TICKS (ACARI: IXODOIDEA) AND THEIR MEDICAL IMPORTANCE IN THE URBAN ENVIRONMENT

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Abstract - Ticks (Acari: Ixodoidea) are worldwide prominent pests as haematophagous parasites on humans and domestic animals. This paper emphasizing the central European situation, outlines the biology and the medical significance of four tick species which have often succeeded to colonize suburban environments, and describes the ecological circumstances of their occurrence. Tick species found in towns in central Europe are *Argas reflexus* (Argasidae), and *Ixodes ricinus* and *I. hexagonus* (Ixodidae). *Rhipicephalus sanguineus*, is occasionally transported unrecognized on pet dogs from southern countries to central Europe. *A. reflexus* was originally a Mediterranean species. Under central European conditions it lives exclusively in human buildings with nearby nesting feral pigeons. If the natural host is not available, humans are bitten. *I. ricinus* is the main European vector of *Borrelia burgdorferi* s.l. and the tick-borne encephalitis (TBE) virus. This tick penetrates into towns by colonizing new and old „green islands“ in the urban environment, where the microclimatic humidity requirements are met, especially in the permanent leaf-litter of forest stands. Transportation of ticks into towns takes place on mobile vertebrate hosts, probably mainly on birds. *I. ricinus* adults are exclusively found on mammals. The rarity of these animals in towns, suburban hedgehogs seem to be most important for adult tick feeding. Suburban *I. ricinus* populations are frequently infected with *B. burgdorferi* and sometimes also with TBE-virus. *I. hexagonus* parasitizes members of the Carnivora and hedgehogs and is common in suburban locations in central Europe. It spends its non-parasitic phases in the burrows/nests of its hosts. Bites in humans are rare, and it is a proven vector of both *B. burgdorferi* and TBE virus, and might support the establishment of these agents in the urban environment.
Key words - Urban pest, Acari, Ixodoidea, *Borrelia burgdorferi*, TBE-virus

INTRODUCTION

Ticks (Acari: Ixodoidea) are haematophagous ectoparasites of terrestrial vertebrates are notorious vectors of pathogens causing disease in animals and humans (Sonenshine, 1993). The >850 tick species known so far colonize highly diverse habitats, e.g. humid temperate and tropical forests, open grassland, deserts, continental cliff-site habitats, and remote islands harbouring sea bird colonies. Although many tick species primarily occur in natural habitats, others accept or even benefit from man-made environmental changes at least in parts of their distribution area (Hoogstraal, 1981). For example, *Boophilus* ticks are most prominent veterinary pests in numerous tropic and subtropic areas with an intensive cattle production (Uilenberg, 1992). *Amblyomma variegatum* (Fabricius), the vector of *Cowdria ruminantium*, causing heartwater in ruminants, was transported with African cattle to the Carribean islands and represents a permanent threat to the cattle industry in the Americas (Norval *et al.*, 1992). *Rhipicephalus sanguineus* (Latreille) and *Argas persicus* (Oken) have become cosmopolitan parasites of dogs and domestic fowl, respectively.

The aim of the present paper is to outline the biological features of four tick species, which have succeeded in colonizing different urban habitats in central Europe by different ways. Soft ticks: *Argas reflexus* (Fab.); hard ticks: *Ixodes ricinus* (L.) [castor bean tick], *I. hexagonus* Leach [hedgehog tick], *Rhipicephalus sanguineus* [brown dog tick]. Also the principal ecological circumstances which have allowed these ticks to successfully penetrate into urban areas will be dealt with. Last but not least, the medical importance of these tick species in the urban environment will be discussed.

URBAN ENVIRONMENT

From an ecological view, the urban environment is characterized by a mosaic-like pattern of heterogeneous habitats (Klausnitzer, 1987). Compared to the non-urban situation, the respective habitats are

Proceedings of the 3rd International Conference on Urban Pests.
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usually small or even fragmented and are very often subject to a varying degree of disturbance caused by human activities (Sukopp, 1990). The usually unstable and random pattern of suitable habitats in towns may favour organisms with a high colonization capability, i.e. high mobility and reproductive rate (Gilbert, 1991). In addition, a marked ecological adaptability, for example the ability to utilize diverse sorts of food or breeding resources, favours the survival in the highly unpredictable urban environment (Klausnitzer, 1987). On other hand, the accumulation of certain animal or plant products, as is common in modern towns, supports more specialized organisms. Concerning biotic conditions, towns often have an impoverished fauna, particularly regarding large vertebrates. Thus, the insufficient availability of suitable hosts might often be a major ecological constraint restricting the occurrence of ticks in the urban environment. Concerning abiotic conditions, many cities, at least in the temperate zone, exhibit a mean annual temperature of about 1-2° C above that of the nearby environs, and especially on sunny summer days, peak temperatures in the inner city can be elevated by up to almost 10°C (Sukopp, 1990). Such elevated temperatures can be advantageous for ectothermic organisms from warmer regions which colonize central European towns.

Argas reflexus

Argasid ticks generally occur in or close to the nests or resting places of their hosts, and most species are found in warm temperate or subtropical areas. One such species colonizing central European towns and originating from the Mediterranean/Near East is the pigeon tick, *A. reflexus*. This rather host specific species parasitizes the rock pigeon *Columba livia* (Gmelin) and its various domesticated forms as well as feral town pigeons *C. livia* var. *domestica*, which are worldwide a characteristic element of many towns. However, *A. reflexus* can also bite humans. The tick was probably introduced to central Europe together with its host. The first record from Germany dates from the 19th century (Boschulte, 1860), and at present *A. reflexus* lives in several European countries up to about 55°N (Dautel *et al.*, 1991). In central Europe, *A. reflexus* occurs only in or at buildings serving as pigeon breeding-sites and showing microclimatically elevated temperatures, especially in summer and autumn but not necessarily in winter. Such conditions are necessary for completion of the embryonic development of *A. reflexus*. At outside conditions in Berlin, Germany (52.5° N), the accumulated summer/autumn temperatures hardly permit hatching of the eggs before winter. However, in contrast to all postembryonic stages, the egg stage is unable to overwinter in this region. Thus, the temperature sum available at pigeon breeding sites for embryonic tick development very probably limits the northern distribution of *A. reflexus* (Dautel and Knülle, 1998a).

Beyond its geographical range, *A. reflexus* is replaced by other *Argas* species with very similar biological features, e.g. *A. polonicus* Siuda, Hoogstraal, Clifford and Wassef and *A. vulgaris* Filippova in the east (Siuda *et al.* 1979; Dusbábek, 1985) and *A. hermanni* Audouin in the south (Hoogstraal and Kohls, 1960), whereas there is no other *Argas* species in the north. The discovery of *A. polonicus* had the remarkable background that trumpeters were repeatedly annoyed by that tick when doing their job in the steeple tower of St. Mary’s Church of Krakow. It is remarkable that there are seemingly no soft ticks parasitizing urban pigeons in North America. A soft tick specifically infesting humans within their homes in central and southern Africa is *Ornithodoros moubata* (Murray), vector of *Borrelia recurrentis*, causing tick-borne relapsing fever (Hoogstraal, 1956).

In common with other town-colonizing arthropods, ticks have to manage their dispersal to suitable urban sites. In *A. reflexus*, the feeding larva is probably the dispersing stage. The larval blood meal lasts for about 6-11 days (Dusbábek and Rosický, 1976; Dautel and Knülle, 1997). Thus the feeding larva may easily be transported to a new breeding-site by its host and drops off at night. All nymphal instars (*A. reflexus* develops through a variable number of 2-4 nymphal instars) as well as the adults are nocturnal feeders taking blood from sleeping pigeons, for up to 12 h and therefore, postlarval stages might not have the opportunity to be transported to distant habitats.

A. reflexus has a relatively long minimum generation time of 2-4 years (Dautel and Knülle, 1997). Oviposition takes place in several relatively small batches and occurs over a period of several years.

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Hence, considerable numbers of ticks can only be found at localities with colonies of pigeons breeding for several years. Once established, however, *A. reflexus* is able to build up large populations. Mayer and Madel (1950) counted a total number of 23,640 nymphal and adult ticks at such a site where about 100 adult pigeons lived, and we also saw some Berlin localities with at least several thousand postlarval *A. reflexus* in a single attic room serving as pigeon breeding-sites for >10 years.

When pigeons are not sufficiently available or disappear completely (e.g. after local lockout or reduction/removal of pigeons), *A. reflexus* can leave their resting places, walk up to some tens of meters, invade nearby flats through windows, supply shafts, air ventilations, etc., and bite people. Because of the remarkable fasting capabilities of the nymphs and adults, which easily survive for 3-5 years and even longer without food (Dautel and Knülle, 1998b), *A. reflexus* bites can occur for several years after complete removal of the natural hosts from a particular site.

There is no evidence to date that *A. reflexus* transmits pathogens to humans in central Europe. This is also true for the spirochaete *Borrelia burgdorferi* s.l., the causative agent of Lyme borreliosis (Sambri *et al.*, 1994; Sinski *et al.*, 1994; Thormaelen, 1996; Dautel *et al.*, 1999), but investigations on other potential human pathogens in pigeon ticks are scarce. *A. reflexus* bites in humans cause more or less harmless local reactions, but sometimes secondary infections require medical treatment. Occasionally, a more serious IgE-mediated type-I allergy develops against *A. reflexus* after repeated tick-bites (Miadonna *et al.*, 1982). There are a number of recent reports describing human cases of a specific anti-*A. reflexus* allergy particularly from Italy, France and Germany (Albertini *et al.*, 1988; Tosti *et al.*, 1988; Bauch and Lübbe, 1990; Laubstein *et al.*, 1993; Trautmann *et al.*, 1995; Veraldi, 1996; Chappard *et al.*, 1996; Kleine-Tebbe *et al.*, 1999). Long-term obervations in Berlin revealed a total of 188 tick-infested buildings during the past ten years (Dautel *et al.*, 1999), and an even higher number of >1,000 infested buildings were reported from Leipzig (Vater, 1996). Both eastern German cities are characterized by a high number of damaged buildings, potential breeding-sites for pigeons. The situation is similar in certain parts of Poland, whereas *A. reflexus* locations might be more seldom in western and southern German cities.

The control of *A. reflexus* is rather difficult because of some outstanding morphological, physiological and ethological features of this species. These include a cuticle with an extremely low permeability for water vapour (Dautel, 1999) as well as the tick‚s ability to actively absorb water vapour from the air above 75-80% RH (relative humidity) when in need for water (Kahl, 1989), a capability shared with all other tick species investigated so far. Additionally, a low level of metabolism allowing the resting tick to close its spiracles for several hours (Kahl and Dautel, unpubl.) or perhaps even for days might help *A. reflexus* withstand the application of toxic gases. Last but not least, the tick‚s propensity to form long-term aggregations deep inside cracks (Dautel *et al.*, 1994) makes it often inaccessible to pesticides. The situation is particularly critical in tick-infested buildings redeveloped without any control measure. In such cases, large numbers of *A. reflexus* can be hidden, e.g. behind gypsum walls attached to the original tick-infested wall, and gradually leave their sheltered microhabitat to bite people. In such a situation, control measures can be extremely costly, because they make uncovering of the original wall necessary and possibly also the temporary evacuation of the inhabitants. Therefore, it is recommended by Berlin public health authorities to inspect pigeon-infested buildings scheduled for redevelopment for the presence of *A. reflexus* and to perform control measures before renovation, if living ticks are found. A successful control measure usually involves three stages: 1) the complete uncovering of all potential tick hiding places, 2) the application of a pyrethrum spray to expel ticks, followed by 3) the use of a propoxur-based contact pesticide. A second control measure is often indicated 3-4 months later because of the resistance of the egg stage (Scheurer and Dautel, 1994).

Rhipicephalus sanguineus

This hard tick species originates from African savannas with >30 cm annual precipitation. It has been distributed worldwide by human activities, and presently occurs from about 35°S to 50° N (Hoogstraal, 1956; Sonenshine, 1993). Although this tick parasitizes a wide range of small and medium-sized mam-

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mals as well as ground-feeding birds and lizards, it has a clear predilection for carnivores, particularly dogs (Hoogstraal, 1956). Like *A. reflexus*, also *R. sanguineus* in central Europe is usually bound to buildings, but it is almost exclusively found in association with dogs. The tick may survive in central Europe in the open during the vegetation period for several months but is unable to overwinter there. Even in Jerusalem (Israel), a more southern locality, while even there the immatures show more or less high mortalities during the winter months (Feldman-Muhsam, 1981). *R. sanguineus* is often introduced to central Europe when attached to pet dogs returning with their owners from holidays in southern Europe, the Near East, or northern Africa. Hoffmann (1981) found >300 localities infested with *R. sanguineus* in the former Berlin (West) between 1968 and 1979. Since this parasite is highly adapted to a warm and dry environment (Ioffe-Uspensky *et al.*, 1997), it can establish in flats all the year round. The off-host tick stages may hide in any kind of cracks there, often close to the sleeping or resting place of the dog. As a typical hard tick, it takes 3 substantial blood meals and may complete its life cyle (at 18-20°C) within approximately 6 months (Hoffmann, 1981). Thus, the increase of tick numbers is much faster than in *A. reflexus*, and heavy infestations can build up within only a few months after the introduction of only single adult female ticks.

R. sanguineus can transmit *Ehrlichia canis*, the causative agent of canine ehrlichiosis, *Rickettsia conorii*, causing Mediterranean spotted fever (Boutonneuse fever) and may also be a carrier of *Coxiella burnetii* causing Q-fever (Rehácek and Tarasevich, 1988; Goddard, 1989; Mumcuoglu *et al.*, 1993; Ioffe-Uspensky *et al.*, 1997). The tick also occasionally bites humans, and the clinical incidence of Mediterranean spotted fever has been reported as being 50/100,000 in Mediterranean countries (Raoult and Roux, 1997).

Ixodes hexagonus

As an endophilic tick, the hedgehog tick *I. hexagonus* spends most of the time inside the burrows or nests of its hosts but does not inhabit buildings. These protected field micro-environments provide rather stable temperature and constantly high humidity conditions which are necessary for the development and survival of the tick (Arthur, 1951; Honzakova, 1973). Beside the hedgehog *Erinaceus europaeus* (L.), carnivores like foxes and Mustelidae are the main natural hosts of this species (Arthur, 1953; Toutoungi *et al.*, 1991). In the urban environment, *I. hexagonus* is frequently found on hedgehogs in fairly high numbers but also infests cats and dogs (Gern *et al.*, 1991; Beichel *et al.*, 1996; Gern *et al.*, 1997; Pichot *et al.*, 1997). It occurs in several urban or suburban areas like private gardens, fallow land, city parks, and deciduous forest. Although foxes and Mustelidae can occasionally occur within towns (especially in suburbs), the hedgehog might be the main host of *I. hexagonus* in towns. Hedgehogs are very common in urban areas and people encourage them. Furthermore, they are highly protected animals by law, at least in Germany, a status that might also be beneficial to its parasite *I. hexagonus*.

Oviposition takes place at 3-30° C (Arthur, 1951), and a small proportion (≤1%) of the deposited eggs may often develop parthenogenetically (Toutoungi *et al.*, 1995). This might support survival of the hedgehog tick in a patchy population structure. Although development from the larva to the adult stage can be completed in the laboratory at 22-23° C within 2 months (Toutoungi *et al.*, 1993), the life cycle under natural conditions probably lasts several years. Toutoungi *et al.* (1993) observed that the highest proportion of larvae feeds only at an age of 11 months. Although the mortality of unfed larvae increased after >12 months in that laboratory study (at the unnaturally high temperature of 22 ºC), one of us (O.K.) observed living *I. hexagonus* larvae kept in undisturbed glass vials in the laboratory at 97% RH and 15 ºC more than 6 years after deposition of eggs. This indicates that *I. hexagonus* may well survive in suitable microhabitats even if the host availability is moderate or low, a feature comparable to that in postlarval *A. reflexus*.

I. hexagonus is a proven vector of the tick-borne encephalitis (TBE)-virus (Radda, 1973) and *B. burgdorferi* (Gern *et al.*, 1991; Toutoungi and Gern, 1993). Its host, the hedgehog, is a proven reservoir host of TBE-virus (Radda, 1973) and *B. burgdorferi* s.l. (Gray *et al.*, 1994; Gern *et al.*, 1997), and Gray (pers. comm.) found *B. afzelii* in *I. ricinus* larvae engorged on a field-collected hedgehog from Ireland. The infection rate with *B. burgdorferi* s.l. of unfed *I. hexagonus* collected in towns was about 3-7% (Liebisch and Olbrich, 1991). However, the medical significance of *I. hexagonus* is undoubtedly low because it only rarely bites humans (Arthur, 1953; Liebisch and Liebisch, 1996). On the other hand, *I. ricinus* and *I. hexagonus* can coexist in certain suburban and forested areas in towns (city parks, gardens, cemeteries, etc.) and co-feed on hedgehogs. In such a case, borreliae may leave the "silent" urban *I. hexagonus*/hedgehog-cycle and reach *I. ricinus*, the main vector tick of *B. burgdorferi* s.l., which parasitizes a wider range of reservoir hosts and can also pass on the infection to humans.

Ixodes ricinus

I. ricinus is the most common tick in many parts of Europe, occurring from northern Africa up to about 65° N and up to 60° E (Gray, 1991; Jaenson *et al.*, 1994). *I. ricinus* has intensively been studied, and much is known about many aspects of its biology and ecology, for example host association, seasonal activity, development, and diapause behaviour (e.g. Milne, 1949; Chmela, 1969; Balashov, 1972; Belozerov, 1982; Gigon, 1985; Kahl, 1989; Gray, 1991; Sonenshine, 1993; Daniel and Dusbábek, 1994). Free-living ticks only survive at places where the microclimatic RH does not fall below about 80% for extended periods of time (McLeod 1936; Kahl and Knülle, 1988). Such requirements are usually fulfilled in all seasons in the leaf litter of temperate deciduous forests containing oaks and/or beech trees, the preferred habitat of the species, but also in coniferous forest floor or grassland areas with sufficient rainfall (Daniel *et al.*, 1998; Gray *et al.*, 1998). The marked requirement for high humidity by the off-host stages restricts the occurrence of *I. ricinus* in towns to a few types of habitat, e.g. naturally laid out city parks, gardens, cemeteries etc. At such sites, *I. ricinus* has been found in significant numbers in several towns of the Czech Republic (Daniel and Cerny, 1990), England (Guy and Farquar, 1991), Austria (Sixl *et al.*, 1981; Radda, pers. comm.), and Germany (Matuschka *et al.*, 1990; Kahl *et al.*, 1992; Bauch, 1993; Plate, 1993). The most limiting biotic factor for *I. ricinus* in urban environments is the availability of medium-sized and large mammals as hosts of the adult stage. Small mammals and birds are common hosts of immature *I. ricinus* but not of adults. Although deer are important hosts in suburban forested areas, they are usually not present in inner-city forested sites. Wild boar invade suburban areas or sometimes also inner-city forested areas (as, for example, in Berlin), but its pronounced rooting activities in the leaf litter might be a threat for all free-living stages of *I. ricinus*. Therefore, hedgehogs, and perhaps also foxes, might be the main hosts for adult *I. ricinus* in central European urban habitats. In concordance with this, we consistently found ticks in only relatively low densities in inner-city locations when compared to forested areas in the periphery or the environs of Berlin with deer (Kahl, Stein and Janetzki-Mittmann, unpubl.). Plate (1993), however, found high numbers of *I. ricinus* in a certain inner city garden of Hannover (Germany), where only hedgehogs were available as hosts of adult ticks. This example nicely illustrates that this insectivore host alone can feed sufficient numbers of adult *I. ricinus* to establish an independent population, if the abiotic conditions for the free-living tick stages are favourable.

Since free-living *I. ricinus* do not walk horizontal distances >10-15 m (Balashov, 1972), the only conceivable way for *I. ricinus* to colonize suitable isolated inner-city habitats is transportation of feeding ticks (larvae, nymphs) by hosts with birds as primary candidates (cf. Hoogstraal *et al.*, 1961, 1964; Olsén *et al.*, 1995). Humair *et al.* (1993) and Hubalek *et al.* (1996) found a high infestation rate of ground-foraging birds by *I. ricinus* larvae and nymphs. Similar observations were made for the closely related *I. scapularis* Say in North America (Rand *et al.*, 1998).

Unless unfed larvae can be found in an area, it is unlikely that there is a more or less independent local population. In such a case, it is much more likely that the occurrence of ticks is largely based on a continuous arrival of engorged tick individuals from other areas which can survive for some time, perhaps even moult to the next stage, quest, and nymphs (but not adults) also find a host. Thus, even small localities may support the survival of individual or low numbers of ticks but do not permit the establishment of an independent population.

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I. ricinus is the most prominent vector tick in Europe with a long list of human pathogenic organisms, among them at least 5 different *B. burgdorferi* genospecies (see Hubálek and Halouzka, 1997; Kurtenbach *et al.*, 1999), the TBE-virus (Nuttall and Labuda, 1994), *Babesia divergens*, the agent of bovine babesiosis (Gray, 1991) and *Ehrlichia* (Granström, 1999, in press). There are at least 16 species of small and medium-sized mammals as well as 19 bird species known as reservoirs of *B. burgdorferi* s.l., whereas 7 ungulate mammals like cattle, deer and sheep are very probably no reservoirs (Gern *et al.*, 1998). Proven reservoir hosts of *B. burgdorferi* s.l. that also occur in urban or suburban areas are, e.g., the brown rat, *Rattus norvegicus* (Berkenhout), the black-striped mouse, *Apodemus agrarius (*Pallas), the hedgehog, the red squirrel, *Sciurus vulgaris* L., and some common synanthropic bird species, the blackbird, *Turdus merula* L., the song thrush, *Turdus philomelos* Brehm, and the robin, *Erithacus rubecula* L. Small and medium-sized mammals are also principal reservoir hosts (or co-feeding hosts) of the TBE-virus (see Radda, 1973; Nuttall and Labuda, 1994). Infection rates of host-seeking *I. ricinus* nymphs with *B. burgdorferi* s.l. vary widely from <5% to about 50% (mean: 8-10%) depending on the habitat, whereas adult tick infection rates are usually higher (mean: 16-17%) (Gray *et al.*, 1998; Hubalek and Halouzka, 1998).

Due to the presence of *I. ricinus* and several reservoir hosts both of *B. burgdorferi* s.l. and the TBE-virus, there is consequently also a risk of acquiring tick-borne diseases in the urban environment. Three strains of TBE-virus were isolated from >10,000 *I. ricinus* from Prague, Czech Republic, (Rosicky and Daniel, 1978), and a further strain was isolated from a total of 4,302 Prague ticks by Malkova *et al.* (1983). In Berlin, 4,593 unfed *I. ricinus* nymphs and adults collected in forest locations in 1978, 1979 and 1986 were examined for TBE-virus. There was one positive pool of 5 adult females. In addition,5 out of 15 roe deer sera contained hemagglutination inhibiting antibodies against TBE-virus (Kahl and Radda, 1988). In a more recent study (Kahl, Stein, Janetzki and Radda, unpublished) almost 8,000 unfed *I. ricinus* nymphs were field-collected in 34 locations in and around Berlin in 1991 and 1992 and fed on tick-naive Mongolian gerbils in the laboratory. On each of the 200 gerbils 35-50 *I. ricinus* nymphs fed to repletion. In 3 of the gerbil sera hemagglutination antibodies against TBE-virus were found (titres: 2 x 1:10, 1 x 1:20). None of the 1,114 collected unfed *I. ricinus* adults, however, contained TBE-virus. *B. burgdorferi* was found by Kahl *et al.* (1989) in *I. ricinus* (n=1,711) from 14 out of 15 examined locations in the former Berlin (West), and Kahl *et al.* (1992) found *Borrelia*-positive ticks in each of 27 locations in Berlin and its close environs. Also Plate (1993), who found 66% of the investigated locations (n=73) in Hannover (Germany) to be infested with *I. ricinus*, reported overall infection rates with *B. burgdorferi* s.l. of about 8 and 20% in nymphs (n=782) and adults (n=313), respectively, including inner city locations and gardens. The situation might be similar in many European towns. As a consequence, *I. ricinus* bites in German and other European towns are associated with a considerable *B. burgdorferi* infection risk. This is not much different from the situation in many non-urban areas.

A similar situation regarding the occurrence of ticks in urban environments exists in parts of North America. There, the related tick, *I. scapularis*, which has rather similar ecological requirements as *I. ricinus,* is the main vector of Lyme borreliosis (Wilson, 1998) and occurs in urban and suburban environments, for example close to New York (Falco and Fish, 1988; Maupin *et al.*, 1991; Magnarelli *et al.*, 1995; Daniels *et al.*, 1997). There, a large number people built their houses in the periphery of towns adjacent to forested areas and subsequently encountered infected vector ticks in their gardens (Fish, 1997). The same is true for parts of Russia, where *I. persulcatus* P. Schulze is the main vector of TBE-virus and *B. burgdorferi* s.l. (Korenberg *et al.*, 1984; Korenberg, 1994).

CONCLUSIONS

There are several tick species with disparate ecological requirements which are able to colonize different habitats in the central European urban environment. The existence of *A. reflexus* is based on 1) the attractivity of the man-made townscape for its natural host, the rock pigeon, 2) the year-round immense supply of any kind of food for the pigeons, and 3) the availability of sites that are suitable for both host breeding and the tick. The two former factors are innate to modern towns. The latter is subject to high variation as a crucial socio-ecological factor, viz. the willingness and capability of a society to maintain their buildings properly and/or the level of tolerance in a town towards the presence of rock pigeons. The risk of humans to acquire bites by *A. reflexus* is local in central Europe. But it is difficult for people living in an infested house to cope with that kind of problem because they are largely unable to prevent nocturnal bites, unless the tick is eradicated from that locality. The sporadic occurrence of *R. sanguineus* in central European towns is based on year-round high temperatures for its propagation available only in heated flats, and a suitable host, usually a pet dog, picking up ticks in the south and taking it to central Europe and serving there as a host. There is no stable ecological basis for a long-term existence of *R. sanguineus* in central European towns. Strictly speaking, this tick is not a special urban problem, although for social reasons most cases in central Europe may occur in towns. *I. hexagonus* in towns is chiefly a tick of areas with suburban character and/or bushy vegetation. As an endophilic tick, it is largely independent from macroclimatic factors but highly dependent on the hedgehog. Together with hedgehogs, as protected and often cared for animals, it can maintain "silent" foci of *B. burgdorferi* in towns, even in well-tended garden areas. Out of the four species dealt with here, *I. ricinus* is the one most linked to non-urban habitats. It may be a residual species in such town areas where naturally infested tick habitats were incorporated by growing towns without being disturbed, but it might also have the ability to invade new green isolated locations in towns, if certain abiotic requirements (microclimatic humidity) are fulfilled. Independent *I. ricinus* populations, however, can only exist, if there are sufficiently available hosts for every life stage. The ecological bottle-neck might be the hosts of the adult stage, because only medium-sized and large mammals are usually accepted. *I. ricinus* is the tick with the highest medical importance for humans in central European towns because of its high abundance in areas attractive for recreation, its readiness to bite humans, and its high vectorial capacity. Human infection risk is the result of "natural risk", i.e. infected tick abundance, human exposure to vector tick-bites, and the application of preventive measures (Kahl, 1996). Although the natural risk in urban tick locations is often lower than in non-urban forest, the level of human exposure might be extremely high there. Therefore, the use of preventive measures against vector tick bites is also indicated in urban tick locations.

ACKNOWLEDGEMENTS

We thank Dr. J. Gray (Dublin) for critically reading the manuscript.

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Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.