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Blood-Sucking Ticks (Acari: Ixodoidea) and their Mammalian Hosts in the Urban Environment: A Review

Igor Uspensky*
Alexander Silberman Institute of Life Science, The Hebrew University of Jerusalem, Israel

Review Article

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***For Correspondence**

Igor Uspensky, 16, Yustman Moshe Street, Apartment 65, Jerusalem 9384208, Israel, Tel: 972-2-6450056

E-mail: igorusp.acarina@gmail.com

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ABSTRACT

The problem of urban ticks arose from the increased rate of urbanization that has taken place after the WWII. Expansion of municipal boundaries encompasses adjacent territories so that large areas of wilderness, together with all their inhabitants, find themselves incorporated into city limits. Current strategies of conservation and preservation of biodiversity include creation of green corridors and other forms of connectivity between wilderness and urban areas, and between green patches within cities. All this allows various mammals and birds from their native habitats to appear in cities and to establish permanent urban populations. Middle-sized and large animals provide adult ticks with blood meal thus creating conditions for establishment of tick populations. The independent tick populations can persist in urban forests, parks, private properties, old cemeteries etc. Some animals can maintain tick-transmitted pathogens, and in some cases can serve as competent reservoir hosts for certain human and animal pathogens. Urban populations of such animals are of importance in circulating these pathogens within municipal boundaries. Cases of human infection after tick bites have been reported in many cities. Thus enlargement of urban green areas followed by their settlement by mammals and birds increase opportunities for establishment urban tick populations with the resulting threat to the health of urban dwellers.

INTRODUCTION

The problem of ticks in the cities has attracted attention of urban inhabitants, mass media and specialists starting at the end of the 20th century [1-5]. This problem appeared as the result of the increased rate of urbanization having taken place after the World War II. The concept of 'urbanization' implies, inter alia, an enlargement of municipal boundaries to encompass adjacent areas of wilderness. Current strategies of nature conservation and preservation of biodiversity have been created in response to unregulated expansion of urban areas. Urbanization has created a new reality in relationship between human population and wildlife increasing the proximity between city dwellers and their environment. Meanwhile the consequences of such proximity may be rather contradictory. Some aspects of this proximity can strongly influence the health of urban inhabitants.

Results of Urbanization and Biodiversity Preservation for Urban Environment

The expansion of cities in the process of urbanization has a dramatic impact on the environment. Large areas, which were wilderness up to that point, find themselves incorporated into the boundaries of cities and towns. Another consequence of human activity is the decrease in landscape heterogeneity, severe fragmentation of natural areas, and change in richness and composition of animal and plant species [6-9]. The principles of nature conservation and preservation of biodiversity in order to mitigate the negative human impact on the environment continues to gain increasing support in developed European and North American countries. Creation of green rings around cities and green corridors between wilderness and urban areas as well as between fragmented areas of wilderness has become an important part of urban planning [10-12]. The connectivity between large green tracts and between small green urban patches makes urban environment more suitable for some species of animals [13,14].

These actions support preservation of biodiversity in urban environment [12]. The intensification of animal and bird migration from their native habitats into and between various parts of the cities is one of the consequences of the policy of green corridors and connectivity. In fact, natural environment together with all its inhabitants transforms into urban environment.

The cases of animal penetration into cities as well as of their residence in urban areas were well known but until recently they mostly concerned small animals (mice, rats, voles) [15,16]. As for middle-sized and large animals, these were more occasional events rather than regular phenomena. Now this process has dramatically increased backed by strong regulation in environmental protection and restrictions on hunting. Tolerant and often positive attitude of urban residents to animals from wilderness, easy availability of anthropogenic food and an opportunity to avoid predators predispose animals to choosing life in urban environment either by regular migration into the cities or by establishment of urban populations. This process is more pronounced in the cities with extensive green areas. Such areas are especially common in the cities of northern and northwestern Europe, where the green space coverage may exceed 40% of the total city area [17].

In Zürich and Geneva, for example, the first appearance of red foxes (*Vulpes vulpes*) documented in the mid-1980s and now several populations of this species thrive within these and other Swiss cities [18]. Rapid urbanization of red foxes has also occured in other European countries [19,20]. Since the middle of the 20th century, wild rabbit (*Oryctolagus cuniculus*) has colonized highly urbanized areas in Warsaw [21]. European brown hare (*Lepus europaeus*) immigrated to Berlin and other German cities during the last decades [22]. The Eurasian red squirrel (*Sciurus vulgaris*) is well adapted to life in urban environments and readily inhabits urban forests, parks and gardens; sometimes its populations reach higher density than in wilderness [23,24]. Likewise, European hedgehogs (*Erinaceus europaeus* and *E. roumanicus*) are permanent inhabitants of urban areas and the density of urban hedgehog populations in Swiss and French cities can be 4-8 times higher than that in adjacent rural areas [25-27]. The expansion of blackbird (*Turdus merula*) into the cities began in 19th century and now this bird is a common inhabitant of many European and Asian cities [28]. Foxes, hedgehogs, squirrels, hares, badgers may now be regularly seen within European cities whereas deer, squirrels, rabbits, raccoons, and coyotes have become human cohabitants in North American cities. The white-tailed deer (*Odocoileus virginianus*) became a regular inhabitant of many small towns and of urban parks in big cities in the USA [29,30]. The eastern gray squirrel (*S. carolinensis*) has become the most visible non domesticated mammal in American cities by the early 20th century [31]. Hedgehogs and squirrels are especially popular among urban residents. People like to have these animals around, in their gardens or in parks, where they can feed the animals and observe their behavior [31,32].

The process of accidental or intentional introduction of wild animals into urban environment has also further intensified over the last decades. In this respect, the case of introduction of the Siberian chipmunk (*Tamias sibiricum*) into Belgium and France is of special interest, because it was followed by spreading of the animal over other European countries and establishment of its independent populations in many cities [4,33,34]. The collapse of deer farming in Australia followed by deliberate release and subsequent translocation of deer of several species resulted in establishment of urban feral populations of deer in many cities and towns of the country [35].

It is important to mention the so-called 'pet tourism', which is people travelling on vacation or business trip take along their pets, mainly dogs, which can be viewed as pet migration. Just in the UK, according to 2010 data, about 2 mln dogs (and about 1 mln other animals, mainly cats, rabbits and turtles) were taken by their owners on vacation [36]. This phenomenon is typical of other European countries as well [37].

The development of green areas improves the quality of life for urban residents, providing adults and children with additional opportunities for mental recreation, games and sporting activities [38,39]. Dog owners use the opportunity to walk with their dogs in urban forests. Since human population in cities is increasingly isolated from nature, animal species in the daily environment are considered an important component of public education and children's development [40-42]. Yet in spite of all these advantages, the enlargement of urban green zones and their settlement by various mammals and birds raises important concerns that need to be recognized and addressed.

Animals in Urban Environment as Tick Hosts

It is well known that mammals of all sizes as well as birds are the hosts of hard and soft ticks (Acari: Ixodidae and Argasidae). Small mammals and birds are the hosts of larval and nymphal exophilic ticks; middle-sized mammals maintain nymphs and adults, while large mammals serve as hosts for adult ticks. Some tick species are ornithophilic so that all their stages feed on birds. All stages of nidicolous ticks feed on small and middle-sized mammals. The mammals that become urban residents are also good hosts for adult ticks. Such middle-sized and large mammals as deer, hares, hedgehogs and squirrels are the primary hosts for adults of many tick species providing them with blood meal, thus creating the conditions for establishment of tick populations. The appearance of such animals in cities contributes to the fulfillment of one of the main conditions of tick population persistence, the presence of the hosts for tick adults.

Various tick species were found in such biotopes as urban forests, public gardens, old cemeteries, river banks etc. where vegetation cover suitable for tick life is available [4,5]. Forested biotopes in some European capitals and other cities are populated by the European wood tick *Ixodes ricinus* [2,43-46], the tick abundance being very high in some cases. In Europe, hedgehogs were found to be heavily infested with all stages of *I. ricinus* and the hedgehog tick *I. hexagonus* [47-49]. The levels of infestation in urban

areas do not differ significantly from those in hedgehog natural habitats, and sometimes are even higher. In some cases, the hedgehog is the only host for adult ticks, but that can be sufficient for persistence of the tick population [48,50]. The hare is the only possible host for adult *I. ricinus* in Helsinki [51]. *Lepus europaeus* is one of the main hosts for the taiga tick *I. persulcatus* adults in the Asian part of Russia [52,53]. In cities of southern Europe, the composition of tick species is much richer than that in northern areas. Such species as *Dermacentor reticulatus, D. marginatus, Haemaphysalis concinna, Rhipicephalus turanicus* and some others can be found there [54-56]. *D. reticulatus* adults prefer to feed on cattle, but in cities they attack all available mammals, mainly dogs. The broadening of the range of this species in Europe [57,58] increase its significance for urban areas. Stray dogs are considered to be the main hosts of adult ticks of 3 species (*I. ricinus, D. reticulatus, D. marginatus*) in Voronezh (European part of Russia) [59]. In the USA, the white-tailed deer is the main host of the deer tick *I. scapularis* (*I. dammini* in earlier publications) [60,61].

Birds are mainly responsible for spreading ticks into urban green spaces [62,63]. *I. pavlovskyi* replaced *I. persulcatus* in urban parks of Tomsk (Western Siberia, Russia) since *I. persulcatus* adults have a relatively poor ability to find hosts there, while adult *I. pavlovskyi* can feed on the birds collecting food from the ground, the abundance of which in city parks has increased over the last decades [64].

All stages of the brown dog tick *Rhipicephalus sanguineus* feed on dogs. The increasingly common practice of bringing dogs when traveling abroad (pet tourism) together with dog importation facilitate spreading of the brown dog tick to new areas, including cities. This is especially important for the points to the north of the accepted northern border of *R. sanguineus* range, where this tick can survive inside human dwellings. This tick species is the only one, capable of initiating in-house populations (colonies) in any area of the globe [65-68]. There are numerous descriptions of in-house populations of *R. sanguineus* in cities and towns of Holland [69], Germany [70-72], the UK [73-75] and other countries. When ticks of this species are introduced with dogs into a new area, quick infestation of naïve dogs and establishment of local population of ticks take place [72,76,77].

Argasid ticks feed on various mammals and birds, and urban pigeons maintain all stages of pigeon ticks *Argas reflexus* s.l. Large populations of pigeons (*Columba livia*) have become a pervasive element of central parts of many big cities during the last decades, though in contrast to hedgehogs and squirrels the majority of urban residents view pigeons as pests ('flying rats'). Pigeons dominate the urban environment; for example, their abundance in Europe is estimated to be as high as 20 to 30 million [78]. In the areas where pigeon populations have been present for many years, ticks can develop very extensive populations. *A. reflexus* sensu stricto inhabits residential as well as non-residential premises in many European cities [2,79]. Other members of *A. reflexus* group can be encountered in cities throughout Eurasia and the Near East. *A. polonicus* was found in a church in Krakow [80], *A. vulgaris* in the cities of south-eastern Europe and Central Asia [81], and *A. latus* in Jerusalem and other cities of Israel [82,83].

Ticks and Animals in Urban Environment and Tick-Transmitted Pathogens

The majority of tick species common in European and American cities are vectors and reservoirs of several pathogens responsible for severe diseases of humans and animals. The most important vectors of human pathogens are the following: (i-ii) *Ixodes ricinus* and *I. persulcatus*, the primary vectors of tick-borne encephalitis virus and several genospecies of *Borrelia burgdorferi* s.l. in Europe and Eurasia, respectively; (iii) *I. scapularis*, the main vector of *B. burgdorferi* s.str. in North America; (iv) the American dog tick *Dermacentor variabilis*, the primary vector of *Rickettsia rickettsii* in North and Central America; and (v) *Rhipicephalus sanguineus*, which transmits several subspecies of *Rickettsia conorii* in different regions of Eurasia and a number of dog pathogens worldwide.

Until recently, the infection in wilderness was considered to be the only source of tick-transmitted diseases in urban inhabitants. Only during the last decades the possibility of infection caused by tick bites within cities was recognized and the first estimates of the scope of the problem were obtained.

Prevalence of various pathogens in ticks inhabiting urban biotopes varies significantly, and may be similar to, lower or higher than in the wilderness. In particular, infection of *I. ricinus* with *Borrelia burgdorferi* s.l., the most studied pathogen in this respect, has been determined in many European cities [2,4,45,46,51,63,84-86]. The general conclusion is that the prevalence of this pathogen in urban ticks is comparable with that of tick populations in their natural habitats.

Tick behavior in urban environment is the same as in wilderness, i.e., they attack all suitable hosts. *I. ricinus* and *I. persulcatus* as well as *I. scapularis* and *D. variabilis* are generalists and they readily attack people and domesticated animals, primarily dogs. In the case of *I. scapularis*, people are attacked by nymphs and adults [87], while in *I. ricinus* all three parasitic stages are able to attack humans [88,89]. *D. reticulatus* can also attack people but not as readily as the above tick species [90]. Incidents of human attacks by nidicolous ticks such as *I. hexagonus* and *I. canisuga* have been registered [91,92].

The importance of mammals and birds permanently living in or migrating into cities is not limited by their role as good hosts for all developmental stages of ticks. They can also maintain pathogens transmitted by ticks, and in some cases can serve as competent reservoir hosts for certain pathogens. The importance of both European hedgehog species as reservoir hosts for certain human pathogens is well established. Both species have been implicated as reservoir hosts for several genospecies of *B. burgdorferi* [93-95]. The possibility of maintaining *Anaplasma phagocytophilum* by hedgehogs of both species has recently been confirmed by several studies [96,97]. It was found that *E. europaeus* could maintain tick-borne encephalitis virus [98]. An important

role of *I. hexagonus* in supporting an enzootic cycle of *B. burgdorferi* s.l. circulation has been demonstrated [99]. Other middle-seized urban mammals such as the red squirrel and the red fox as well as birds (the blackbird) were found to be reservoir hosts for that pathogen as well [53,100]. Urban populations of animals are also of importance in circulating such pathogens as *Anaplasma*, *Rickettsia* and others [86,101,102]. The importance of small urban mammals as reservoir hosts for many tick-transmitted pathogens was proved by many researchers [53,86,100].

I. ricinus infected with *B. burgdorferi* have been found in Richmond and Bushy parks in London, and park workers reported tick bites. Three of them described symptoms compatible with Lyme disease and in 10 workers (24% of examined) raised antibody levels were detected [103,104]. In an inner-city park in Baltimore attacks and bites of *I. scapularis* ticks were reported by park workers, and a case of Lyme disease infection was documented [105]. Several cases of infection with Rocky Mountain spotted fever were found in visitors of a city park in Bronx (New York City); many adult *D. variabilis* were collected in the park during its further survey, and up to 8% of ticks were found to be positive for rickettsiae [106]. In 1994, about 30% of all inhabitants in Ekaterinburg (Ural, Russia) bitten by *I. persulcatus* ticks (i.e., about 5,000 people) have been bitten in the city [107]. According to one estimation [108], approximately 10% of people afflicted with tick-borne encephalitis in Russia in the territory of "Ural and Siberian Regions" have been bitten by infected adult *I. persulcatus* in the cities' parks and squares. For the city of Irkutsk (Eastern Siberia) the same index is estimated to be 7.1% [109].

The brown dog tick *R. sanguineus* has a very close affinity with dogs. Under certain conditions this tick can be very aggressive towards humans [110,111], attacking and infecting people both outdoors and indoors. When 103 incidents of human disease with Mediterranean spotted fever (MSF) in Jerusalem were analyzed, it was found that 72% of the patients had been infected inside their residences [112]. Cases of infection and disease with MSF after intra-house *R. sanguineus* bites were well documented [113-115]. Death of a homeless man from MSF after multiple tick bites in Marseille has been reported [116]. In all above cases, dogs were a serious factor in infecting people through tick bites. Ascertainment of the role of dogs as reservoir hosts for *R. conorii* [117] confirmed the critical importance of these animals not only as main tick feeders but also as a main source of tick infection by the MSF pathogen. An additional indication of the important role played by these animals in human infection by MSF is provided by clusters of infections at the sites frequented by dogs or in dwellings with dogs [118,119].

When inside dwellings, ticks of the *A. reflexus* group often attack sleeping people at night. Their bites provoke allergic responses, sometimes serious enough to require hospitalization [82,83,120,121]. A fatality as the result of anaphylactic shock induced by tick bites has been described [122].

Is it Possible to Resolve the Contradiction?

Consequently, expansion of wilderness inhabitants into cities along with efforts to protect nature and biodiversity are followed by increasing threat to the health of urban residents. Finding ways of preserving the positive impact of green areas with their mammalian and avian inhabitants without increasing the risk to human health in present-day cities is a pressing and challenging problem of our times. Narrowly focused aggressive interventions, such as, e.g., shooting all hares in urban forests, or indiscriminate acaricidal treatment of urban parks does not meet modern reality but also would produce only short-lived, if any, positive results.

If we are to make any real progress in this area, we must develop a balanced multi-pronged approach directed not only to the conditions required for the persistence of urban tick populations, i.e., suitable biotopes and the availability of hosts for adult ticks, but also at increasing awareness of the dangers of tick attacks. The public must be informed about the locations where they can be exposed tick bites and taught basic self-protection techniques. Tick biotopes can be controlled by proper cultivation of urban parks and forests, including regular removal of garbage and moving of grass, in particular around the footpaths. The success of these simple and cost-effective measures in reducing tick population was demonstrated in the city of Tomsk [123]. Equally straightforward approaches can be found for reducing the availability of hosts for adult ticks. An experience in Basel provides a poignant example, where the population of pigeons was reduced by half simply by posting signs proscribing feeding of the birds [124]. With regard to increasing public awareness of the danger posed by ticks, it is important to keep in mind that simply providing the relevant information only marginally affects the behavior of people engaged in leisure activities in urban parks and forests [125].

It is clear that in order to develop an effective system of measures protecting people from tick-borne pathogens in modern urban environment, coordinated efforts of specialists in a variety of fields are required, and that such measures must be specific for each city or group of cities. In particular, it might be necessary to include specialists in public behavior, such as marketing professionals, to develop effectiove ways of convincing city dwellers to take simple precautions against the risk posed by ticks. It is possible to effectively protect public health while preserving the benefits of green spaces in urban environment, but only if this multifaceted problem is addressed by a well-coordinated systemic approach rooted in the knowledge base of multiple scientific disciplines.

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