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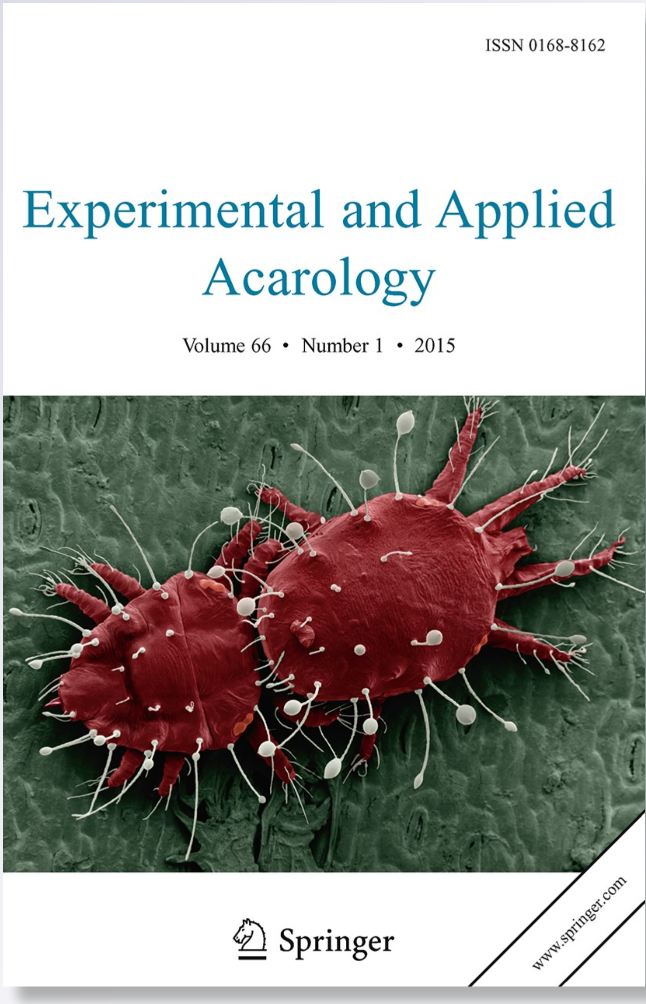

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Abstract Monitoring of two tick species (*Ixodes persulcatus* Schulze 1930 and *Ixodes pavlovskyi* Pomerantsev) was performed in four city parks of Tomsk, Russia (Camp Garden, University Park, Southern Cemetery, and Polytechnic Stadium) and in a control wild biotope in city environs (Kolarovo) in 2002–2013. Ticks were collected by flagging repeatedly after each 10 ± 1 days, starting from the disappearance of the snow cover till the end of tick activity (April–August). Gradual penetration of both tick species into city parks was demonstrated. In the wild biotope, *I. persulcatus* dominated during the whole period of monitoring, forming about 95 % of tick population, whereas in urban biotopes *I. pavlovskyi* became the dominant species. Two peaks of population density during each season of spring-summer activity were observed in both species. Possible explanations of the phenomena are discussed.

Keywords *Ixodes persulcatus* · *Ixodes pavlovskyi* · Urban habitats · Monitoring · Population dynamics

Introduction

Ixodid ticks of the genus *Ixodes* are widespread in the forest zone of the Holarctic, being very important vectors of dangerous transmissive infections of humans and animals, such as tick-borne encephalitis, Lyme disease, babesioses, ehrlichioses, etc. (Jongejan and Uilenberg 2004). Among all the ticks of the genus *Ixodes*, the Taiga tick *Ixodes persulcatus* Schulze is the most abundant species in the taiga zone of Siberia and the Russian Far East

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(Filippova 1985; Leonovich 1989). Ticks appeared in suburbs of the city of Tomsk, adjacent forests, and some marginal city parks in late 1980ies. The number of people visiting health facilities for treatment against tick bites abruptly increased; noteworthy, the majority of these people had never visited wild forests (Zhoukova et al. 2006). In the same period, tick attacks (including attacks by *I. persulcatus*) were also observed in some other Russian cities, as in European Russia, so in Siberia, such as St. Petersburg, Voronezh, Omsk, Novosibirsk and others (Fedorov et al. 1999; Antykova and Kurchanov 2002; Gaponov et al. 2008).

According to our previous data (Romanenko 1999), hard ticks of the genus *Ixodes* were repeatedly found in many large parks of the city of Tomsk. The presence of immature *I. persulcatus* ticks on captured rodents (Romanenko 1999) had proved that these ticks had developed in the city and were not introduced. The genus *Ixodes* in urban biotopes was represented by 2 species: the Taiga tick *Ixodes persulcatus* and *Ixodes pavlovskyi* Pomerantsev (the subspecies *I. p.occidentalis* Filipova et Panova) (Romanenko 2006). *Ixodes pavlovskyi* is typical mainly of more southern regions (Altai, Mountain Shoriya); it had appeared in Tomsk Province and in Tomsk only at the end of 20th century (Romanenko and Chekalkina 2004). Together with these species, representatives of other two genera of hard ticks were also found, namely, *Dermacentor reticulatus* Fabricius and *Haemaphysalis concinna* Koch (Romanenko 2006).

It should be noted that the virus of the tick-borne encephalitis (TBE) was isolated from ticks that had attached to humans during visiting city parks of Tomsk and forest-parks situated in city outskirts. The fraction of ticks infested with TBE in the city, constituted 55 and 25 % of specimens of *I. persulcatus* and *I. pavlovskyi*, respectively; in city outskirts, 43.5 and 50 % of *I. persulcatus* and *I. pavlovskyi*, respectively (Romanenko and Kondratyeva 2011). Together with adult ticks, TBE virus was detected by PCR methods in preimaginal studies and in birds (Mikryukova et al. 2014). Mean rate of infestation of ticks of the genus *Ixodes*, collected by flagging in environs of Tomsk in 2002–2011 (species were not determined) with TBE virus and *Borrelia*, vector of Lyme disease, constituted 3.3 % (varying from 0.5 to 7.7 %) and 29.7 % (varying from 21.3 to 50 %), respectively (Pankina et al. 2013). *Borrelia garini* and *B. afzelii* (two main bacteria species causing Lyme disease in Asia) were also revealed by PCR method in both tick species from Tomsk area (infection rates constituting 35.7 ± 12.8 % and 30.0 ± 13.0 % in *I. pavlovskyi* and *I. persulcatus*, respectively) (Korenberg et al. 2010). Taiga ticks collected in Novosibirsk and Tomsk areas, were infested (together with borrelias) with *Anaplasma phagocytophilum* (2.4 ± 1.4 %), *Ehrlichia muris* (8.8 ± 2.5 %), and *Bartonella* spp. (37.6 ± 4.3 %), agents of anaplasmosis, erlichiosis, and bartonellosis (Rar et al. 2005).

It was noted, that the number of ticks collected in certain biotopes varied during the season of tick activity, and these fluctuations also varied in different years. As far as ticks of the genus *Ixodes* play an important role in transmission of dangerous diseases and their populations change in time, we decided to study their population dynamics in detail. The goal of the present paper included the study of population dynamics of ixodid ticks of two most important species (*I. persulcatus* and *I. pavlovskyi*) revealed by long-term detailed monitoring. Collecting of ticks was performed during the entire activity period (April–August) once per each 10 days in the same sites in each of 5 monitoring localities in Tomsk, a city in Western Siberia (population 580,000) and its outskirts during 12 years (2002–2013). We tried to trace tendencies in changes of urban tick populations and to reveal factors determining these long-term changes and fluctuations in population density.

Materials and methods

Monitoring was performed in 2002–2013 in four biotopes situated in Tomsk: Lagerny Sad (Camp Garden) park, Universitetskaya Roshcha (University Park), Polytechnic Stadium (Stadium of Tomsk Polytechnic University), and Southern Cemetery, and also in a forest near Kolarovo Village. The latter biotope served as the control for the comparison of tick populations in urban and natural environments.

In each monitored site, ticks were collected along the same recording route repeatedly after each 10 ± 1 days, starting from the disappearance of the snow cover in the main part of the examined biotope till the end of tick activity. The length of routes, in dependence of the size of each monitoring site, varied from 0.9 to 1.5 km. Collecting was performed according to a common technique by a standard 60 × 120 cm flag made of waffle cloth. Flagging allows collecting mainly adult *I. persulcatus* ticks; nymphs and larvae of this species are poorly revealed by this method and must be collected from small trapped mammals (Filippova 1985). The overwhelming majority of ticks collected in the present study was represented by adults; nymphs were collected only occasionally in very small numbers. Therefore, they were excluded from our analysis and our monitoring data concerns only adult ticks of all the species.

Our previous studies demonstrated that withdrawal of adult ticks collected during recordings from certain biotopes did not affect their population density, because previously collected, marked, and released ticks were never collected for the second time (Romanenko 1988). Therefore, all the ticks collected during monitoring were brought to laboratory for correct determination of species. In more detail, sites where long-term monitoring was performed can be described as follows.

Camp Garden and University Park are the oldest, largest, and most visited city parks. The Camp Garden is situated on the high right bank of the Tom River; its area is about 40 ha. Central entrance to the park is a "continuation" of the main street of Tomsk (Lenin's Prospect). Vegetation is formed of artificially planted birches, poplars, pines, Siberian pines and also of small sections of natural mixed forest. The forest is rather light, therefore, grass cover of various density is present nearly everywhere. Leaf and twig litter is removed only in the central part of the park, whereas it is retained in marginal areas. At the same time, the litter never forms a thick layer, being mechanically ruined by humans. Coordinates of the center of the monitoring route in the Camp Garden: 56°27′11″ N, 84°56′47″ E (in GPS decimal minutes: N 56° 27.191′, E 84°56.787′). In this biotope, monitoring was performed in 2003–2013.

University Park is a park where a complex of Tomsk State University buildings is situated. By the character of vegetation, the University Park, in spite of its artificial origin, is most closely related to natural mixed forests of southern Tomsk Province, being formed of birches, pines, larches, spruces, and poplars; the well-developed understory is formed of different shrub species; grass layer is sparse, formed mainly of motley grasses. Coordinates of the center of the monitoring route in the University Park: 56°28′5″ N, 84°56′53″ E (N 56°28.084′, E 84°56.886′).

The Polytechnic Stadium is the stadium of the Tomsk Polytechnic University. It is situated in southern outskirts of the city of Tomsk. The stadium is surrounded by a 40–60-year-old forest belt of artificially planted pines and shrubs, with admixture of aspens and birches. Monitoring route ran through this forest. Visitors walk mainly along special central paths or pedestrian precincts between forest belts. Leaf and twig litter is well retained in the forest belt; in some places, the litter is thick. Remnants of the natural birch forest with weakly developed shrub understory are found at margins of the territory. The territory around the stadium is used for promenade and dog walking and is actively visited by humans. Grass cover is rather depressed and in forest plantings, sparse. Coordinates of the center of the monitoring route in the TPU Stadium: 56°26′37″ N, 84°58′42″ E (N 56°26.629′, E 84°58.709′).

Southern Cemetery is the smallest forest-park with an area of 19 ha, situated in southern outskirts of Tomsk. It is not used for funerals since the beginning of 1960-ies. The territory is rather densely covered with more than 100-years-old forest formed of birches, aspens, poplars, and pines, with developed understory. Grass cover is represented either by motley grasses or tall large-leaved grasses (depending on the degree of illumination of certain plots). Leaf litter is removed only in a small territory of military burial ground. In the rest of the territory, leaf litter accumulated year-by-year and has formed a very thick layer. The cemetery is visited very rarely, except for separate remembrance days. Coordinates of the center of the monitoring route in the Southern Cemetery: 56°26′47″ N, 84°58′55″ E (N 56°26.787′, E 84°58.918′).

Forest near Kolarovo Village is situated at a distance of 10 km from Tomsk and is free of anthropogenic press. The biotope is represented by light mature pine tracts with well-developed high-grass layer. Besides, a part of recording route passed through a young pine forest and through a deciduous forest with clearings; grass layer is represented by tall grasses and nettles. Coordinates of the center of the monitoring route in the forest near Kolarovo Village: 56°20′57″ N, 84°57′11″ E (N 56°20.958′, E 84°57.187′). In this biotope, monitoring was performed in 2006–2013.

Collected ticks were determined using keys assumed by Filippova (1977, 1997). The number of collected ticks in each biotope and at each date was transformed into a common index, namely, the number of ticks collected per 1 km of the recording route (specimens per km, sp./km). This index allowed comparing population density of ticks in each biotope during entire long-term monitoring. Additionally, fraction (percentage) of each collected species was determined for each biotope. 3D graphs were made with Microsoft office excel 2007 software.

Results

In all the examined biotopes, tick activity was observed since April till July–August, but in the majority of years and biotopes, since April–May till June–July. First ticks appeared mainly on the next day after disappearing of snow cover. We considered disappearance of snow in each territory when approximately 90 % of it was free of snow cover. According to our own observations, snow disappeared in the following dates: May 1 (city biotopes), May 3 (Kolarovo) (2002); May 1–2 (2003); May 7 (city biotopes), May 9 (Kolarovo) (2004); April 22–23 (2005); May 4 (2006); April 24 (2007); April 25–26 (2008); April 17–18 (2009); April 29 (2010); April 15 (2011); April 10 (2012); April 27–28 (2013). As seen from these data, the date of snow melting distinctly shifted from early May to late April.

According to literary data, adult *I. persulcatus* ticks activated in spring are represented by specimens that had molted from nymphs in the previous year and spent 8–9 months in the state of the diapause (Filippova 1985). Previous studies of this species had demonstrated that adult ticks that had emerged from nymphs in spring-early summer do not attack hosts in the present year, never demonstrate questing activity, staying in the state of the behavioral diapause, and, therefore, cannot be collected by flagging (Babenko 1985; Leonovich 1985).

In the control wild biotope (Kolarovo forest) monitoring was performed in 2006–2013. In all these years, population density of *I. persulcatus* was high, varying from 118 tick specimens per km (in May 1–10, 2010) to 15 sp./km (May 11–20, 2012, 2013) (Fig. 1). During 7 out of 8 years of monitoring, two peaks of tick activity were observed: the first peak was higher, the second one, lower, but also rather distinct (Fig. 1). Simultaneously, we also observed periodical fluctuations in the maximum values of the population density of this species from year to year (in May 2007 and May 2010 it was significantly higher than in preceding and following years). Population density of *I. pavlovskyi* in this biotope was significantly lower, never exceeding 4 sp./km (Fig. 2). We had also observed two peaks of the population density of this species in the majority of years of monitoring (in 2007, 2009, 2010, 2012), similarly to those observed in *I. persulcatus* (Fig. 1), and also similar fluctuations of the long-term population density (Fig. 2).

In the Southern Cemetery, the monitoring site in outskirts of the city of Tomsk, population density of *I. persulcatus* was significantly lower than in the wild biotope, varying from 8 (2002) to 0.5 sp./km (Fig. 3). Two peaks of population density per each year were also observed (in 2003–2006, 2009, 2011, 2012), similarly to fluctuations of the peak of maximum population density from maximum in 2002 to minimum in 2008, and again to maximum in 2011 (Fig. 3). At the same time, population density of *I. pavlovskyi* in this biotope was about ten times higher, varying from 67 sp./km in May 21–31, 2012 to 12 in May 11–20, 2002 (Fig. 4). Two peaks of population density per each year were less distinct; they were observed in 2003, 2008, and 2011 (Fig. 4). Maximum population

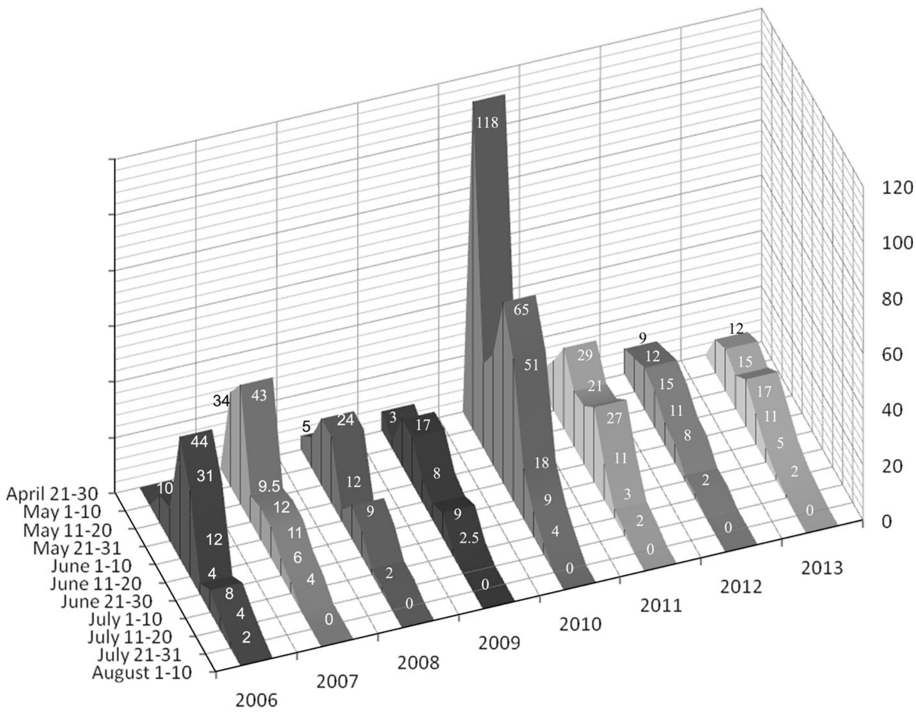

Fig. 1 Population density of *Ixodes persulcatus* in Kolarovo forest during entire periods of tick activity in 2006–2013. Abscissa (x): number of ticks collected per 1 km of monitoring rout (specimens/km); ordinate (y) 10-day-long periods (dates) when monitoring was performed; applicate (z) years of monitoring

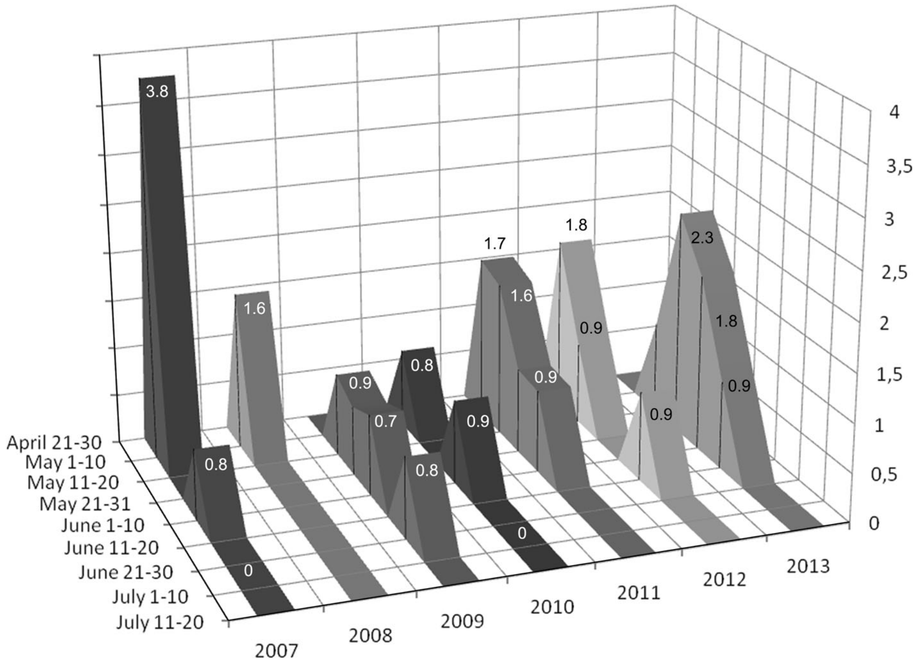

Fig. 2 Population density of *Ixodes pavlovskyi* in Kolarovo forest during entire periods of tick activity in 2006–2013. Abscissa (x): number of ticks collected per 1 km of monitoring route specimens/km); ordinate (y) 10-day-long periods (dates) when monitoring was performed; applicate (z) years of monitoring

density also fluctuated during 12 years of monitoring (pronounced peaks were observed in 2003, 2005, 2009, 2012) (Fig. 4).

In the Polytechnic Stadium, population density of *I. persulcatus* was even lower than that in the Southern Cemetery (Fig. 5), varying from 4 sp./km in May 21–31, 2003 to zero in 2006–2007. Two peaks of population density were observed in 2004 and in 2008–2011 (Fig. 4), and peaks of maximum population density were also fluctuating (they were the highest in 2003, 2009, and 2011, alternating with years where maximum population density was significantly lower (Fig. 5). Population density of *I. pavlovskyi* in this biotope was lower than in the Southern Cemetery (Fig. 4), but significantly higher than that of *I. persulcatus*, varying from 30 sp./km in May 11–20, 2003 to 6.5 sp./km in May 21–31, 2004 (Fig. 6).

In the Camp Garden, monitoring was performed in 2003–2013. Population density of both tick species was lower than in the abovementioned city biotopes (Figs. 7, 8). Population density of *I. persulcatus* varied from zero (in 2007) to 4 (in May 1–10, 2011). Such low population density makes revealing of annual peaks statistically unreliable, but, still, such tendency was observed (Fig. 7). As in other city biotopes, population density of *I. pavlovskyi* was higher than that of *I. persulcatus* (Fig. 8), increasing from 1.5 sp./km (in May 21–31, 2004) to 13 sp./km (in May 1–10, 2011). Two peaks of population density were observed in 2003, 2005, and 2012 (Fig. 8). Four peaks of maximum population density are also distinct (in 2005, 2008, 2011, and 2013 (Fig. 8).

In the University Park, the last among monitored biotopes, population density of both tick species was the lowest among all the sites examined (Figs. 9, 10). In this biotope,

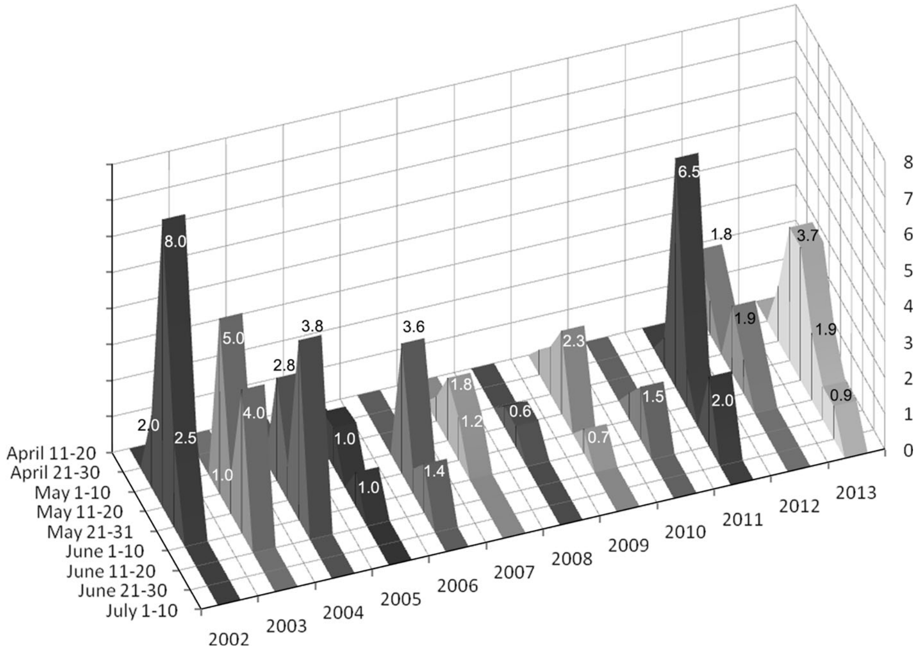

Fig. 3 Population density of *Ixodes persulcatus* in the Southern Cemetery city biotope during entire periods of tick activity (April–August) in 2002–2013. Abscissa (x): number of ticks collected per 1 km of monitoring rout (specimens/km); ordinate (y) 10-day-long periods (dates) when monitoring was performed; applicate (z) years of monitoring

specimens of *I. persulcatus* were not collected in 2002–2005, and first solitary specimens (0.6 sp./km) were revealed in this site only in 2006 (Fig. 9). Since that year, their population density was rather stable and low, never exceeding 2 sp./km (in May 11–20, 2011). Nevertheless, slow but constant increase of the population density of this species, being statistically unreliable, is observed in the graph (Fig. 9). *Ixodes pavlovskyi* was also not revealed in 2002–2005 (Fig. 10). In June 1–10, 2006, first representatives of this species were collected (population density constituting 0.7 sp./km). After a small increase in population density observed in 2007–2008 (population density constituting 1.5 sp./km), and disappearance of this species in 2009, population density of this species gradually increased since 2010 (maximum population density was observed in June 1–20, 2011, constituting 8.2 sp./km), and stayed rather stable in subsequent years, with maximum population density observed in May 11–20 and constituting 3–4 sp./km (Fig. 10).

Summarizing the number of all the specimens of all species collected in each biotope during the entire monitoring period allowed us revealing a fraction (percentage) of each species collected in each biotope (Table 1). As seen from this table, the ratio between *I. persulcatus* and *I. pavlovskyi* in a wild biotope (Kolarovo forest) stayed stable, with the fraction of the Taiga tick constituting about 96 %. In the Southern Cemetery, a biotope situated in outskirts of the Tomsk city, the situation was quite different: the fraction of *I. persulcatus* gradually decreased since 2002, when it formed nearly a half of the entire tick population, and *I. pavlovskyi* became the main component of the tick community, with the fraction constituting about 90 % of the entire population (Table 1). At the same time, two

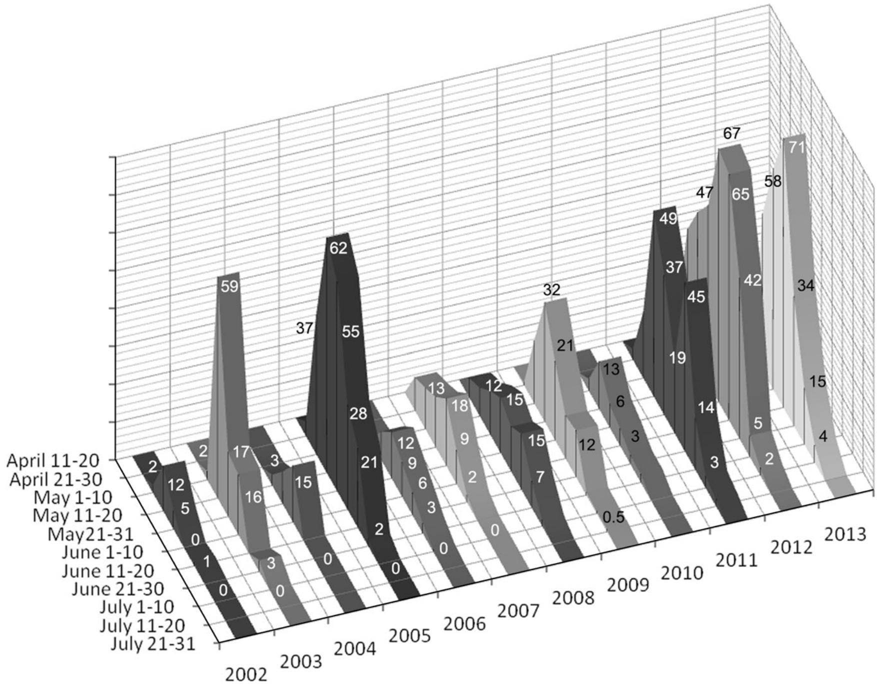

Fig. 4 Population density of *Ixodes pavlovskyi* in the Southern Cemetery city biotope during entire periods of tick activity (April–August) in 2002–2013. Abscissa (x): number of ticks collected per 1 km of monitoring rout (specimens/km); ordinate (y) 10-day-long periods (dates) when monitoring was performed; applicate (z) years of monitoring

tick species of other genera (*D. reticulatus* and *H. concinna*) were also collected in this biotope. A single specimen of *H. concinna* was collected in the Southern Cemetery in 2008. The majority of adult *D. reticulatus* ticks were collected in the Southern Cemetery (1, 3, 5, 3, 1, 1, and 4 specimens in 2004, 2005, 2006, 2007, 2010, 2012, and 2013, respectively). In the Polytechnic Stadium, this species appeared only in 2011, and, later, it was revealed in 2012 and 2013 (a single specimen per each year). In the Camp Garden, a single specimen of this species was flagged in 2012.

In the Camp Garden and University Park, ticks (only *I. persulcatus* and *I. pavlovskyi*) had appeared only in 2003 and 2006, respectively (Table 1). Although the population density of these species is low (Figs. 7, 8, 9, 10), the number of collected representatives of *I. pavlovskyi* exceeded the number of *I. persulcatus* (Table 1).

Discussion

One of phenomena revealed in our long-term monitoring studies is the following: during last 12 years, species of the genera *Ixodes* and (to a lesser extent) *Dermacentor* had penetrated city habitats. In the University Park, the biotope that is most remote from city borders, no ticks were collected in 2002–2005; first specimens of *I. persulcatus* and *I. pavlovskyi* appeared there only in 2006 (Figs. 9, 10). In the Camp Garden, the park situated

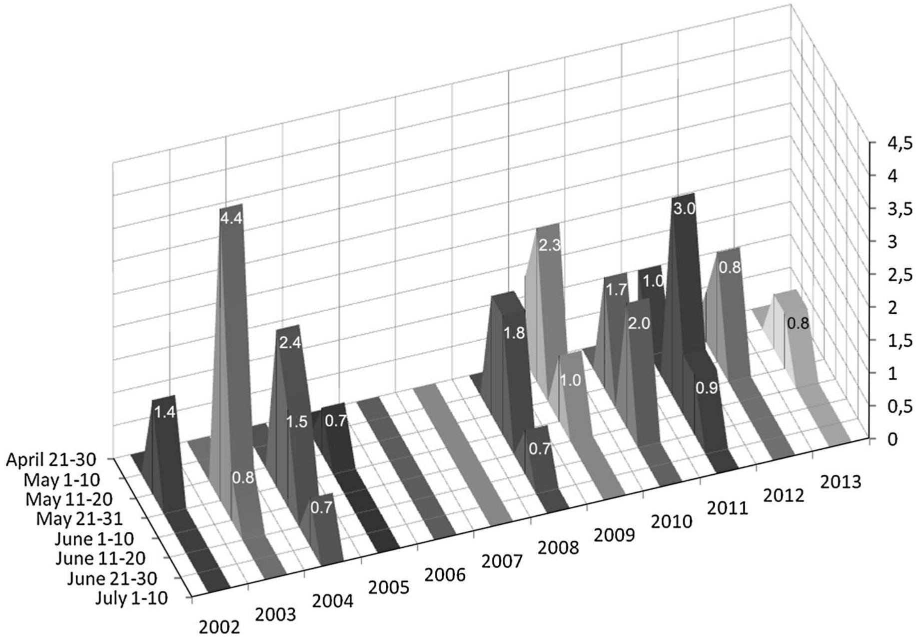

Fig. 5 Population density of *Ixodes persulcatus* in the Polytechnic stadium city biotope during entire periods of tick activity (April–August) in 2002–2013. Abscissa (x): number of ticks collected per 1 km of monitoring rout (specimens/km); ordinate (y) 10-day-long periods (dates) when monitoring was performed; applicate (z) years of monitoring

closer to city borders, first ticks were recorded in 2003. It these biotopes, both species had formed stable populations.

Significant changes in the distribution of *I. persulcatus* and *I. pavlovskyi* were also noted after 1990 in some other regions of Western Siberia; e.g., local stable populations of *I. persulcatus* were formed to the south of its main range in Omsk and Novosibirsk Provinces (Mal'kova et al. 2012). West-northward shift of the range border of *I. persulcatus* during last decades was also observed in Karelia (Bugmyrin et al. 2013). Changes in ranges of other medically important species of the genus *Ixodes* (*I. ricinus*) were also noted in Europe (see e.g., Medlock et al. 2013; Porretta et al. 2013, etc.).

Both examined species (*I. persulcatus* and *I. pavlovskyi*) can be transported to a new habitat by birds, as far as immature stages of both species feed on small mammals and birds, but stable population can be formed when there are suitable conditions for the development of all stages of a species. For example, adult *I. persulcatus* were repeatedly found in the suburbs of Yakutsk, the capital of the Sakha Republic (former Yakutia), far to the north of its geographical range (Uspensky et al. 2003). Engorged nymphs of this tick have been brought there by birds migrating along river valleys. Single nymphs could molt into adults but there was no chance for establishing an independent population (Uspensky et al. 2003). On the other hand, *I. pavlovskyi* were revealed for the first time in Hokkaido in 1992, where they formed a stable population (together with adults, collected by flagging, immature stages were collected from small mammals) (Nakao et al. 1992). Hence, environmental conditions in Tomsk parks became suitable for the development of both ticks species examined.

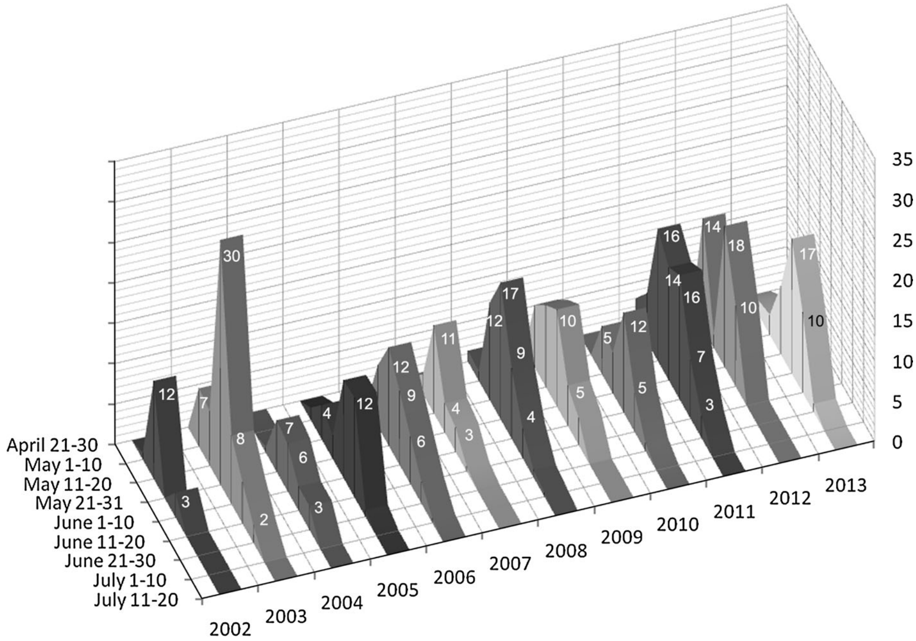

Fig. 6 Population density of *Ixodes pavlovskyi* in the Polytechnic Stadium city biotope during entire periods of tick activity (April–August) in 2002–2013. Abscissa (x): number of ticks collected per 1 km of monitoring rout (specimens/km); ordinate (y) 10-day-long periods (dates) when monitoring was performed; applicate (z) years of monitoring

According to some data, conditions providing enlargement of the range of the European forest tick *I. ricinus* are associated first of all with the warming of the climate (Gray 2008; Gray et al. 2009; Estrada-Peña et al. 2012; Jaenson et al. 2012; Porretta et al. 2013). Together with this factor, factors determining changes in the distribution of *I. ricinus* in Europe include those related to changes in the distribution of tick hosts; other ecological changes such as habitat connectivity and changes in land management; and finally, anthropogenically induced changes (Medlock 2013). Probably, all these conditions also explain penetration of *I. pavlovskyi* and *I. persulcatus* into Tomsk parks.

After penetration into city biotopes, *I. pavlovskyi* distinctly dominates over *I. persulcatus*, replacing the latter in the majority of parks. At the same time, in wild biotopes (Kolarovo) the ratio between both species did not change in time during the entire monitoring period, constituting about 96 % of *I. persulcatus* and about 4 % of *I. pavlovskyi* (Table 1). Sympatric dwelling of *I. persulcatus* and *I. pavlovskyi* in the same biotope (and even simultaneous feeding on the same host) is supported by nearly similar environmental demands and, at the same time, by the existence of the morphological barrier (reliable prevalence of the male hypostome diameter over the length of female genital opening), making copulation between these species impossible (Filippova 2002). But why *I. pavlovskyi* becomes dominating species in city biotopes? We think the reasons are the following. As was demonstrated during studies of territories of sympatric distribution of both species in the southwestern Altai (Filippova 2001), immature stages (larvae and nymphs) of both species (*I. pavlovskyi* and *I. persulcatus*) fed in the same biotopes and on the same

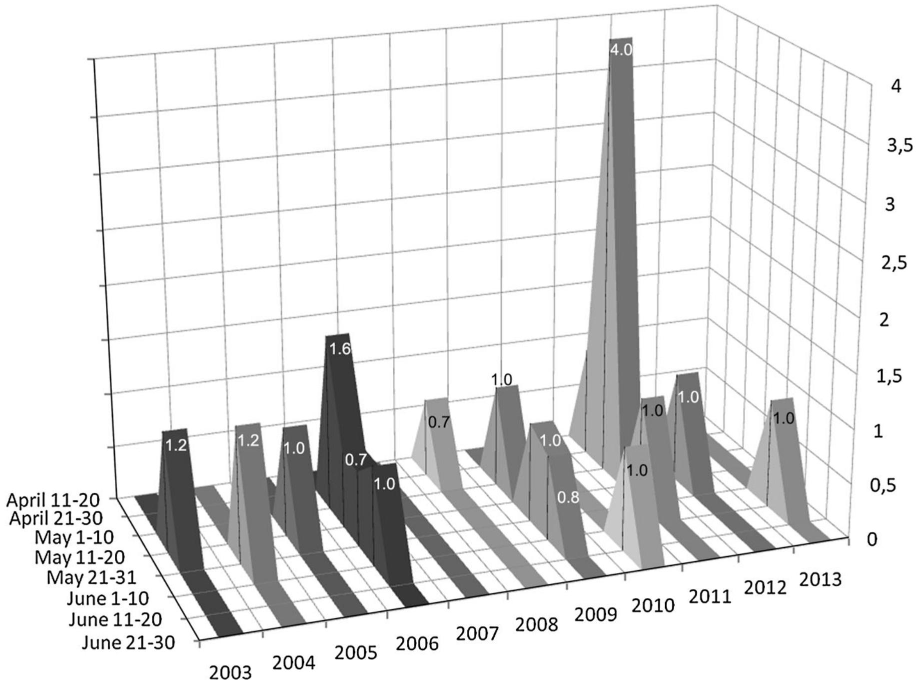

Fig. 7 Population density of *Ixodes persulcatus* in the Camp Garden city biotope during entire periods of tick activity (April–August) in 2002–2013. Abscissa (x): number of ticks collected per 1 km of monitoring rout (specimens/km); ordinate (y) 10-day-long periods (dates) when monitoring was performed; applicate (z) years of monitoring

hosts: small mammals and birds collecting food on the ground. In adult ticks of both species, the situation was quite different: whereas *I. persulcatus* adults fed on wild mammals of large and medium size and on cattle and dogs, *I. pavlovskyi* adults fed on birds collecting food from the ground (Filippova 2001). So, in our opinion, adult *I. persulcatus* have very poor ability to find hosts (medium size mammals, dogs, or cattle) for feeding of the adult stage in city parks, by contrast to wild biotopes (Kolarovo). At the same time, adult *I. pavlovskyi* can easily feed on birds, collecting food from the ground in city parks. Studies of city birds of Tomsk, performed in 1990-ies and in 2002–2003 demonstrated that during this period population density of birds in the city on the whole had decreased, but at the same time it increased in the Camp Garden park by 1.23 times, and in other parks by 1.1 times (Milovidov and Nekhoroshev 2007). Simultaneously, population density of birds collecting food from the ground had also increased (e.g., of the Eurasian magpie, of the carrion crow, and of the hooded crow by 1.5, 10, and 9 times, respectively) (Milovidov and Nekhoroshev 2007). Probably, activity peaks of *I. pavlovskyi* observed in 2011 in the University Park and Camp Garden can be explained by preceding masting years, although no direct data confirming this assumption are available.

As far as no adult *D. reticulatus* were collected in the control wild biotope (Table 1) and, at the same time, larvae of this species were not collected from trapped small mammals (Romanenko 1999), we can assume that this species had not formed stable populations in Tomsk urban biotopes and engorged larvae were brought there by birds,

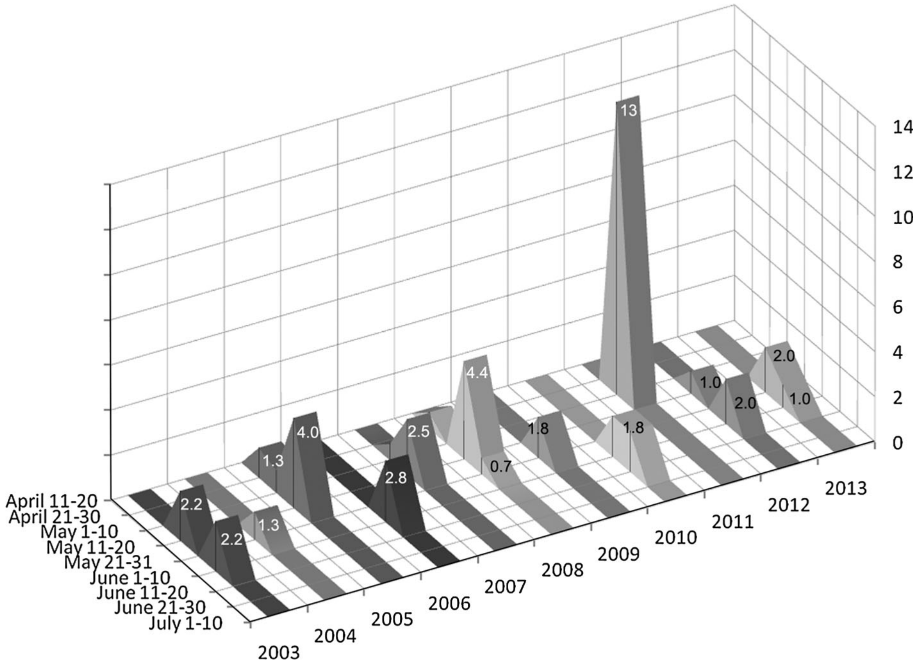

Fig. 8 Population density of *Ixodes pavlovskyi* in the Camp Garden city biotope during entire periods of tick activity (April–August) in 2002–2013. Abscissa (x): number of ticks collected per 1 km of monitoring rout (specimens/km); ordinate (y) 10-day-long periods (dates) when monitoring was performed; applicate (z) years of monitoring

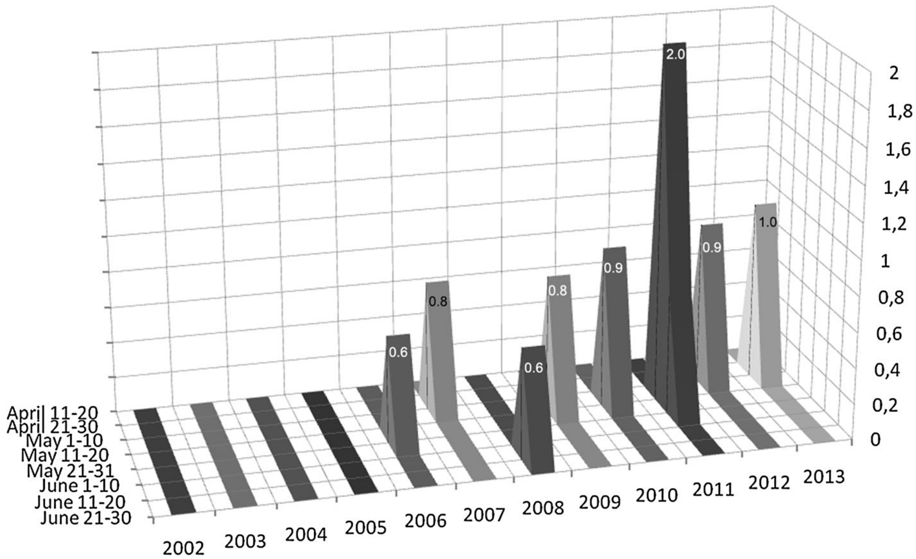

Fig. 9 Population density of *Ixodes persulcatus* in the University Park city biotope during entire periods of tick activity (April–August) in 2002–2013. Abscissa (x): number of ticks collected per 1 km of monitoring rout (specimens/km); ordinate (y) 10-day-long periods (dates) when monitoring was performed; applicate (z) years of monitoring

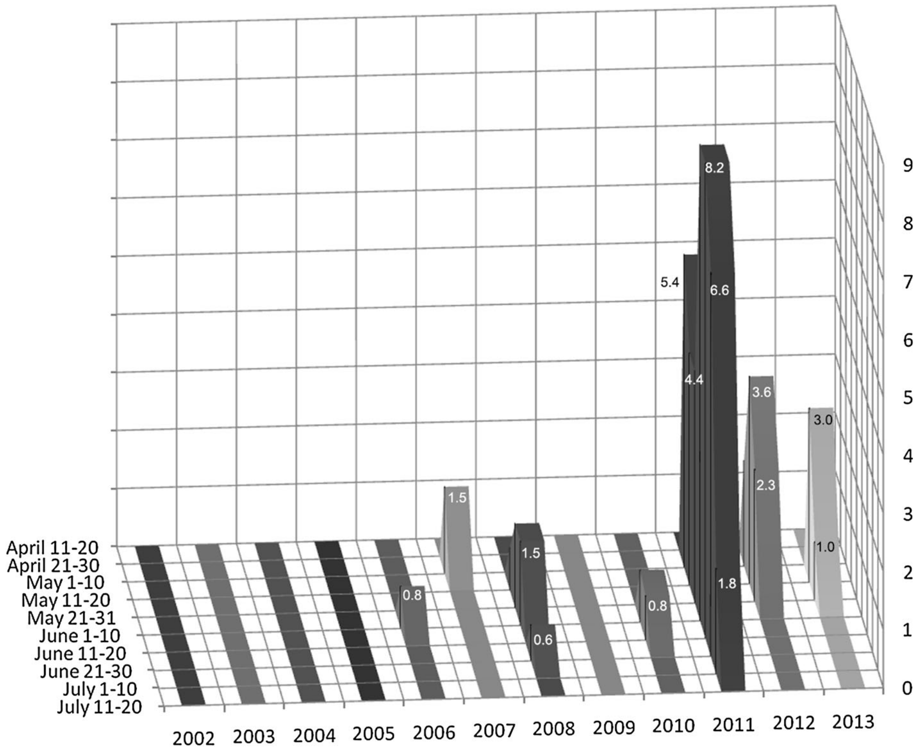

Fig. 10 Population density of *Ixodes pavlovskyi* in the University Park city biotope during entire periods of tick activity (April–August) in 2002–2013. Abscissa (x): number of ticks collected per 1 km of monitoring rout (specimens/km); ordinate (y) 10-day-long periods (dates) when monitoring was performed; applicate (z) years of monitoring

similarly as it had happened to *I. persulcatus* in Yakutsk (Sakha Republic) (Uspensky et al. 2003). This assumption, however, needs further studies including collecting of immature stages from trapped small mammals. At present, the question of appearance of *D. reticulatus* and its movement into the city biotopes in Tomsk remains open, needing further investigations.

Long-term monitoring had demonstrated that both studied tick species sometimes (not annually) were characterized by the presence of two late spring-early summer peaks of activity (Figs. 1, 2, 3, 4, 5, 6, 7, 8). The only exception is the population from the University Park (Figs. 9, 10), the youngest among city park populations. Probably, this phenomenon can be explained by different dates of activation of adult ticks belonging to different age cohorts. Long-term studies of the demographic structure of *I. persulcatus* in Izhevsk district of Udmurtia (a republic of the Russian Federation, situated in the eastern portion of the Eastern European Plain between the Kama and Vyatka Rivers) had shown that in natural environment hungry *I. persulcatus* were represented by specimens with 3-, 4-, and 5-year-long cycles, constituting 70.4, 28.0, and 1.6 % of the entire population of adult ticks activated in spring, respectively (Korotkov 2004). Probably, dates of spring activation of similar age cohorts of ticks dwelling in Tomsk habitats differ, thus forming two peaks of spring-summer activity.

Table 1 Ratio between fractions of hard tick species revealed in monitored biotopes of Tomsk

	Fractions of tick species (%) among all specimens collected during each year in certain biotope													
	Kolarovo forest		Southern cemetery				Polytechnic stadium			Camp garden			University park	
	IPE	IPA	IPE	IPA	DR	HC	IPE	IPA	DR	IPE	IPA	DR	IPE	IPA
2002	–	–	38.7	61.3	0	0	8.8	91.2	0	0	0	0	0	0
2003	–	–	9.5	90.5	0	0	6.9	93.1	0	20. 0	80.0	0	0	0
2004	–	–	25.0	75.0	0	0	19.4	80.6	0	50.0	50.0	0	0	0
2005	–	–	1.44	97.1	1.46	0	2.1	97.9	0	12.5	87.5	0	0	0
2006	100	0	4.65	92.4	2.91	0	0	100	0	57.1	42.9	0	33.3	66.7
2007	96.8	3.2	5.61	91.6	2.8	0	0	100	0	0	100	0	33.4	66.6
2008	97.6	2.4	1.6	97.6	0	0.8	8.2	91.8	0	11.1	88.9	0	12.5	87.5
2009	95.0	5.0	5.18	94.1	0	0	11.5	88.5	0	60.0	40.0	0	100	0.0
2010	99.3	0.7	6.25	91.7	2.05	0	11.1	88.9	0	20.0	80.0	0	33.3	66.7
2011	95.9	4.1	5.12	94.9	0	0	8.1	90.5	1.4	31.6	68.4	0	7.9	92.1
2012	91.7	8.3	1.8	97.9	0.3	0	5.18	93.1	1.72	20.0	60.0	20.0	9.1	90.9
2013	92.5	7.5	5.3	93.2	1.5	0	5.08	93.1	1.82	25.0	75.0	0	20.0	80.0
On average	96.1 ± 1.05	3.9 ± 1.05	9.18 ± 3.2	89.8 ± 3.12	0.92 ± 0.34	0.07 ± 0.07	7.19 ± 1.57	92.4 ± 1.56	0.41 ± 0.22	27.9 ± 5.9	70.2 ± 5.9	1.8 ± 1.8	31.2 ± 10.6	68.8 ± 10.6

Tick species: IPE—*Ixodes persulcatus*; IPA—*Ixodes pavlovskyi*; DR—*Dermacentor reticulatus*; HC—*Haemaphysalis concinna*. (-) collecting was not performed

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