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CONDITIONS OF TICK (ACARI: IXODOIDEA) POPULATION PERSISTENCE IN THE URBAN ENVIRONMENT

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Abstract Tick pests and vectors of human and animal diseases are a permanent component of urban fauna. The present paper addresses the conditions required for persistence of tick populations in urban environment. All urban tick populations originate from populations in natural habitats around towns. Some of these can successfully persist under urban conditions without continuous replenishment by additional specimens brought by hosts from outside. Availability of 'green corridors' between natural habitats of ticks and urban localities with suitable vegetation creates a unique opportunity to support urban tick populations. Exotic tick species brought into towns by birds, with pets or by other means, have no chance for prolonged persistence since they have no resources for replenishment. The persistence of tick species (*Rhipicephalus sanguineus* and *Argas reflexus* s.l.) that can live in man-made structures depends on the availability of their main hosts. Both species are able to create independent urban populations.
Key Words Tick hosts, green corridors

INTRODUCTION

The problem of ticks and tick-borne diseases in urban areas has attracted attention of researchers for several decades (Korenberg et al., 1984; Daniel and Černý, 1990; Dautel and Kahl, 1999; Wilamowski et al., 1999), and new data concerning the occurrence of ticks and recognition of zoonoses in urban areas are continuing to accumulate. The sporadic and disparate nature of published observations calls for a thorough review and analysis in order to identify patterns and regularities determining tick persistence in our towns. In our previous papers (Uspensky, 2008a, 2014) a general picture of the problem of urban ticks was given and the main groups of ticks living in urban environment were described. The goal of the present paper is to analyze the suitability of various localities within urban environment for tick existence and to classify tick populations inhabiting these localities.

URBAN LOCALITIES POTENTIALLY SUITABLE FOR TICK EXISTENCE

Ticks which inhabit urban localities originate from tick populations persisting in wild natural habitats around cities and towns (Uspensky, 2014). The successful survival of ticks depends on optimal temperature and humidity, the main components of microclimate, in their habitats. Exophilic ticks which live in the lower parts of vegetation, litter and upper layer of the soil are especially dependent on microclimate. The more environmental conditions in urban localities correspond to those under which tick populations live in wild nature, the more suitable for ticks these localities are. The suitability of urban localities for tick persistence has to be maximal in suburban areas near the boundary to wild nature and minimal in the central parts of cities. The availability of appropriate tick hosts is the second requirement to an urban locality suitable to tick life. As a rule, the localities suitable to ticks are also suitable for many small mammalian hosts of immature ticks. However, the vulnerability of exophilic

ticks to climatic conditions, especially humidity, is higher than that of their hosts. In our analysis we follow the classification of urban localities used by other authors to the extent possible, even though the exact status of a locality where surveys were carried out may be unclear in some published reports. Most reported tick surveys were carried out in urban forests exploited as recreational areas, while many other types of localities have been inspected rarely if at all. That is why in some cases we extrapolate possible tick existence from data on small mammals living in the given locality.

Urban Forests

Urban forests as a category consist of several types of forest localities. This category includes residential areas situated inside woodlands, parts of natural forests absorbed by developing towns, and those surrounded by built-up areas (forest parks). The two latter types of forests are often used as recreational sites for urban residents. Urban forests are usually characterized by a complex of small mammals typical for the adjacent wilderness as well as by one or more species of medium-sized mammals (hedgehogs, squirrels, raccoons, badgers, hares) and large mammals such as deer, wild boar, and foxes regularly migrated from the wilderness.

Residential areas in the U.S.A. are characterized by the same abundance of *Ixodes scapularis* as their forest surroundings (Falco and Fish, 1988; Maupin et al., 1991; Carroll et al., 1992). A high abundance of adult taiga tick *I. persulcatus* was found in spacious areas on the periphery of St. Petersburg covered with deciduous forests, connected with large forest tracts and exposed to low anthropogenic pressure (Gorbunova and Tretyakov, 2012; Tretyakov et al., 2012). Immature ticks were regularly found on several species of small mammals. These areas are favorable for medium-sized and large mammal hosts of adult ticks which either live there or migrate from the adjacent forest tracts. Localities similar with or smaller than previous ones, under anthropogenic pressure of different degrees and connected with adjacent forest tracts not so tightly were characterized by a lower abundance of adult *I. persulcatus*. Immature ticks were also found on small mammals. Urban forest parks are small in size, have rather weak or no connection with natural forests and are exposed to strong anthropogenic pressure; the abundance of adult ticks in such localities was very low and findings of immature ticks on small mammals were rare (Gorbunova and Tretyakov, 2012; Tretyakov et al., 2012).

I. ricinus ticks infected with *Borrelia burgdorferi* were found in two large forest parks of London (955 and 445 ha) close to the downtown and surrounded by roads and buildings (Guy and Farquhar, 1991). Herds of deer roaming free and other medium-sized and small mammals inhabit both parks. Numerous tick bites and symptoms of Lyme disease were reported in workers of these parks (Rees and Axford, 1994). *I. ricinus* persistence was observed in recreational areas of Helsinki where the hare was the only possible host for adult ticks (Junttila et al., 1999). Five species of ticks (with *Rhipicephalus turanicus* dominance) were found in a large forest park in Rome (740 ha), which is characterized by woods and bush strips and is linked with green zones outside the city (Di Luca et al., 2013).

Public Gardens, Boulevards, Cemeteries

The abundance of *I. ricinus* ticks in public gardens (cultivated parks) significantly varies being higher in the sites with forest-like vegetation (Maetzel et al., 2005). Ticks are absent in the localities where trees and undergrowth are scarce. Another condition of this species prosperous existence is a permanent thick layer of leaf litter which provides a stable humid microenvironment (Kahl et al., 1992). In city

parks of Košice, Slovak Republic, the abundance of ticks correlated with the size of the park, the density of plant and bush cover and the tie with peripheral forests (Nadzamová et al., 2000). No ticks were found in urban parks of Lyon (Quessada et al., 2003), which is thought to be to good maintenance of park vegetation. Thousands of ticks, mainly *I. ricinus* but also *I. hexagonus*, were collected from hedgehogs at Margaret Island in central Budapest during two surveys (Földvári et al., 2011). The island (96.5 ha) is a landscape park and a popular recreational area. *I. ricinus* and *Dermacentor reticulatus* were found in parks in and near the central part of Kiev (Akimov and Nebogatkin, 2002).

D. variabilis has been established in many urban areas of the U.S.A. In 1978 it was collected from 153 outdoor locations in New York City (Committee.., 1980). Dozens of adult ticks were collected in a park of Bronx, New York City after several cases of Rocky Mountain spotted fever (RMSF) were diagnosed in residents of the area. Many adults of this species were also collected in a park of Brooklyn, whereas no ticks were found in 7 other parks of New York City (Salgo et al., 1988). Recently one more case of RMSF was diagnosed in Bronx and ticks from an urban park were incriminated (Community.., 2011). All stages of *I. scapularis* were found in a city park of New York City (Daniels et al., 1997) and in an inner-city park of Baltimore (Schwartz et al., 1991). In the latter case several workers of the zoo located in the park regularly removed ticks from themselves and one of them was diagnosed with Lyme disease. Both parks are rather large, surrounded by urban development and have small and medium-sized mammals as permanent inhabitants (several deer inhabit the park in Baltimore).

Cemeteries comprise a variable group of localities depending on their status (used or disused), size and localization in the town. Old heavily wooded cemeteries which are visited only sporadically might be considered as urban forests with low anthropogenic pressure. Such a cemetery in a Siberian town of Tomsk was characterized by very high abundance of ticks of several species (Romanenko, 2011). An interesting phenomenon was noted by Romanenko (2009): the heavier is anthropogenic pressure in public gardens and cemeteries, the higher is proportion of *I. pavlovskyi* as compared with *I. persulcatus*. The first species can survive in localities with a thin layer of leaf litter characteristic for intensively trampled areas while the second one needs in a permanent thick layer of leaf litter.

Private Gardens, Yards, Grass-Plots

Although the possibility of finding ticks in any urban grass-plot is often assumed, there are only single documented records of such events. Attachment of *D. silvarum* female to a boy in the central part of Omsk was recorded (Fedorov, 1968). High numbers of *I. ricinus* were found in some inner-city gardens of Hannover where hedgehogs were the only hosts for adults (Plate, 1993). Only sporadic findings of this tick were reported on ruderal vegetation in the central part of Košice (Nadzamová et al., 2000). In Bonn, these ticks were found in private gardens adjacent to forested areas (in some of the gardens deer were observed); in gardens which were not tied with forested areas no ticks were found (Maetzel et al., 2005). Green localities small in size surrounded by urban built-up areas were called ‘urban isolates’ (Sokolov et al., 1995) characterized by low numbers of small mammals. However, even in small urban localities (2.25 to 3.75 ha) of Berlin deer, wild sheep, foxes and hedgehogs can serve as hosts for adult ticks (Matuschka et al., 1990). An example of tick importation into urban isolates was given by Korenberg (personal communication). On a fenced-in property located near the central part of Sofia a case of Lyme disease was diagnosed in a boy who had not left the property for several weeks. *I. ricinus* adults were found on the lawn under cherry trees, and thrushes, the known hosts of nymphs of this tick, were observed migrating to the trees.

Railway Right-Of-Way Zones And River Banks

This category of landscape can be considered as 'green corridors' connecting wild nature with towns, sometimes with their central parts. The number of species of small mammals as well as their abundance can be rather high, especially on the river banks. Cases of dog piroplasmosis transmitted by ticks in Orenburg, Russia, were mostly registered in flood-lands of the Ural River (Khristianovsky, 2004). Migratory routes of birds are often determined by valleys of big rivers. River banks serve as stopovers for migrating birds where engorged immature ticks infesting birds drop off. An example of tick dispersal over river stream was given by Romanenko (2005, 2011). He presented data on appearance of populations of *I. pavlovskyi* in Tomsk, which are associated with the banks of the Tom' River. River banks are considered the area of *I. ricinus* and *D. reticulatus* survival on the islands of Dnepr River in the boundaries of Kiev (Nebogatkin, 2012).

CONDITIONS OF TICK POPULATION PERSISTENCE

From the above data one can see that tick persistence in a particular locality depends on many factors. The importance of a strong association of urban forest localities with wilderness for persistence of abundant tick populations was pointed out by Vershinsky et al. (1988) for *I. persulcatus* and by Nadzamová et al. (2000) and Supergan and Karbowiak (2009) for *I. ricinus*. Apparently, such association will be more common in the future because the idea of 'green corridors' is a key part of conservation strategy in Europe (Jongman et al., 2004). Another important condition for tick persistence is the availability of hosts for adult ticks (Korenberg et al., 1984; Daniel and Černý, 1986; Dautel and Kahl, 1999). As noted above, even one species of medium-sized hosts (hare, hedgehog) can support the tick population. The size of the locality, the type of adjacent territories, the scale of anthropogenic pressure over the locality, and the degree of its isolation from other potential tick localities are also of importance. Anthropogenic pressure can be controlled (landscape replanning, replanting and development) or uncontrolled (trampling understorey vegetation by visitors). When urban parks are visited by a high number of people who can move only over designated paths, such pressure has little influence on tick population persistence.

Urban forests that are large and tied with wilderness are characterized by independent populations of exophilic ticks [according to the classification proposed by Beklemishev (1960)] (Table 1). Independent populations are self-sufficient and can persist and flourish without constant replenishment by specimens from other populations. The migrations of medium-sized and large mammalian hosts provide constant exchange by tick specimens between urban forests and adjacent forest tracts. In some cases independent tick populations can persist in public parks even of small size having no direct ties with natural woodlands. Proper vegetation covering and constant presence of adult tick hosts support persistence of the tick population. When these conditions are not met, the tick population finds itself in dependence on additional tick specimens brought by hosts from outside. Such populations may be semi-dependent or dependent. The existence of a number of ticks in a locality unsuitable for prolonged persistence is characteristic of temporary populations. This can happen in any type of localities with either poor microclimate or the absence of hosts. Occasional (even regular) findings of ticks in gardens, yards and grass-plots reflect an existing possibility of importing new tick specimens by their hosts.

Table 1. Classification of tick populations according to Beklemishev (1960).

Populations	Conditions of populations persistence
Independent	Self-sufficient populations which can persist and flourish without replenishment.
Semi-dependent	Populations can persist but cannot flourish without replenishment.
Dependent	Populations cannot persist without constant replenishment.
Temporary	Short-lived populations in unfavorable habitats periodically appearing after importation of tick specimens by their hosts from outside.

EXOTIC TICKS IN URBAN ENVIRONMENT

Chances of ticks brought outside of their geographic range establishing a viable population are rather low. When ticks are brought to the north or to the south of their reproductive range they are found themselves under unfavorable climatic conditions. Regular findings of *I. persulcatus* adults in Yakutsk and surrounding areas, far north from the northern limit of their reproductive range, were reported and discussed by us previously (Uspensky et al., 2003). When ticks move in zonal direction (west-east), they may find themselves under unusual climatic conditions with a number of unusual hosts. It is important that in the great majority of cases, artificial introduction of exotic ticks occurs when a single specimen or, in rare cases, a small number of specimens are delivered to a single locale, usually a point of animal quarantine or another place that is under observation. Single specimens of exotic ticks may be of danger when they carry human or animal pathogens but they cannot initiate even a temporary population. The only exception is the brown dog tick (or kennel tick) *Rhipicephalus sanguineus* (see below).

CONSTANT INHABITANTS OF URBAN ENVIRONMENT

There are tick species that are highly adapted to life in urban environment, specifically the brown dog tick *R. sanguineus* and the pigeon tick *Argas reflexus* s.l. (Uspensky, 2008a, 2014). The persistence of their populations absolutely depends on the availability of their main hosts, dogs and pigeons, respectively. Both species are able to create independent urban populations. *R. sanguineus* is enabled to create independent urban populations mostly due to the close association of all developmental stages of the tick with dogs (Uspensky, 2008c), whereas in argasid ticks this quality is based on their ability to survive prolonged starvation (Uspensky, 2008b). The initiation of new populations of both species is a result of tick specimens being brought by hosts from other sites. There are numerous examples of appearance of *R. sanguineus* populations when infested dogs returned home after being for some time in endemic countries (see Uspensky, 2014). All stages of these ticks actively attack humans in urban conditions and in dwellings. *A. reflexus* provokes severe allergic responses while *R. sanguineus* transmit several pathogens to humans and dogs.

CONCLUSION

Thus, each locality in urban environment can be inhabited by a certain type of tick population depending on a number of factors. Our attempt to find some patterns and regularity in tick

existence under urban conditions should be considered as a preliminary one because of the scarcity of material. The main part of publications concerning urban ticks has been devoted to estimating infection rate of these ticks with various pathogens but important biological details have been ignored. The fragments of information which were possible to be extracted from numerous publications gave an initial picture that might create a basis for purposeful studies of the problem. The better understanding of the regularity of tick existence is a necessary condition for the development of protective measures for urban residents against ticks living near them. This is precisely the independent populations of ticks that should attract primary attention of researchers and public health managers.

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