Proceedings of the Sixth International Conference on Urban Pests
William H Robinson and Dániel Bajomi (editors), 2008
Printed by OOK-Press Kft., H-8200 Veszprém, Pápai út 37/a, Hungary

TICKS (ACARI: IXODOIDEA) AS URBAN PESTS AND VECTORS WITH SPECIAL EMPHASIS ON TICKS OUTSIDE THEIR GEOGRAPHICAL RANGE

IGOR USPENSKY
A. Silberman Institute of Life Sciences, The Hebrew University of Jerusalem, Israel

Abstract The development of any urban area has been followed by dramatic changes in floral and faunal biodiversity, which also touches upon vectors of human and animal diseases, and provides strong impacts on wildlife-pathogen interaction. Although the urban environment creates a new reality for animal existence and the urbanization process is followed by impoverishment of biodiversity, new conditions meet tick requirements both in developing and developed countries. Numerous hosts of adult ticks are either preserved in individual properties or specially bred in small farms in suburban areas of many developing countries. In developed countries, environmental protection and ecologically-based standards of the urban growth preserve green spaces inside urban and residential areas together with increasing number of hosts including those which can amplify tick populations. Urbanization has been connected with the sharp increase of urban pet populations, both domesticated and stray, which are excellent hosts for ticks. Pet owners comprise a group of high risk for tick attacks and infection with trick-transmitted diseases. The main task of the review is not in comprehensively cataloguing cases of tick findings in towns but in trying to outline some general dependence of tick survival in urban areas and possible ways of protection from tick attacks and, hence, from the danger of infections with tick-transmitted pathogens in towns.
Key Words Argasidae, Ixodidae, urbanization, allergic response, vectors, reservoir hosts

INTRODUCTION

Ticks were always a part of urban fauna, especially in suburban areas. However, if argasid (soft) ticks (family Argasidae) were recognized as urban pests long ago (e.g., Bénoit-Bazill, 1909), ixodid (hard) ticks (family Ixodidae) were long thought to mainly be inhabitants of wild nature. This opinion was reconsidered only in the last decades of the 20th century. The increased rate of urbanization has attracted attention to the problem of vectors and vector-borne diseases in urban areas, in particular ticks and tick-borne diseases (Steere, 1994; Gratz, 1999; Dautel and Kahl, 1999; Comer et al., 2001). However, we are still far from completely understanding all aspects of the problem and creating an efficient system of human protection from tick attacks and, hence, from the danger of possible human and animal infections from tick-transmitted pathogens inside urban areas.

Although new data on the occurrence of ticks in urban areas and recognition of zoonoses under urban conditions have regularly appeared, it is difficult to create a comprehensive database. Such data are spread over a great variety of sources and often have a rather limited information value presenting only indirect evidence of tick occurrence. The fact of a tick finding in a town may be a side result of another study and mentioned in passing. This is especially true when the main task of a study is the detection of tick-transmitted pathogen DNA from human patients, animals or ticks. Very often such details as the precise site of the tick finding or even of the tick species involved are absent. Sometimes the name of a town in the title or in the text of a paper only implies that ticks were found on the territory of the corresponding region and, conversely, it is possible to find some information concerning tick findings inside an urban area in a paper, the title of which has nothing to do with this problem. Because of these studies more information about urban ticks has been obtained. Extensive studies directly concerning urban ticks have been conducted only in several Central European countries whereas in most countries such studies are sporadic if at all.

In this review I shall try to show the conditions for the existence and appearance of bloodsucking ticks in urban areas, as well as the medical and veterinary consequences of these events. My review will mostly concern European countries, and the USA, as well as the countries where I myself worked, Russia and Israel. I see my task not in cataloguing cases of tick findings in towns but in trying to outline some general dependence of tick existence in urban areas.

URBANIZATION: TENDENCIES AND CONSEQUENCES FOR TICK EXISTENCE

During recent decades, the accelerating rate of urbanization is occurring worldwide but the most apparent trend toward urbanization is taking place in the developing world. If the urban population of the developed countries doubled between 1950 and 1985, it quadrupled in the developing countries (Goldstein, 1990). In 1975, only one third of the world's human population lived in urban areas but by the year 2025 over 65% of people will be living in towns, the global population having increased about 3-fold (Ghirotti, 1999). There is an obvious tendency of merging separate towns and cities in huge metropolitan areas. This fast urbanization is followed by an increased mobility of the human population, intensive long-distance trade, and new contacts between humans and their pets with wild nature, all of which may contribute to changes of epidemiological and epizootiological conditions in urban areas.

The urban area is a complex structure created by man and developed from small villages or settlements. It has increased as a result of urban intervention into natural areas and agricultural lands to provide dwellings and working places for growing numbers of urban inhabitants. This structure includes sets of living, administrative and industrial buildings together with a certain infrastructure, sometimes rather complicated, as well as places for human resting, which altogether create an urban environment (Robinson, 2005). An urban area consists of various sites that represent a continuum between many-story office buildings in the downtown area and the industrial or residential suburbs, which may be a dozen km from the central parts of the town. There are differences in the development of urban areas between different countries. The tendency to increase the quality of life by preserving green spots (parks, gardens, boulevards) in the central parts of towns, developing new quarters in accordance with ecologically-based standards and with special attention to existing green areas, and by creating residential districts at the border with natural localities is characteristic for developed countries of Europe and North America. In contrast, in developing countries with the dramatic rate of urban growth this tendency either appears on a minor scale or not at all. The existence of dense and impoverished suburban areas as well as the preservation of private poultry, sheep and goats, or household farming activities in those areas is characteristic for towns in the developing world (Ghirotti, 1999).

The development of any urban area has been followed by dramatic changes in floral and faunal biodiversity. It touches upon vectors of human and animal diseases as well, and provides strong impacts on wildlife-pathogen interaction and, hence, on human health (Bradley and Altizer, 2007). The most important point is that vectors in general and ticks in particular can find conditions for their survival under any tendency of the urbanization process. Although the urban environment creates a new reality for animal existence and the urbanization process is followed by impoverishment of biodiversity, proper environmental conditions for ticks inside their geographical range mostly remain in suburban areas and may be found even in central parts of large cities. A factor of vital importance in the process of urbanization is the presence of appropriate hosts for all parasitic stages of ticks. Landscape modification as a result of urbanization creates a fragmented suburban landscape which may alter host diversity and abundance (Ostfeld and Keesing, 2000). Such kinds of human activity as logging or fire management create better habitats for many tick hosts. Contacts between wild and urban fauna are increasing in expanding cities. Excellent conditions for tick existence are found in many developing countries where numerous hosts of adult ticks are either preserved in individual properties or specially bred in small farms in suburban areas.

ARGASID TICKS IN URBAN AND SUBURBAN AREAS

Argasid ticks have not been a priority group for study for several decades. It is mainly caused by the emergence or re-emergence of several serious human diseases transmitted by ixodid ticks during the last three decades which has attracted the attention of researchers and financing bodies. Another cause might be the presence of several groups of closely related argasid tick species that creates the difficulty of their precise identification.

Species Characteristic to Urban Areas

The European pigeon tick, *Argas reflexus*, is the most common inhabitant of urban areas in Central and Western Europe being closely tied with the main urban pest bird, the rock pigeon *Columba livia*. The

capability of pigeons to cope perfectly with urban conditions allows them to dominate the urban environment (Dautel et al., 1991). In sites where colonies of pigeons have lived for years, *A. reflexus* can develop large populations. Ticks penetrate into human dwellings where they hide in cracks and crevices in the walls, in cracks around the window shutters, in electricity points, and from where they can attack humans mainly at night. These attacks are especially intensive when pigeons have been removed from the area or in the case of tick overpopulation. The capacity of ticks to fast up to several years allows them to survive even when pigeons become unavailable. *A. reflexus* also feeds on other synanthropic nesting birds, such as martins, swifts and small birds of prey. In the 1960s it was found that there are several species closely related to *A. reflexus* so that some earlier findings of this species appeared to be misidentifications (Filippova, 1966). Other species from the *Argas reflexus* group either replace the pigeon tick beyond its range or are sympatric with *A. reflexus* s.str. inside its range. The ticks collected from the steeple tower of St. Mary's Church in the central square of Krakow and described as *A. polonicus* (Siuda et al., 1979) were also found in churches of several towns in the central and eastern parts of the former Czechoslovakia (Dusbábek, 1985). This tick actively attacked the trumpeters in the Krakow Church (Siuda et al., 1982). *A. vulgaris* is distributed in south-eastern Europe and primarily in central Asia parasitizing synanthropic birds, including *C. livia* (Filippova, 1966). It was found in several towns of the Ukraine, Armenia, and all Central Asian states of the former USSR. In Israel, another representative of the *A. reflexus* group, *A. latus*, was found in Jerusalem and other towns (Filippova et al., 1999). Both species attack and bite humans inside dwellings even in multi-story buildings.

The fowl tick *Argas persicus* parasitizes several economically important poultry species and inhabits aviaries, which often are located in suburban areas. The tick can also parasitize synanthropic birds. The capacity for prolonged fasting by all stages determines the stability of their populations when hosts are absent. *A. persicus* spread after people and poultry worldwide, from 50-55°N to about 40°S, and found in warm climatic conditions in all continents (Filippova, 1966). The data concerning Australia that were called into question for a certain time have been recently confirmed (Petney et al., 2004). Occasional attacks of humans by this tick have been recorded.

Representatives of the genus Ornithodoros are more closely connected with wild nature living in caves, rodent burrows or squirrel nests. Nonetheless, some species of this genus are not uncommon in urban and suburban areas. *O. coniceps* described from specimens collected at St. Mark's Cathedral in Venice, Italy, is widely distributed in Mediterranean countries and in Central Asia as far as India. In urban areas it parasitizes pigeons but also sparrows, swifts and chickens (Hoogstraal et al., 1979a). Attacks by *O. coniceps* on humans in urban areas have been documented (Merdivenci, 1968; Wilamowski et al., 1999). *O. erraticus* is spread over the Mediterranean region. This tick inhabits rat burrows in urban areas of Egyptian towns and attacks humans while migrating from one burrow to another (Hoogstraal et al., 1954). The African tampan, *O. moubata*, inhabits dwellings of special construction (huts from mud and grass), which are typical for rural areas of African countries south of the Sahara but also characteristic for the suburbs of African towns (Sonenshine, 1993). In the Sahara and Sahel, *O. sonrai* inhabits rodent burrows near houses and is aggressive toward people. The sand tampan, *O. savignyi*, distributed in the Near East, India, and many African countries does not occur in human dwellings but may found under trees around buildings. This tick mainly attacks cattle, sheep and camels but also humans (Sonenshine, 1993). *O. turicata* in the southern United States and *O. hermsi* in the western part of the country inhabits cabins in recreational areas but sometimes can be met with in living areas in primitive or damaged houses that have obvious rodent infestation under flooring or between walls. This is especially critical for houses that are located on newly urbanized territories. Both these ticks actively attack humans (Barbour, 2005). *O. tholozani*, which usually inhabits caves in nature, can inhabit buildings of old construction in towns and attack people inside their dwellings.

Medical and Veterinary Significance

An allergy occurring after bites from A. reflexus was observed long ago. It has now been established that such bites can provoke IgE-mediated type I allergy in people that may lead to life-threatening symptoms of anaphylactic shock (Müller-Doblies and Wikel, 2005; Kleine-Tebbe et al., 2006). A fatal case after an *A. reflexus* bite that triggered anaphylactic shock was described by Buczek and Solarz (1993). Allergies

were also recorded following bites of other ticks of the *A. reflexus* group, such as *A. vulgaris* and *A. latus* (Filippova, 1966; Filippova et al., 1999). *A. vespertilionis* (now *Carios vespertilionis*), normally parasitizing bats, may sometimes attack humans. Jaenson et al. (1994) recorded attacks of *C. vespertilionis* on people in their bedroom (Stockholm area) followed by severe multiple allergic reactions. The involvement of *C. vespertilionis* in infecting chickens in Pakistan and the transmission of some bacterial pathogens was recorded (Shah et al., 2006). Though there is no direct evidence that ticks of this group are competent vectors of human pathogens, a number of agents potentially pathogenic for humans or animals have been isolated from these ticks (Hoogstraal et al., 1979b; Labuda and Nuttall, 2004). *A. persicus* is an efficient vector and reservoir of several bacterial pathogens fatal for chickens (Hoogstraal et al., 1979b; Khalil, 1979). Dense populations of this tick may result in exsanguination or paralysis of its bird hosts. A well-grounded suspicion that *A. reflexus* may be involved in the Q-fever pathogen transmission was presented (Stein and Raoult, 1999). Several other pathogens of humans were isolated from *A. persicus* but their real role in epidemiology is unclear.

Ticks of the genus *Ornithodoros* are known as competent vectors of several *Borrelia* species causing tick-borne relapsing fever of people (Barbour, 2005; Rebaudet and Parola, 2006). Each *Borrelia* species is specific for its tick vector species. *B. duttoni* is a specific agent for *O. moubata*, *B. crocidurae* for *O. erraticus* and *O. sonrai*, while *B. turicatae* is connected with *O. turicata*, and *B. hermsii* with *O. hermsi*. The relapsing fever morbidity is rather high in Africa being the second cause of human illness after malaria in such countries as Senegal, Mali and Mauritania (Guilliame, 2006). The number of relapsing fever cases in Europe and the USA is comparatively low. The infection mainly takes place in recreational areas but 16% of cases analyzed by Dworkin et al. (2002) took place in the homes of patients. Recently *O. turicata* bites and infection with relapsing fever in a very severe form were recorded in an urban area of South Lake Tahoe (Anonymous, 2006). An anecdotal story of consistent human morbidity with relapsing fever in the old part of the town of Namangan (Tadzhikistan) where the only possible vector might be *O. tholozani* (*O. papillipes* in Russian literature) living under flooring in old houses was described (Abidov et al., 1993). *O. erraticus* and *O. sonrai* are also vectors of the African swine fever virus and this disease is considered to be the cause of elimination of a number of pigsties in townships of Spain (Vial et al., 2007). The sand tampan bite may cause the death of domestic animals induced by toxins contained in salivary gland extracts (Mans et al., 2002). Just recently, evidence was obtained that *O. savignyi* may take part in the transmission of Alkhurma hemorrhagic fever virus provoking a very severe human disease with >30% fatality (Charrel et al., 2007). Bites by *O. coniceps* provoked a severe allergic response in several inhabitants of a Jerusalem apartment so that one person had to be hospitalized (Wilamowski et al., 1999).

IXODID TICKS IN URBAN AND SUBURBAN AREAS

In the process of urbanization, encroachment into forested and uncultivated areas as well as protection of existing green spots create opportunities for populations of local ixodid ticks to continue to live under urban and especially suburban conditions. Urbanization very often creates better habitats for various tick hosts, from mice to deer, thus providing conditions for tick development. In any case, human activities may often positively influence the tick abundance both in short-term and long-term perspectives.

Species Characteristic to Urban Areas

The European wood tick, *Ixodes ricinus*, is the tick species most commonly registered in urban and suburban areas of Central Europe. In Germany *I. ricinus* was found in Berlin and many other towns (e.g., Kahl et al., 1988, 1989; Matuschka et al., 1990; Dautel and Kahl, 1999; Maetzel et al., 2005), in the Czech Republic in Prague and other towns (e.g., Daniel and Černý, 1990; Hubálek et al., 1993; Bašta et al., 1999; Hercík et al., 2007; Pejchalova et al., 2007), in Poland in Warsaw and other towns (e.g., Siński and Rijpkema, 1997; Michalik et al., 2003; Stańczak et al., 2004). This tick was also noted in towns of some other European countries as well as of the states of the former Soviet Union (Moldova, Russia and Ukraine). The closely related taiga tick, *I. persulcatus*, has been met with in towns and cities over its extensive range, from Latvia to the Far East (e.g., Korenberg et al., 1984; Antykova and Kurchanov, 2002; Romanenko, 2005). The dominant role of these two species as urban inhabitants is determined by their biological features

(high abundance, prolonged activity, capacity to diapause, very large number of hosts). Both ticks actively attack people. Adult *I. persulcatus* was repeatedly found in the suburbs of Yakutsk, the capital of the Sakha Republic (former Yakutia), far to the north of its geographical range (Egorov et al., 1996; Uspensky et al., 2003). Engorged nymphs of this tick have been brought by birds migrating along the great Siberian river valleys. Single nymphs could molt into adults but there was no chance for establishing an independent population.

Rodents living in urban areas (rats and mice) or constantly migrating between wild nature and suburban areas (mice and voles), as well as many ground-dwelling birds, can be hosts for subadults of both species. Squirrels and hedgehogs are adequate hosts for the adult stage even in centrally located urban parks. Domestic pets when outdoors and stray dogs and cats also serve as tick hosts. Large animals regularly attending suburban and residential areas such as deer, foxes, wild boars, and hares may be hosts for both tick species. Animals such as deer, that may feed a great number of tick females thus providing a numerous tick progeny, significantly amplify tick populations.

In addition to *I. ricinus* and *I. persulcatus*, other ticks may be found regularly in towns located inside their geographical ranges. In European towns, the hedgehog tick, *I. hexagonus*, has been regularly met with. In addition to hedgehogs, this tick can also feed on badgers, martens and foxes which are regular visitors to suburban areas, as well as on dogs and cats (Gern et al., 1997; Nijhof et al., 2007). Hedgehogs are now protected animals and their importance in amplifying urban tick populations is in no doubt. *Dermacentor reticulatus* and *Haemaphysalis concinna* were found in urban and suburban areas over their entire ranges in Europe as well as in Asia. The adults of *D. reticulatus* do not attack people often but *Ha. concinna* attacks people rather aggressively. The expansion of the *D. reticulatus* range in Central and Western Europe during the last decades (Sréter et al., 2005; Dautel et al., 2006) has increased the potential of this tick as an urban pest. *Ha. concinna* together with *D. marginatus* were collected in the vicinities of two Bulgarian towns (Angelov et al., 1996). In urban areas of Istanbul, *Hyalomma aegyptium*, *Hy. m. marginatum*, *D. marginatus* and *Rhipicephalus sanguineus* were found to attack people (Vatansever et al., 2008). In the Far East, *I. persulcatus* and *Ha. concinna* together with *D. silvarum* had to be controlled on intensively urbanized territories around the town of Zeya (Uspensky et al., 1974). In Khabarovsk, the same three species were found parasitizing the brown rat and the field mouse under flooring in suburban houses (Chernykh and Kozlovskaia, 1976). A case of blood-gorging by an adult *Ha. longicornis* on an old woman for at least 7 days took place in the suburb of a business city of Japan (Shimizu et al., 2000).

Ixodes scapularis (former *I. dammini)* is a usual inhabitant of urban and especially suburban areas in the United States. A series of studies was devoted to the occurrence of *I. scapularis* in a park and in suburban residential areas of New York City (Falco and Fish, 1989; Daniels et al., 1997). The occurrence of this species was recorded in other towns on the eastern cost of the USA (Magnarelli et al., 1995) as well as in the northern Midwest (Neitzel et al., 1993). The dominant host of preadult ticks is the white-footed mouse but other rodents, as well as many birds also contribute to tick feeding (Anderson and Magnarelli, 1993; Battaly and Fish, 1993). Brown rats and house mice that are good hosts for *Ixodes* ticks are abundant even in large towns (Childs et al., 1991). Adults can feed on deer, raccoons, opossums, foxes, bobcats, and lagomorphs regularly visiting suburban and residential areas. The spreading of the white-tailed deer across the United States is followed by an extension of the *I. scapularis* range. Urban populations of deer have become a common phenomenon and have initiated the appearance of urban populations of *I. scapularis*. In residential areas of the USA, dogs moving freely over properties may bring to the house any tick living in the area. On the Pacific coast, in California, the western black-legged tick, *I. pacificus*, has a tendency to settle among urbanized foothill communities where larvae of this tick were collected from the black rat (Wright, 2000). *I. dentatus* was found on cottontail rabbits in the botanical gardens of New York City and Millbrooks, New York (Anderson et al., 1989).

Medical and Veterinary Significance

The epidemiological importance of *I. persulcatus* and *I. ricinus* as competent vectors and reservoirs of several pathogens is well-known and new data have constantly been added. The list includes causative agents of tick-borne encephalitis (TBE), Lyme borrelioses, erlichioses, and babesiosis (Sonenshine, 1993;

Labuda and Nuttall, 2004; Goodman et al., 2005) and recently *Bartonella henselae*, the causative agent of cat-scratch disease, was identified in both ticks (Sanogo et al., 2003; Morozova et al., 2004; Hercík et al., 2007). Tick-borne pathogens or their DNA were isolated from most of the ticks found in urban areas mentioned in the previous chapter. In Helsinki, 32% of nymphal and adult *I. ricinus* collected in urban parks harbored *Borrelia burgdorferi* s.l. (Junttila et al., 1999). The prevalence of this spirochete in *I. ricinus* ticks and rodents in the area of gardens and recreational activity of the town of Bruchsal (Germany) did not significantly differ from the control forest area and the morbidity with Lyme borreliosis among the town inhabitants was common (Maiwald et al., 1995). The increase in TBE morbidity in the 1990s in the former Soviet Union has been connected with the number of urban cases. In 1994, about 30% of people bitten by *I. persulcatus* in Ekaterinburg (Ural Mountains) received these bites inside the town (Anonymous, 1995). *I. hexagonus* was proven to be a competent vector of *B. burgdorferi* s.l. and together with *I. ricinus* participates in the transmission cycle of this agent through hedgehogs in urban and suburban areas of Switzerland (Gern et al., 1991, 1997). *Anaplasma phagocytophilum* and *Rickettsia helvetica* were also detected in this tick (Nijhof et al., 2007). A focus of canine babesiosis with *Babesia canis* as a causative agent and *D. reticulatus* as a vector was discovered in the eastern area of Munich (Zahler et al., 2000).

I. scapularis is the main vector and reservoir of Lyme borreliosis, babesiosis and human granulocytic ehrlichiosis (HGE) pathogens as well as the Powassan virus (Sonenshine, 1993; Labuda and Nuttall, 2004; Goodman et al., 2005). The results of DNA analyses in *I scapularis* from a New York City park for *B. burgdorferi* as well as *Ehrlichia* sp. causing HGE were positive (Daniels et al., 1997). *I scapularis* infected with *A. phagocytophilum* or *Babesia microti* were found in several towns of Maine, USA, and co-infected ticks were found in the town of Wells (Holman et al., 2004). *B. burgdorferi* spirochetes were isolated from engorged subadult *I. dentatus* collected in urban areas of New York (Anderson et al., 1989).

Some tick hosts are of importance in maintaining and/or amplifying tick-transmitted pathogens. Brown rats which might be met with in nearly all towns and cities were shown to be a reservoir host of Lyme borrelioses spirochetes (Matuschka et al., 1990) and *Bartonella* sp. (Ellis et al., 1999). The European hedgehog was proven to be a reservoir host of *B. burgdorferi* s.l. (Gray et al., 1994). The Siberian chipmunk, one of the main hosts of *I. persulcatus* preadults in Siberia, was introduced in several Central European countries in the 1970s. This rodent collected near Paris was found to be an important reservoir host for *B. burgdorferi* s.l. (Vourc'n et al., 2007). A study in a northern suburb of New York City showed that the white-footed mouse, the primary reservoir host of *B. burgdorferi* s.str., lives in the vicinity of homes of Lyme disease patients (Falco and Fish, 1988). The contacts between wild and urban rodent fauna are increasing in rapidly expanding cities of developing countries (Mohr et al., 2007), thus raising the risk of tick-borne disease infections among humans and animals. Many species of birds that are hosts of *Ixodes* preadults were proven to be reservoir hosts for Lyme borreliosis spirochetes (Humair, 2002; Comstedt et al., 2006). On the other hand, deer which may be heavily parasitized by all parasitic stages of *I. ricinus* in Europe or *I. scapularis* in the USA, are incompetent as reservoir hosts for Lyme disease spirochetes (Jaenson and Tälleklint, 1992; Telford et al., 1988).

Sporadic cases of Rocky Mountain spotted fever (RMSF) acquired in urban areas were described (reviewed by Salgo et al., 1988). Several cases of RMSF were diagnosed in people living in Bronx, New York City, who had not left the area for several weeks (Salgo et al., 1988). The main vector, *D. variabilis* (Say), was collected in the local park and 5 to 8% of them were found to be positive for rickettsiae. In Long Island which is a suburban area of New York City, RMSF has been annually registered and *Rickettsia*-infected *D. variabilis* ticks were documented in some parts of 2 most inhabited counties of Long Island (White and Flynn, 1990). Sometimes the presence of ticks in urban areas may be deduced from the data on the tick-borne pathogens or antibodies to tick-transmitted diseases in the hosts. Thus, positive dog serum samples to spotted fever group antigens in metropolitan Chicago (Sexton et al., 1976) might be considered as indirect evidence of the presence of *D. variabilis* in the area. Tick toxicoses with various manifestations were described following the bites of several dozens of different species (Mans et al., 2004). A tick bite followed by paralysis was recorded for *D. andersoni* in Los Angeles (Gordon and Giza, 2004). Fatal results after the attachment of *I. holocyclus* to dogs in suburban areas all along the eastern seaboard of Australia were described (Bulke, 2006).

EXOTIC TICKS IN URBAN AREAS

Three cases of *D. variabilis* introduction from the USA to other continents have been described: to Australia (Canberra) (Halliday and Sutherst, 1990), to Sweden (Gothenburg) (Jaenson et al., 1994) and to Israel (Jerusalem) (Uspensky et al., 1997). Obviously the ticks were transported with people, either in their luggage or just attached to the travelers. Other tick species have also been sporadically brought to Israel by humans both from the United States, *A. americanum* (to Jerusalem) and *I. scapularis* (to Zichron-Yaakov) (Wilamowski et al., 1999), and from the former USSR, *I. ricinus* (to Jerusalem and Tel-Aviv) (Uspensky, unpublished). An adult *A. variegatum* was seen in a London bus coming from Heathrow airport in the 1980s (Y. Rechav, personal communication). McGarry et al. (2001) presented the records on the cases of tick importation to UK by British tourists from such countries as the USA (*A. americanum* and *R. sanguineus*), Nepal (*Hyalomma* sp., *Amblyomma* sp. and *R. sanguineus*), South Africa (*Rhipicephalus* sp.) and Scandinavia (*I. ricinus*); about 80% of all ticks were partially engorged.

Rhipicephalus sanguineus: A Tick Flourishing in Towns Outside its Geographical Range

The brown dog tick (or kennel tick) *Rhipicephalus sanguineus* is the second tick, after *A. persicus*, considered to be cosmopolitan. Although many species of ticks may be brought into human dwellings, only *R. sanguineus* can initiate there a local population. Several cases of such populations in Israeli towns were described (Uspensky and Ioffe-Uspensky, 2002).

Rhipicephalus sanguineus is, beyond doubt, the main urban tick pest. Having a very close affinity to dogs, this tick may inhabit kennels, yards and surrounding building-sites as well as human dwellings. When uncontrolled in kennels, populations of *R. sanguineus* may grow to exceedingly high levels. Great ecological plasticity is characteristic for this tick (Ioffe-Uspensky et al., 1997). Its capacity for starvation, however, is much lower than in argasid ticks. The tick is a three-host species but all parasitic stages can feed on one and the same dog. Under conditions of extreme closeness with dogs, the tick may develop by a two-host type (Uspensky and Ioffe-Uspensky, 2002). *R. sanguineus* is considered by many authors as not readily attacking humans but numerous cases of its attacks toward humans have been documented in various parts of the world. Undoubtedly, this tick has an obvious preference for dogs as hosts but when dogs are absent or under conditions of very high tick density even when dogs are available as hosts, adult *R. sanguineus* can very aggressively attack people. There are also many records of immature tick attacks on humans (Gilot et al., 1990; Merten and Durden, 2000) and the number of such attacks is obviously underestimated since the preadults are easily overlooked because of their small size.

The geographical range of this tick in nature is roughly limited by the latitudes of 50°N and 35°S (Filippova, 1997) but in Europe the distributional border runs more south, about 45°N. It includes all Mediterranean countries, as well as the southern parts of Ukraine and Russia (Siuda and Sebesta, 1997). However, the cases of tick findings in houses and even of prolonged existence of tick populations in human dwellings were reported from towns of much more northern countries: England, Austria, Germany, Denmark, Netherlands, Belgium, the Czech Republic, and Poland. Thus, in the Netherlands in the 1970s (Garben et al., 1980), *R. sanguineus* was found in houses in 16 towns and cities including Amsterdam and Rotterdam, in all parasitic stages, and in several cases the infestation continued for more than 1 year and even up to 3 years. The ticks were brought into the Netherlands with dogs mostly from Mediterranean countries but also from USA and Curaçao. It is essential that *R. sanguineus* cannot survive outside in cold climate of all these countries.

Rhipicephalus sanguineus is of great medical and veterinary significance being the vector and reservoir of many human and animal pathogens (Parola and Raoult, 2001; Uspensky, 2008). The most important is the group of bacteria now called the *Rickettsia conorii* complex which are causative agents of a number of similar human diseases known earlier as Mediterranean spotted fever (Parola et al., 2005). Recently, a focus of RMSF with *R. sanguineus* as the only vector was described in Arizona and later the DNA of *Rickettsia rickettsii* and *Bartonella henselae* were isolated from this tick collected near a suburban house in Riverside, California (Demma et al., 2005; Wikswo et al., 2007). Several new species of *Rickettsia* were also isolated from *R. sanguineus*, and *R. massiliae* was documented as a human pathogen (Parola et al., 2005). The brown dog tick was shown to harbor *Coxiella burnetii* (the causative agent of Q-fever) for many years after the death of the tick. *R. sanguineus* also transmits several agents pathogenic for dogs. The causative agent

of canine ehrlichiosis, *Ehrlichia canis*, originally described in the Mediterranean area, was later found worldwide, and today its distribution completely coincides with the tick range. *R. sanguineus* also transmits protozoan dog pathogens, such as *Babesia canis*, endemic in the U.S.A. and Africa, and *B. gibsoni* specific for the Far East and North Africa.

ROLE OF PETS IN TICK SURVIVAL AND DISPERSAL OF TICK-TRANSMITTED DISEASES IN URBAN AREAS

The process of urbanization has been connected with a sharp increase of urban pet populations both in developed and developing countries. Pets, or companion animals, mainly comprise dogs and cats. The population density of dogs is higher in urban than in rural areas by about one order of magnitude. Dogs are good hosts for many species of ticks. In fact, several species of ticks besides *R. sanguineus* have been called 'dog ticks': *I. canisuga* Johnston and *D. reticulatus* in Europe, *D. variabilis* in the United States. Cases in Siberian towns of bringing *I. persulcatus* ticks into houses by dogs after hunting in forest areas are common (personal observations). Since dogs are regularly taken by their owners to green areas and are often allowed to run about freely among the vegetation, they may collect any adult ticks that live in the area. Dogs may be good sentinel animals for ticks or tick-transmitted pathogens when ticks have been not registered or not studied in the area (Punda-Polić et al., 1995). Nonetheless, *R. sanguineus* is the main dog ectoparasite worldwide.

Cats are also known as hosts of *R. sanguineus* and several other tick species (Filippova, 1997); however, the data concerning their real involvement in tick feeding are absent. The role of cats as tick hosts should be considered more thoroughly since evidence of their close connection with ticks has been accumulating. More than 10 species of ticks were collected on domestic cats in Japan, *Ha. longicornis* and *I. ovatus* being mostly found in urban and suburban areas (Shimada et al., 2003). Several *Borrelia* species were detected in *Ixodes* ticks removed from dogs and cats (Hiraoka et al., 2007). Molecular evidence of several tick-transmitted pathogens was obtained for cats in the Barcelona area (Tabar et al., 2008). The mutual role of stray dogs and cats as potential reservoirs for *Hepatozoon canis*, a tick-borne parasite, with *R. sanguineus* as its definitive host was demonstrated (Jittapalapong et al. 2006). All this makes it possible to speculate that cats might be of greater importance as tick hosts than has been considered until now.

The occurrence of ticks and cases of tick-borne diseases are closely connected with the presence of pets: pet owners are more often attacked by ticks and suffer more often from tick-transmitted diseases than people without pets (Curran and Fish, 1989; Wilamowski et al., 1999; Uspensky and Ioffe-Uspensky, 2002; Demma et al., 2005). The pet owners should be considered as a group of high risk for tick attacks and infection with tick-transmitted pathogens. The less attention the owners pay to their animals, the higher is the risk. Homeless people in towns may be recognized as the group of highest risk. Many such people have dogs but pay them either minimal or no attention. A homeless person in Marseille who was bitten by 22 *R. sanguineus* ticks and died from Mediterranean spotted fever (Hemmersbach-Miller et al., 2004) is an extreme example of this kind.

CONCLUSION

Tick species having an advantage for life in urban areas are those that can use one and the same host at all parasitic stages, can starve for a prolonged time, can use as hosts either urban pests (rodents, birds, stray animals) or domesticated animals (pets, poultry), and can live in man-made constructions. The high reproductive rate of ticks is also to their advantage. The ticks of the genus *Argas* comply with practically all conditions necessary for successful survival in urban area. *R. sanguineus* corresponds to most of these conditions, exceeding soft ticks in its reproductive rate. Ticks living in nature are mostly three-host ticks needing different hosts at each parasitic stage. Conditions of modern urban environments meet tick requirements both in developing and developed countries. Appropriate conditions for tick existence may be found in many developing countries where numerous hosts of adult ticks are either preserved in individual properties or specially bred in small farms in suburban areas. In developed countries, the environmental protection and ecologically-based standards in the development of new areas create suitable conditions for

ticks living in nature. Such countries have green spaces inside urban areas, recreational or residential areas in the suburbs with increasing numbers of hosts including those which can amplify tick populations.

The ability of ticks to transmit numerous pathogens and the presence of many reservoir hosts in urban and suburban areas create constant danger for human population and for animals. The protection from tick attacks in urban areas is a very specific task as compared with the general problem of protection from tick-borne diseases. Indeed, a comprehensive database including all findings of ticks in a town is the first necessary step. All the findings should be drawn on the map to estimate the risk a particular area might have. The most threatened areas must be thoroughly inspected with subsequent regular monitoring. This primarily concerns recreational areas where thousands of people may rest precisely at the period of tick maximal activity. The task of soft tick control is easier as compared with that for hard ticks. The limitation of pigeon reproduction will reduce the risk of *Argas* penetration into dwellings and attacks on humans. Improved housing may provide sustainable protection against *Ornithodoros*. There is no such 'simple' solution for ixodid ticks. It is unrealistic to recommend such measures as application of acaricides or repellents. The only thing is obvious that urban inhabitants should be professionally informed about danger of tick attacks. It is necessary to constantly repeat this information by any possible way, especially during the tick activity season. The main target of this information must be pet owners who, as it was mentioned above, are in the group of high risk. Such measures as constant control of urban rodents and stray dogs and cats are highly desirable.

ACKNOWLEDGMENTS

I am greatly indebted to Dr. H.J. Schnur for her excellent linguistic assistance.

REFERENCES CITED

Abidov, Z.I., Vasilyeva, I.S., Rakhimov, N.R., and Parpiev, A.M. 1993. Tick-borne relapsing fever morbidity in the town of Namangan. Med. Parazitol. Parasit. Bolezni 1: 32-35 (in Russian).

Anderson, J.F. and Magnarelli, L.A. 1993. Natural history of *Borrelia burgdorferi* in vectors and vertebrate hosts. In: Ginsberg, H.S., ed. Ecology and Environmental Management of Lyme Disease, New Brunswick: Rutgers Univ. Press.

Anderson, J.F., Magnarelli, L.A., LeFebvre, R.B., Andreadis, T.G., McAninch, J.B., Perng, G.-C., and Johnson, R.C. 1989. Antigenically variable *Borrelia burgdorferi* isolated from cottontail rabbits and *Ixodes dentatus* in rural and urban areas. J. Clin. Microbiol. 27: 13-20.

Angelov, L., Dimova, P., and Berbencova, W. 1996. Clinical and laboratory evidence of the importance of the tick *Dermacentor marginatus* as a vector of *B. burgdorferi* in some areas of sporadic Lyme disease in Bulgaria. Eur. J. Epidemiol. 12: 499-502.

Anonymous. 1995. Information on tick-borne encephalitis morbidity. Mebiur 1: 12 (in Russian).

Anonymous. 2006. Severe tick-borne relapsing fever in the Tahoe basin. Vector News, Winter 2005-2006: 4 http://www.washoecounty.us/health/ehs

Antykova, L.P. and Kurchanov, V.I. 2002. Tick-borne encephalitis and Lyme disease epidemiology in Saint-Petersburg. EpiNorth 3: 7-9.

Barbour, A.G. 2005. Relapsing fever. . In: Goodman, J.L., Dennis, D.T., and Sonenshine, D.E., eds. Tick-Borne Diseases of Humans, Washington, D.C.: ASM Press.

Bašta, J., Plch, J., Hulínská, D., and Daniel, M. 1999. Incidence of *Borrelia garinii* and *Borrelia afzelii* in *Ixodes ricinus* ticks in an urban environment, Prague, Czech Republic, between 1995 and 1998. Eur. J. Clin. Microbiol. Infect. Dis. 18: 515-517.

Battaly, G.R. and Fish, D. 1993. Relative importance of bird species as hosts for immature *Ixodes dammini* (Acari: Ixodidae) in a suburban residential landscape of southern New York State. J. Med. Entomol. 30: 740-747.

Bénoit-Bazill, H. 1909. L'*Argas reflexus* (Fabr.) et son parasitisme chez l'homme. Mém. Soc. Zool. France 22: 261-280.

Bradley, C.A. and Altizer, S. 2007. Urbanization and the ecology of wildlife diseases. Trends Ecol. Evol. 22: 95-102.

Buczek, A. and Solarz, K. 1993. Attacks on people by *Argas reflexus* (Ixodida, Argasidae) — harmful parasites for humans and animals. Pol. Tyg. Lek. 48: 238-239 (in Polish).

Bulke, A. 2006. Deadly killers-paralysis ticks. Dogs NSW.http://www.dogsnsw.org.au/ticks-deadly-killers.

Charrel, R.N., Fagbo, S., Moureau, G., Alqahtani, M.H., Temmam, S., and de Lamballerie, X. 2007. Alkhurma hemorrhagic fever virus in *Ornithodoros savignyi* ticks. Emerg. Infect. Dis. 13: 153-155.

Chernykh, P.A. and Kozlovskaia, O.L. 1976. Ectoparasites of murid rodents in human dwellings of Amur-side territories. Med. Parazitol Parazit. Dis. 45: 573-580 (in Russian).

Childs, J.E., Glass, G.E., and LeDuc, J.W. 1991. Rodent sightings and contacts in an inner-city population of Baltimore, Maryland, USA. Bull. Soc. Vector Ecol. 16: 245-255.

Comer, J.A., Paddock, C.D., and Childs, J.E. 2001. Urban zoonoses caused by *Bartonalla, Coxiella, Ehrlichia,* and *Rickettsia* species. Vector-Borne Zoonotic Dis. 1: 91-118.

Comstedt, P., Bergström, S., Olsen, B., Carpmo, U., Marjavaara, L., Mejlon, H.,Barbour, A.G. and Bunikis, J. 2006. Migratory passerine birds as reservoirs of Lyme borreliosis in Europe. Emerg. Infect. Dis. 12: 1087-1095.

Curran, K.L. and Fish, D. 1989. Increased risk of Lyme disease for cat owners. N. Engl. J. Med. 320: 183.

Daniels, T.J., Falco, R.C., Schwartz, I., Varde, S., and Robbins, R.G. 1997. Deer ticks (*Ixodes scapularis*) and the agents of Lyme disease and human granulocytic ehrlichiosis in a New York City park. Emerg. Infect. Dis. 3: 353-355.

Dautel, H. and Kahl, O. 1999. Ticks (Acari: Ixodoidea) and their medical importance in the urban environment. In: Proceedings of the 3rd International Conference on Urban Pests. Prague, Czech Republic: Czech University of Agriculture, pp.73-82.

Dautel, H., Kahl, O., and Knülle, W. 1991. The soft tick, *Argas reflexus* (Acari, Argasidae) in urban environments and its medical significance in Berlin (West). J. Appl. Entomol. 11: 380-390.

Dautel, H., Dippel, C., Oehme, R., Hartelt, K. 2006. Evidence for an increased geographical distribution of *Dermacentor reticulatus* in Germany and detection of *Rickettsia* sp. RpA4. Int. J. Med. Microbiol. 296 (Suppl. 40): 149-156.

Demma, L.J., Traeger, M.S, Nicholson, W.L., Paddock, C.D., Blau, D.M, Eremeeva, M.E., Dasch, G.A., Levin, M.L., Singleton Jr., J., Zaki, S.R., Cheek, J.E., Swerdlow, D.L., and McQuiston, J.H. 2005. Rocky Mountain spotted fever from an unexpected tick vector in Arizona. N. Engl. J. Med. 353: 587-594.

Daniel, M. and Černý, V. 1990. Occurrence of the tick *Ixodes ricinus* (L.) under the conditions of anthropopressure. Folia Parasitol. 37: 183-186.

Dusbábek, F. 1985. Identity of *Argas* (*Argas*) *polonicus* populations in Czechoslovakia and Poland. Folia Parasitol. (Praha) 32: 163-171.

Dworkin, M.S., Shoemaker, P.C., Fritz, C.L., Dowell, M.E., and Anderson, D.E., Jr. 2002. The epidemiology of tick-borne relapsing fever in the United States. Am. J. Trop. Med. Hyg. 66: 753-758.

Egorov, I.Y., Ochirov, Y.D., Vershinin, E.A., Androsov, I.A., and Mironchuk, Y.V. 1996. Contacts of the human population of the Sakha Republic (Yakutia) with the tick *Ixodes persulcatus* Sch., 1930. Med. Parazitol. Parazit. Bolezni 2: 37-40 (in Russian).

Ellis, B.A., Regnery, R.L., Beati, L., Bacellar, F., Rood, M., Glass, G.G., Marston, E., Ksiazek, T.G., Jones, D., and Childs, J.E. 1999. Rats of the genus *Rattus* are reservoir hosts for pathogenic *Bartonella* species: an Old World origin for a New World disease? J. Infect. Dis. 180: 220-224.

Falko, R.C. and Fish, D. 1988. Prevalence of *Ixodes dammini* near the homes of Lyme disease patients in Westchester County, New York. Am. J. Epidemiol. 127: 826-830.

Falko, R.C. and Fish, D. 1989. Potential for exposure to tick bites in recreational parks in a Lyme disease endemic area. Am. J. Public Health 79: 12-15.

Filippova, N.A. 1966. Argasid Ticks (Argasidae). Fauna of USSR, Arachnoidea 4(3), Moskva-Leningrad: 'Nauka' (in Russian).

Filippova, N.A. 1997. Ixodid Ticks of Subfamily Amblyomminae. Fauna of Russia and neighbouring countries, Arachnoidea 4(5), St. Petersburg: 'Nauka' (in Russian).

Filippova, N.A., Wilamowski, A., Bromley-Schnur, H., and Uspensky, I. 1999. Ticks of the subgenus *Argas* and findings of *Argas latus* in Israel. Med. Vet. Entomol. 13: 212-213.

Garben, A.F.M., Bosman, B.T., and van Bronswijk, J.E.M.H. 1980. The brown dog tick *Rhipicephalus sanguineus* Latreille in the Netherlands, and analysis of imported cases including their veterinary and medical significance. Tijdschr. Diergeneesk. 105: 192-203 (in Dutch).

Gern, L., Toutoungi, L.N., Hu, C.M., and Aeschlimann, A. 1991. *Ixodes* (*Pholeoixodes*) *hexagonus*, an efficient vector of *Borrelia burgdorferi* in the laboratory. Med. Vet. Entomol. 5: 431-435.

Gern, L., Rouvinez, E., Toutoungi, L.N., and Godfroid, E. 1997. Transmission cycle of *Borrelia burgdorferi* sensu lato involving *Ixodes ricinus* and/or *I. hexagonus* ticks and the European hedgehog, *Erinaceus europaeus*, in suburban and urban areas in Switzerland. Folia Parasitol. 44: 309-314.

Ghirotti, M. 1999. Making better use of animal resources in a rapidly urbanizing world: a professional challenge. World Animal Rev. 92-1999/1. http://www.fao.org/docrep/x1700t/x1700t02.htm

Gilot, B., Laforge, M.L., Pichot, J., and Raoult, D. 1990. Relationships between the *Rhipicephalus sanguineus* complex ecology and Mediterranean spotted fever epidemiology in France. Eur. J. Epidemiol. 6: 357-362.

Goldstein, G. 1990. Urbanization, health and well-being: a global perspective. The Statistician 39: 121-133.

Goodman, J.L., Dennis, D.T., and Sonenshine, D.E., eds. 2005. Tick-Borne Diseases of Humans, Washington, DC: ASM Press.

Gordon, B.M. and Giza, C.C. 2004. Tick paralysis presenting in an urban environment. Pediatr. Neurol. 30: 122-124.

Gratz, N.G. 1999. Urbanization, arthropod and rodent pests and human health. *In*, Proceedings of the 3rd International Conference on Urban Pests. Prague, Czech Republic: Czech University of Agriculture, pp.51-58.

Gray, J.S., Kahl, O., Janetzki-Mittman, C., Stein, J., and Guy, E. 1994. Acquisition of *Borrelia burgdorferi* by *Ixodes ricinus* ticks fed on the European hedgehog, *Erinaceus europaeus* L. Exp. Appl. Acarol. 18: 485-491.

Guillaume, M. 2006. Record morbidity in Africa from borreliosis, or relapsing fever. News-Medical.Net http://www.news-medical.net/?id=19835

Halliday, R.B. and Sutherst, R.W. 1990. An Australian record of the American dog tick *Dermacentor variabilis*, and the risk of its establishment outside North America. Exp. Appl. Acarol. 8: 65-70.

Hemmersbach-Miller, M., Parola, P., Raoult, D., and Brouqui, P. 2004. A homeless man with maculopapular rash who died in Marseille, France. Clin. Infect. Dis. 38: 1493-1494.

Hercík, K., Hášová, V., Janeček, J., and Branny, P. 2007. Molecular evidence of *Bartonella* DNA in ixodid ticks in Czechia. Folia Microbiol. 52: 503-509.

Hiraoka, H., Shimada, Y., Sakata, Y., Watanabe, M., Itamoto, K., Okuda, M., Masuzawa, T., and Inokuma, H. 2007. Detection of *Borrelia garinii, Borrelia tanukii* and *Borrelia* sp. closely related to *Borrelia valaisiana* in *Ixodes* ticks removed from dogs and cats in Japan. Vet. Parasitol. 144: 188-192.

Holman, M.S., Caporale, D.A., Goldberg, J., Lacombe, E., Lubelczyk, C., Rand, P.W., and Smith, R.P. 2004. *Anaplasma phagocytophilum. Babesia microti,* and *Borrelia burgdorferi* in *Ixodes scapularis*, Southern Coastal Maine. Emerg. Infect. Dis. 10: 744-746.

Hoogstraal, H., Clifford, C.M., and Keirans, J.E. 1979a. The *Ornithodoros (Alectorobius) capensis* group (Acarina: Ixodoidea: Argasidae) of the Palearctic and Oriental Regions. *O. (A.) coniceps* identity, bird and mammal hosts, virus infections, and distribution in Europe, Africa, and Asia. J. Parasitol. 65: 395-407.

Hoogstraal, H., Clifford, C.M., Keirans, J.E., and Wassef, H.Y. 1979b. Recent developments in biomedical knowledge of *Argas* ticks (Ixodoidea: Argasidae). *In*, Rodriguez, J.G., ed. Recent Advances in Acarology, Vol. 2, New York: Academic Press, pp. 269-278.

Hoogstraal, H., Salah, A.A., and Kaiser, M.N. 1954. Summary of the known distribution and biology of *Ornithodoros erraticus* (Lucas, 1849) (Ixodoidea, Argasidae) in Egypt. J. Egypt. Public Health Assoc. 29: 127-138.

Hubálek, Z., Halouzka, J., and Juřicová, Z. 1993. Prevalence of borreliae in *Ixodes ricinus* ticks from urban parks. Folia Parasitol. 40: 236.

Humair, P.-F. 2002. Birds and *Borrelia*. Int. J. Med. Microbiol. 291 (Suppl. 33): 70-74.

Ioffe-Uspensky, I., Mumcuoglu, K.Y., Uspensky, I., and Galun, R. 1997. *Rhipicephalus sanguineus* and *R. turanicus* (Acari: Ixodidae): closely related species with different biological characteristics. J. Med. Entomol. 34: 74-81.

Jaenson, T.G.T. and Tälleklint, L. 1992. Incompetence of roe deer as reservoirs of the Lyme borreliosis spirochete. J. Med. Entomol. 29: 813-817.

Jaenson, T.G.T., Tälleklint, L., Lundqvist, L., Olsen, B., Chirico, J., and Mejlon, H. 1994. Geographical distribution, host associations, and vector roles of ticks (Acari: Ixodidae, Argasidae) in Sweden. J. Med. Entomol. 31: 240-256.

Jittapalapong, S., Rungphisutthipongse, O., Maruyama, S., Schaefer, J.J. and Stich, R.W. 2006. Detection of *Hepatozoon canis* in stray dogs and cats in Bangkok, Thailand. Ann. N.Y. Acad. Sci. 1081: 479-488.

Junttila, J., Peltomaa, M., Soini, H., Marjamäki, M., and Viljanen, M.K. 1999. Prevalence of *Borrelia burgdorferi* in *Ixodes ricinus* ticks in urban recreational areas of Helsinki. J. Clin. Microbiol. 37: 1361-1365.

Kahl, O. and Radda, A.C. 1988. Occurrence of tick-borne encephalitis (TBE) virus in Berlin (West). Zbl. Bakt. Hyg. A268: 482-486.

Kahl, O., Schmidt, K., Schönberg, A., Laukamm-Josten, U., Knülle, W., and Bienzle, U. 1989. Prevalence of *Borrelia burgdorferi* in *Ixodes ricinus* ticks in Berlin (West). Zbl. Bakt. Hyg. A270: 434-440.

Khalil, G.M. 1979. The subgenus *Persicargas* (Ixodoidea: Argasidae: *Argas*). 31. The life cycle of *A.* (*P.*) *persicus* in the laboratory. J. Med. Entomol. 16: 200-206.

Kleine-Tebbe, J., Heinatz, A., Gräser, I., Dautel, H., Hansen, G.N., Kespohl, S., Rihs, H.-P., Raulf-Heimsoth, M., Vater, G., Rytter, M., and Haustein, U.-F. 2006. Bites of the European pigeon tick (*Argas reflexus*): risk of IgE-mediated sensitizations and anaphylactic reactions. J. Allergy Clin. Immunol. 117: 190-195.

Korenberg, E., Černý, V., and Daniel, M. 1984. Occurrence of ixodid ticks — the main vectors of tick-borne encephalitis virus in urbanized territory. Folia Parasitol. (Praha) 31: 365-370.

Labuda, M. and Nuttall, P.A. 2004. Tick-borne viruses. Parasitology 129: S221-S245.

Maetzel, D., Maier, W.A., and Kampen, H. 2005. *Borrelia burgdorferi* infection prevalence in questing *Ixodes ricinus* ticks (Acari: Ixodidae) in urban and suburban Bonn, western Germany. Parasitol. Res. 95: 5-12.

Magnarelli, L.A., Denicola, A., Stafford III, K.C., and Anderson, J.F. 1995. *Borrelia burgdorferi* in an urban environment: white-tailed deer with infected ticks and antibodies. J. Clin. Microbiol. 33: 541-544.

Maiwald, M., Petney, T.N., Brückner, M., Krämer, C., Röhler, B., Beichel, E., und Hassler, D. 1995. Untersuchungen zur natürlichen Epidemiologie der Lyme-Borreliose anläßlich des gehäuften Auftretens von Erkrankungen in einem Vorort einer nordbadischen Gemeinde. Gesundheitswesen 57: 419-425.

Mans, B.J., Gothe, R., and Neitz, A.W.H. 2004. Biochemical perspectives on paralysis and other forms of toxicosis caused by ticks. Parasitology 129: S95-S111.

Mans, B.J., Steinmann, C.M.L., Venter, J.D., Louw, A.I., and Neitz, A.W.H. 2002. Pathogenic mechanisms of sand tampan toxicosis induced by the tick, *Ornithodoros savignyi*. Toxicon 40: 1007-1016.

Matuschka, F.-R., Lange, R., Spielman, A., Richter, D., and Fischer, P. 1990. Subadult *Ixodes ricinus* (Acari: Ixodidae) on rodents in Berlin, West Germany. J. Med. Entomol. 27: 385-390.

McGarry, J.W., McCall, P.J., and Welby, S. 2001. Arthropod dermatoses acquired in the UK and overseas. Lancet 357: 2105-2106.

Merdivenci, A. 1968. *Ornithodoros coniceps* (Canestrini, 1890) infestation in man in Istanbul. Tip. Fak. Mecm. 31: 460-468 (in Turkish).

Merten, H.A. and Durden, L.A. 2000. A state-by-state survey of ticks recorded from humans in the United States. J. Vector Ecol. 25: 102-113.

Michalik, J., Hofman, T., Buczek, A., Skoracki, M., and Sikora, B. 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.

Mohr, K., Leirs, H., Katakweba, A. and Machang'u, R. 2007. Monitoring rodentsmovements with a biomarker around introduction and feeding foci in an urban environment in Tanzania. Afr. Zool. 42: 294-298.

Morozova, O.V., Cabello, F.C., and Dobrotvorsky, A.K. 2004. Semi-nested PCR detection of *Bartonella henselae* in *Ixodes persulcatus* ticks from Western Siberia, Russia. Vector-Borne Zoonotic Dis. 4: 306-309.

Müller-Doblies, U.U. and Wikel, S.K. 2005. The human reaction to ticks. In: Goodman, J.L., Dennis, D.T., and Sonenshine, D.E., eds. Tick-Borne Diseases of Humans, Washington, DC: ASM Press.

Neitzel, D.F., Jarnefeld, J.L., and Sjogren, R.D. 1993. An *Ixodes scapularis* (deer tick) distribution study in the Minneapolis-St. Paul, Minnesota area. Bull. Soc. Vector Ecol. 18: 67-73.

Nijhof, A.M., Bodaan, C., Postigo, M., Nieuwenhuijs, H., Opsteegh, M., Franssen, L., Jebbink, F., and Jongejan, F. 2007. Ticks and associated pathogens collected from domestic animals in the Netherlands. Vector-Borne Zoonotic Dis. 7: 585-595.

Ostfeld, R.S. and Keesing, F. 2000. Biodiversity and disease risk: the case of Lyme disease. Conserv. Biol. 14: 722-728.

Parola, P. and Raoult, D. 2001. Ticks and tickborne bacterial diseases in humans: an emerging infectious threat. Clin. Infect. Dis. 32: 897-928.

Parola, P., Paddock, C.D., and Raoult, D. 2005. Tick-borne rickettsiosis around the World: emerging diseases challenging old concepts. Clin. Microbiol. Rev. 18: 719-756.

Pejchalova, K., Žákovská, A., Mejzlíková, M., Halouzka, J., and Dendis, M. 2007. Isolation, cultivation and identification of *Borrelia burgdorferi* genospecies from *Ixodes ricinus* ticks from the city of Brno, Czech Republic. Ann. Agric. Environ. Med. 14: 75-79.

Petney, T.N., Andrews, R.H., McDiarmid, L.A., and Dixon, B.R. 2004. *Argas persicus* sensu stricto does occur in Australia. Parasitol. Res. 93: 296-299.

Punda-Polić, V., Bradarić, N., Klišmanić-Nuber, Z., Mrljak, V., and Giljanović, M. 1995. Antibodies to spotted fever group rickettsiae in dogs in Croatia. Eur. J. Epidemiol. 11: 389-392.

Rebaudet, S. and Parola, P. 2006. Epidemiology of relapsing fever borreliosis in Europe. FEMS Immunol Med. Microbiol. 48: 11-15.

Robinson, W.H. 2005. Handbook of Urban Insects and Arachnids, Cambridge: Cambridge University Press.

Romanenko, V.N. 2005. Specific features of biology of ixodid ticks inhabiting the vicinity of the town of Tomsk. Parazitologiya 39: 365-370 (in Russian).

Salgo, M.P., Telzak, E.E., Currie, B., Perlman, D.C., Litman, N., Levi, M., Nathenson, G., Benach, J.L., Al-Hafidh, R. and Casey, J. 1988. A focus of Rocky Mountain spotted fever within New York City. N. Engl. J. Med. 318: 1346-1348.

Sanogo, Y.O., Zeaiter, Z., Caruso, G., Merola, F., Shpynov, S., Brouqui, P., and Raoult, D. 2003. *Bartonella henselae* in *Ixodes ricinus* ticks (Acari: Ixodidae) removed from humans, Belluno province, Italy. Emerg. Infect. Dis. 9: 329-332.

Sexton D.J., Burgdorfer, W., Thomas, L., and Norment, B.R. 1976. Rocky Mountain spotted fever in Mississippi: survey for spotted fever antibodies in dogs and for spotted fever group rickettsiae in dog ticks. Am. J. Epidemiol. 103: 192-197.

Shah, A.H., Khan, M.N., Iqbal, Z., Sajid, M.S., and Akhtar, M.S. 2006. Some epidemiological aspects and vector role of tick infestation on layers in the Faisalabad district (Pakistan). World's Poultry Sci. J. 62: 145-157.

Shimada, Y., Inokuma, H., Beppu, T., Okuba, M., and Onishi, T. 2003. Survey of ixodid tick species on domestic cats in Japan. Vet. Parasitol. 111: 231-239.

Shimizu, I., Mitani, H., Shono, M., Omoya, T., Musashi, Y., Sannomiya, K., Suzuki, M., Horie, T., Honda, H., and Ito, S. 2000. An incident involving blood sucking by a tick in a suburb in Japan. J. Med. Invest. 47:145-147.

Siński, E. and Rijpkema, S.G. 1997. Prevalence of *Borrelia burgdorferi* infection in *Ixodes ricinus* ticks in urban and suburban forest habitats. Przegl. Epidemiol. 51: 431-435 (in Polish).

Siuda, K. and Sebesta, R. 1997. Central European ticks — a zoogeographical review (Acari: Ixodida). Genus 8: 115-133.

Siuda, K., Hoogstraal, H., Clifford, C.M., and Wassef, H.Y. 1979. Observations on the subgenus *Argas* (Ixodoidea: Argasidae: *Argas*). 17. *Argas* (*A.*) *polonicus* sp.n. parasitizing domestic pigeons in Krakow, Poland. J. Parasitol. 65: 170-181.

Siuda, K., Jarosz, Z., and Norek, L. 1982. The case of attack of trumpeters in St. Mary's Church in Krakow by the tick *Argas* (*Argas*) *polonicus* Siuda, Hoogstraal, Clifford et Wassef, 1979 (Acarina, Ixodides, Argasidae). Wiadom. Parazytol. 28: 57-62 (in Polish).

Sonenshine, D.E. 1993. Biology of Ticks, Vol. 2, New York: Oxford University Press.

Sréter, T., Széil, Z., and Varga, I. 2005. Spatial distribution of *Dermacentor reticulatus* and *Ixodes ricinus* in Hungary: evidence for change? Vet. Parasitol. 128: 347-351.

Stańczak, J., Gabre, R.M., Kruminis-Łozowska, W., Racewicz, M., and Kubica-Biernat, B. 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.

Steere, A.C. 1994. Lyme disease: a growing threat to urban populations. Proc. Natl. Acad. Sci. USA 91: 2378-2383.

Stein, A. and Raoult, D. 1999. Pigeon pneumonia in Provence: a bird-borne Q-fever outbreak. Clin. Infect. Dis. 29: 617-620.

Tabar, M.-D., Altet, L., Francino, O., Sánchez, A., Ferrer, L., and Roura, X. 2008. Vector-borne infections in cats: molecular study in Barcelona area (Spain). Vet. Parasitol. 151: 332-336.

Telford III, S.R., Mather, T.N., Moore, S.I., Wilson, M.L., and Spielman, A. 1988. Incompetence of deer as reservoirs of the Lyme disease spirochete. Am. J. Trop. Med. Hyg. 39: 105-109.

Uspensky, I. 2008. Brown dog tick (or kennel tick), *Rhipicephalus sanguineus* (Latreille) (Acari: Ixodida: Ixodidae). *In*, Capinera, J. L., ed. Encyclopedia of Entomology, 2nd Ed., Vol. 1, Dordrecht: Springer.

Uspensky, I. and Ioffe-Uspensky, I. 2002. The dog factor in brown dog tick *Rhipicephalus sanguineus* (Acari: Ixodidae) infestations in and near human dwellings. Int. J. Med. Microbiol. 291 (Suppl. 33): 156-163.

Uspensky, I., Garruto, R.M., and Goldfarb, L. 2003. The taiga tick *Ixodes persulcatus* (Acari: Ixodidae) in the Sakha Republic (Yakutia) of Russia: distributional and reproductive ranges. J. Med. Entomol. 40: 119-122.

Uspensky, I. V., Koltunov, V.V., and Dineva, A. I. 1974. Tick-borne encephalitis and prospects for its prevention in the area of Zeya HEPS construction. Med. Parazitol. Parazit. Dis. 43: 528-537 (in Russian).

Uspensky, I., Wilamowski, A., and Bromley-Schnur, H. 1997. *Dermacentor variabilis* in Israel. Vector Ecol. Newsletter 28(3): 9-10.

Vatansever, Z., Gargili, A., Aysul, N.S., Sengoz, G., and Estrada-Peña, A. 2008. Ticks biting humans in the urban area of Istanbul. Parasitol. Res. 102 http://www.springerlink.com/content/4320267828173l42/fulltext.pdf

Vourc'h, G., Marmet, J., Chassagne, M., Bord, S., and Chapuis, J.-L. 2007. *Borrelia burgdorferi* sensu lato in Siberian chipmunks (*Tamias sibiricus*) introduced in suburban forests in France. Vector Borne Zoonotic Dis. 7: 637-642.

White, D.J. and Flynn, M.K. 1990. Rocky Mountain spotted fever in New York State. Ann. N.Y. Acad. Sci. 590: 248-255.

Vial, L., Wieland, B., Jori, F., Etter, E., Dixon, L., and Roger, F. 2007. African swine fever virus DNA in soft ticks, Senegal. Emerg. Infect. Dis. 13: 1928-1931.

Wikswo, M.E., Hu, R., Metzger, M.E., and Eremeeva, M.E. 2007. Detection of *Rickettsia rickettsii* and *Bartonella henselae* in *Rhipicephalus sanguineus* ticks from California. J. Med. Entomol. 44: 158-162.

Wilamowski, A., Bromley-Schnur, H.J., Ioffe-Uspensky, I., and Uspensky, I. 1999. Ticks (Ixodoidea) in Israeli towns. In: Proceedings of the 3rd International Conference on Urban Pests. Prague, Czech Republic: Czech University of Agriculture, pp.477-483.

Wright, S.A. 2000. The western black-legged tick and Lyme disease in California's Sierra Nevada foothills. Vector Ecol. Newsletter 31(1): 10-12.

Zahler, M., Steffenz, T., Lutz, S., Hähnel, W.-C., Rinder, H., and Gothe, R. 2000. *Babesia canis* und *Dermacentor reticulatus* in München, ein neuer Naturherd in Deutschland. Tierarztl. Prax. 28(K): 116-120.