (Lower Silesia).] W: Buczek A. Błaszak C. (red.). Stawonogi. Pasożyty i nosiciele. Wyd. KGM. Lublin. 87-91.

Michalik, J., T. Hofman, A. Buczek, M. Skoracki, and B. Sikora. 2003. *Borrelia burgdorferi* s.l. in *Ixodes ricinus* (Acari: Ixodidae) ticks collected from vegetation and small rodents in recreational areas of the city of Poznań. J. Med. Entomol. 40: 690-697.

Niscigorska, J, B. Skotarczak, and B. Wodecka. 2003. *Borrelia burgdorferi* infection among forestry workers - assessed with an immunoenzymatic method (ELISA), PCR and correlated with the clinical state of the patients. Ann. Agric. Environ. Med. 10: 15-19.

Nowosad, A., J. Jenek, A. Głazaczow, and M. Wal. 1999. [Ticks *Ixodes ricinus* (Linnaeus, 1758) from selected municipal forests of the city Poznan and their infection with the spirochetes *Borrelia burgdorferi* senso lato.] Przegl. Epidemiol. 53: 299-308.

Perret, J.L., E. Guigoz, O. Rais, and L. Gern. 2000. Influence of saturation deficit and temperature on *Ixodes ricinus* tick questing activity in a Lyme borreliosis-endemic area (Switzerland). Parasitol. Res. 86: 554-557.

Pietzsch, M.E., J.M. Medlock , L. Jones, D. Avenell, J. Abbott, P. Harding, and S. Leach. 2005. Distribution of *Ixodes ricinus* in the British Isles: investigation of historical records. Med. Vet. Entomol. 19: 306-314.

Prokopowicz, D. 1995. [Diseases transmited by ticks.] Wyd. Fundacji Bûchnera. Warszawa.

Radziejowski, J. 1996. [Protected areas in Poland.] Instytut Ochrony Środowiska. Warszawa.

Siuda, K. 1993. [Ticks of Poland (*Acari: Ixodida*). Part II. Systematics and distribution.] Monografie Parazytologiczne PTP. Warszawa.

Siuda, K. 1996. Bionomical and ecological characteristic of ticks (Acari:Ixodida) of significant medical importance on the territory of Poland. Rocz. Akad. Med. Bialymst. 41: 11-19.

Siuda, K., A. Buczek,K. Solarz, A. Deryło, T. Sadowski, S. Kwiatkowski, B. Horak, and A. Procyk. 1991. Preliminary studies of the occurrence of *Ixodes ricinus* (Acari: Ixodida: Ixodidae) in the areas of the Cracow-Czestochowa highland at various stages of human industrial activities Wiad. Parazytol. 37: 17-20.

Stanczak, J., R.M. Gabre, W. Kruminis-Lozowska, M. Racewicz, and B. Kubica-Biernat. 2004. *Ixodes ricinus* as a vector of *Borrelia burgdorferi* sensu lato, *Anaplasma phagocytophilum* and *Babesia microti* in urban and suburban forests. Ann. Agric. Environ. Med. 11: 109-114.

Vail, S.G. and G. Smith. 1998. Air temperature and relative humidity effects on behavioral activity of blacklegged tick (Acari: Ixodidae) nymphs in New Jersey. J. Med. Entomol. 35: 1025-1028.