CURRENT STATUS and FUTURE of VECTOR ECOLOGY and VECTOR CONTROL in the EUROPEAN URBAN ENVIRONMENT

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Abstract Human vector-borne diseases, such as malaria, lymphatic filariasis, and dengue hemorrhagic fever are a global health problem. These diseases affect millions of people in developed and undeveloped countries. Entomologists, biologists, and vector ecologists from North America and Europe share information and work together on resolving problems with vector-borne diseases in the Society for Vector Ecology. Cooperation in mosquito ecology and control has led to formation of the European Mosquito Control Association. The objective of the discussion presented here is to summarize the present status of vector-borne diseases and vector control in Europe. The present and future European environment has vector-borne diseases that threaten human health. Ticks are endemic in the Czech Republic and many parts of Europe, where they are important disease vectors; they are linked to tick-borne encephalitis, Lyme borreliosis, and ehrlichiosis. Mosquitoes are nuisance pests in almost all European countries; *Aedes vexans*, *Ochlerotatus caspius*, and *Culex pipiens* are the most important pest species. Malaria, *Plasmodium vivax*, is still endemic in Turkey, with more than 10,000 cases per year, and is re-emerging in the Caucasian countries and Russia. West Nile fever poses a threat in countries where *Cx. pipiens* mosquitoes occur. The tiger mosquito, *Aedes albopictus*, is a potential vector of mosquito-borne virus diseases, and is established in urban areas of northern Italy and Albania. Unusual abundance of some vectors, such as ticks, or changes in behavior, such as higher anthropophily of *Cx. pipiens*, in some areas may be attributed to climate changes. In many countries *Bacillus thuringiensis israelensis* is replacing the use of chemical insecticides in effective mosquito control.

Key Words Vector-borne diseases vector ecology and control ticks mosquitoes

INTRODUCTION

Human vector-borne diseases have plagued humanity for centuries. Now, at the start of the 21st century, several diseases remain as global health concerns, including malaria and lymphatic filariasis. About 300 million people suffer from acute malaria each year; malaria kills at least 1 million people each year, about 3,000 every day. Forty percent of the world population lives in areas with malaria risk. However, nine out of ten cases occur in sub-Saharan Africa, where 90% of the malaria occurs in children (Teklehaimanot, 2000; WHO, 2002a). In some regions malaria has been successfully suppressed, while in other areas it is getting worse. In 1998 a worldwide program, The Roll Back Malaria Partnership, was launched by the World Health Organization (WHO) in cooperation with the World Bank, UNICEF, and UNDP. Malaria is not only a public-health problem, but it also complicates the socio-economic situation in already poor countries. It is estimated that malaria slows economic growth by up to 1.3% a year in Africa.

Many factors contribute to the spread of malaria, including health systems failure, resistance by *Plasmodium falciparum* to the anti-malarial drug chloroquine, vector resistance to insecticides, deteriorating sanitation, and unplanned development activities. The situation is further aggravated by the shortage of efficient and economically acceptable insecticides, or the general lack of finances caused by political instability. According to current knowledge, long-term vaccines for malaria-prone areas and transgenic mosquitoes are still years away. Short-term vaccines that benefit travelers and tourists may be much closer.

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More than 100 million people in urban and suburban areas of Asia, Africa, and South America are victims of lymphatic filariasis, which is caused by the nematodes *Wuchereria bancrofti*, *Brugia malayi*, and *B. timori*. One of the mosquito vectors, *Culex quinquefasciatus*, finds favorable conditions for development due to the unrestricted urbanization in some regions. *Aedes aegypti* is also very well adapted to human settlements, and has become the most important vector of dengue fever and dengue hemorrhagic fever. Dengue and dengue hemorrhagic fever are serious arboviral human diseases; about 1.5 billion people in the tropics are at permanent risk of infection. An unprecedented 1.3 million cases of dengue and dengue hemorrhagic fever, including more than 3,500 deaths, were reported to WHO in 1998. The pandemic affected the Americas, Southeast Asia, and the Western Pacific. In the year after the pandemic of 1999-2001, about 0.5 million cases, with fewer than a thousand deaths, were reported annually (WHO, 2001). Recently, a major epidemic of dengue, with 18,000 cases and some deaths, occurred in Rio de Janeiro.

Research in vector ecology can provide effective tools for resolving the transmission of infection. The Society for Vector Ecology is comprised of a group of entomologists, biologists, and vector ecologists who seek to understand the relationship between the ecology of vectors and the diseases. The goal of the Society is to share multidisciplinary knowledge in solving complex vector problems in public health. European specialists joined in 1986, and now are cooperating in solving problems that have existed for more than a quarter of a century. Cooperation in mosquito ecology and control has led to formation of the European Mosquito Control Association, patterned after the American Mosquito Control Association. The European members of the Society for Vector Ecology initiated the Mosquito Taxonomy Working Group. Recently, a multinational project for an environmental approach to the problems caused by mosquitoes of public health and economic importance has been submitted to the European Commission. The objective of the project is improving public health, quality of life, and sustainable economic prosperity of the region by reducing the mosquito nuisance level and the risk of re-emerging mosquito-borne infectious diseases. The project would establish locally suitable integrated biological control programs aimed at suppressing mosquito populations.

Around the world there are other vector-borne diseases, and diseases where rodents are reservoirs of their pathogenic agents, but their listing is beyond the scope of this paper. The occurrence of diseases and the possibility of re-emerging vector-borne diseases and their vectors in certain European regions has been discussed by Lundström (1999), Gratz (1999, 2000), and Dautel and Khal (1999). The objective of the discussion presented here is to summarize the present status of vector-borne diseases and vector control in Europe and to point out certain achievements of the European Society for Vector Ecology.

Disease Vectors in Europe

Vector-borne diseases are less threatening in Europe than in tropical and subtropical regions. Diseases such as plague and malaria that decimated urban populations in medieval Europe have practically disappeared with the discovery of the transmission pathway of plague, or by changes in living conditions and agricultural practices. Also contributing to decreasing the danger from vector-borne diseases in the European region are chemical and biological insecticides, better understanding of the pathways of transmission, improved diagnostic methods, financial support for research, monitoring, control of vectors and reservoirs, adequate means for treatment, and better public health education.

In the modern European environment certain vector-borne diseases remain a real threat to human health. There is a potential danger of emerging or re-emerging diseases due to the increased presence, introduction, or re-emergence of vector species. Vectors respond to climate change, and the increasing volume of commercial shipments of goods, animals, and people. For example, *Ae. albopictus*, due to increased trade of used tires, has been introduced to Albania, Italy, France, and quite recently to Belgium and Serbia. Body lice have re-emerged as vectors of serious diseases (e.g., bartonellosis) in some European countries. These pests are connected with a new social category in the region, the homeless, and they are a result of forced dispersal and dwellings that are maintained in poor condition. Also significant is the movement of refugees into European cities from developing countries where vector-borne diseases are endemic and exist in reservoir populations. The combination of all these factors can bring together exotic species of vectors and increase the potential for disease transmission.

Ticks. Europeans take interest in vectors and pests that decrease their quality of life. Large portions of the European population have more leisure time and use this time in various ways: walking in natural areas, where there may be tick populations; participating in outdoor sports, where they are exposed to ticks and mosquitoes; and travel as tourists to other countries in Europe. Ticks are common and often occur in large numbers in gardens and parks within urban areas. *Ixodes ricinus* occurs in city parks. Because of their fear of ticks, some people may avoid going to natural areas. Ticks are found in places where an inexperienced person does not expect them, and protection against them, or their extermination, can be difficult because of their size and behavior.

In central Europe *Ix. ricinus* is the most important vector of tick-borne encephalitis and Lyme borreliosis. Tick-borne encephalitis is the most serious threat to human health in the region, although its frequency is much less than Lyme borreliosis. In the Czech Republic in 2001 the morbidity rate per 100,000 people was 633 cases of tick-borne encephalitis, and 3,547 cases of Lyme borreliosis (Figure 1). Tick-borne encephalitis is more serious due to its higher pathogenicity. In the past several years there have been 3 or 4 fatal cases of tick-borne encephalitis annually, whereas there has been one fatal case of Lyme borreliosis since the middle 1980s. Tick-borne encephalitis often causes serious complications, including lasting damage to the brain. It is ex-

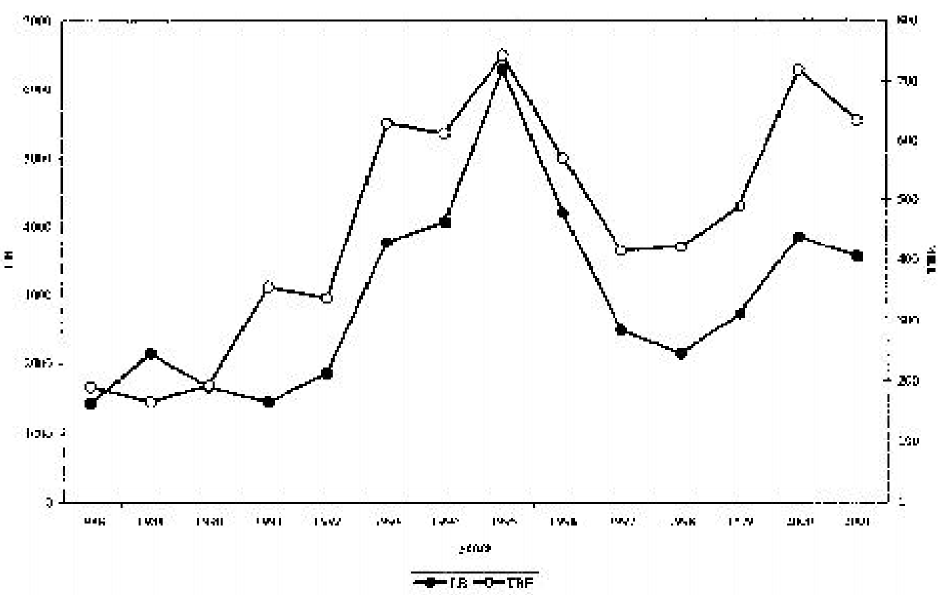

Figure 1. Tick-borne encephalitis and Lyme borreliosis, Czech Republic, years 1988–2001.

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pected that sequelae (secondary consequences) of Lyme borreliosis shall be apparent in later years, due to damage of affected joints.

Tick-borne encephalitis has been reported in the Czech Republic since 1945; however, reports up to 1971 were not conclusive. In the past 20 years most cases appeared in southern Bohemia and northern Moravia, apparently due to favorable climatic conditions for large populations of *Ix. ricinus***,** and because of the reservoir of small rodents such as *Apodemus flavicollis* or *Clethrionomys glareolus.* The region is popular for recreational purposes by urban dwellers. Since the beginning of the 1990s there has been a marked increase in tick-borne encephalitis morbidity, and that has continued in following years (Figure 1) due to increases in morbidity in April, May, October, and November (Table 1). Daniel and Danielová (2002) reported the increase was linked to climate changes in autumn. These led to the prolongation of host-seeking activity, while the period of their ontogenetic development has shortened and their numbers have risen in the following spring. Long-term observations confirm that such situations took place in the 1950s. In the 1990s, this trend became continuous and evident by the increased density of *Ix. ricinus*, and the extension of its horizontal as well as vertical distribution. The occurrence of ticks even in winter is becoming commonplace during warm winter months.

The Czech Republic is highly endemic for Lyme borreliosis, along with certain regions in central European countries such as Germany, Austria, Poland, Slovakia, and Slovenia. Hungary and southern European countries have a low incidence, apparently due to the lesser incidence of *Ix. ricinus*.. In Russia *Ix. persulcatus* plays an important role in Lyme borreliosis transmission. It is expected that Lyme borreliosis has been in the European region for 50-100 years. Erythema migrans (bull's-eye rash) was described here by Afzelius as early as in 1921, and the pathogenic agent — a spirochete — was correctly diagnosed in the 1980s by Burgdorfer et al. (1982). In the Czech Republic Hulínská et al. (1989) demonstrated *B. burgdorferi* in the tissue of a Czech patient with erythema migrans and acrodermatitis chronica atrophicans, and presented the ultrastructure of borreliae in the connective tissue of the skin. Four species of *Borrelia burgdorferi sensu lato*: *B. burgdorferi sensu stricto, B. garinii, B. afzelii,* and *B. valaisiana* (Hulínská et al., 2001a) have been diagnostically confirmed. The incidence of each of the genotypes differs in various parts of the Czech Republic (Hulínská, 2002b). In eastern Bohemia there is *B. garinii* (types 4 and 5). In western Bohemia *B. afzelii*, type 2, is very abundant. In Prague and central Bohemia *B. burgdorferi sensu stricto* is the most common form. In 1995 a greater incidence of

Table 1. Comparison of seasonality of tick-borne encephalitis human cases in the period 1971-1980 and 1991-2000 in spring and autumn (4-5,10-11) months vs.summer months (6-9)

Period- years	Months 4,5,10,11	Months 6,7,8,9	Total
1971-1980	323	3277	3600
1991-200	1058	4244	5302
Total	1381	7251	8902
Chi-quadrate 197.32		p=0.0000	

Period- years	Odds Ratio
1971-1980	1.
1981-1990	1.98
1991-2000	2.53

Analysis of linear trend
Chi-quadrate for trend 191.613 p=0.0000

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Lyme borreliosis was observed (Figure 1), in the years 1996-1998 there was a moderate decrease, and since 1999 it is again on the rise.

The incidence of Lyme borreliosis is similar to tick-borne encephalitis, directly linked with the increased occurrence of ticks due to favorable conditions for their excessive breeding, not as a result of improved diagnostics. The infection of ticks with borreliae does not have any focal character (infection rate 5–30%) as compared to tick-borne encephalitis in which infection of its vectors is of a focal character and ranges from none to 50%. In the urban environment the infection of ticks with borreliae is almost the same as in rural localities.

In the Czech Republic, 11% of *Ix. ricinus* ticks recently have been found co-infected with agents of Lyme borreliosis and of human ehrlichiosis, *Ehrlichia phagocytophila* bacteria. In 8 of 106 patients with Lyme borreliosis, human granulocytic ehrlichiosis has been directly demonstrated serologically with the aid of indirect immuno-fluorescence. This diagnosis was verified by Western blot with specific antigen, and demonstration of the agent's DNA through PCR sequencing (Hulínská et al., 2001b). Co-infection with *B. garinii* has been demonstrated in one deceased patient. A total of 5 ticks out of 35 examined (5%) in 2001 by PCR were positive for the human granulocytic ehrlichiosis genogroup, and 30% out of 750 examined ticks contained DNA of *B. burgdorferi sensu lato*. A total of 89 birds, 32 small mammals, and 105 game animals from endemic areas were tested by PCR for the genera *Borrelia* and *Ehrlichia*. Birds were positive for *B. burgdorferi sensu lato* in 39.3% of the cases, and for *Ehrlichia* sp. in 33.9%. The game animals were positive in 32.3% and 30.4% of cases, respectively (Hulínská et al., 2002a, published figures modified by the author). Co-infection in *Ix. ricinus* with Lyme borreliosis and human ehrlichiosis known from Germany or Sweden has been recently found in Poland (Stanczak et al., 2001).

The National Institute of Public Health in Prague has begun an investigation to determine the presence of borreliae in young children (<5 years) who have had attached ticks removed, and for a pediatrician to decide treatment. That is important for the detection of *B. garinii* type 4, which is a serious neurotropic agent. When the tick is attached for a longer period of time, there is risk in delaying therapy until the appearance of erythema migrans. Up to two weeks after attachment of a tick, it is possible to cure without sequelae; after 4-5 weeks it is usually too late for effective therapy because of the risk of developing disseminated borreliosis.

Congo-Crimean hemorrhagic fever is transmitted by *Ixodes, Argas,* and *Hyaloma* ticks in which transovarial transmission plays a key role. Humans are infected through contact with tissue of infected animals, less often by attached feeding ticks. In 2001, WHO reported 39 suspect cases, including 4 deaths, due to Congo-Crimean hemorrhagic fever from southwestern Kosovo. Congo-Crimean hemorrhagic fever has been reported in Kosovo since 1954; there was an epidemic in 1995, with 65 confirmed cases and 19 deaths.

The role in the perpetuation of an active enzootic focus of tularemia (*Francisella tularensis*) by ticks of the genera *Dermacentor, Ixodes,* and *Haemophysalis,* or by mosquitoes, was studied in a flood-plain forest in southern Moravia and Lower Austria, where the infection rate in *D. reticulatus* was 2.1% (Hubálek and Halouzka, 1997; Hubálek et al., 1998b). The role of ticks and mosquitoes as direct vectors and transmitters of tularemia infection to humans was not confirmed.

In addition to being vectors, ticks are unpleasant blood-sucking arthropods. Very often their attachment causes a severe allergic reaction. The site of feeding itches for a long time, and the wound may become inflamed. The problem of *Argas reflexus* ticks in Czech cities is increasing because of an increase in construction of attic extensions. *Argas reflexus* occur in attics inhabited currently or in the past by pigeons. The ticks can spread throughout the house and feed on people while they sleep. *Argas* ticks survive without feeding for a long time and their control is difficult.

For personal protection against ticks, repellents containing diethyltoluamide (DEET) (recommended 20% concentration) are being used, with approximately 2-hours effectiveness when

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applied to the skin. Markedly longer effectiveness is evident for DEET repellents combined with permethrin or permethrin alone when applied on textiles. There is not much experience with the efficacy of new repellents against ticks, such as IR 3535 and KBR 3025.

Mosquitoes. Mosquitoes are important vectors because they are able to transmit several diseases, even in temperate regions. Methods of protection against mosquitoes and their extermination are more elaborate that those for ticks. However, mass-scale field control measures are costly, and not all European countries can afford them. Some measures often interfere with the natural environment and arouse criticism from ecological activists. Mosquitoes often breed in the urban environment or fly into it from natural or undisturbed areas.

Large populations of mosquitoes regularly follow snow thaws or abundant rainfall in areas of large European rivers, such as the Rhine, Danube, or Elbe. The most important mosquito pests, and possible vectors of diseases in these areas are *Aedes vexans* and *Ochlerotatus sticticus*. *Oc. caspius and Oc. detritus* occur in the Mediterranean areas, particularly in salt-marsh ecosystems of southern France, Spain, or Italy. *Oc. caspius and Culex pipiens* are dominant species in rice fields of northern Italy and Greece. *Aedes* and *Ochlerotatus* usually develop outside urban areas, and some species such as *Oc. cantans* do not move far from their breading site. The mosquitoes adapted to the urban environment include *Ae. vexans*. This species can easily fly 10 km or more. In natural areas it usually does not occur more than 6 m from the ground (Petric et al., 1999). However, it can bite people as high as in the twelveth floor in city buildings. *Cx. pipiens* is typically an urban mosquito of Central Europe. It occurs in two forms: autogenous (a blood meal is not required for egg development) and anautogenous (these forms were formerly considered species or subspecies, *Cx. pipiens molestus* and *Cx. pipiens pipiens*, respectively). At latitudes north of 50^{o}, these two forms seem to live separately: *Cx. p. pipiens* lives primarily outdoors, and *Cx. p. molestus* lives indoors (Rettich, 1983; Vinogradova, 2000). Overlap of both of these forms is reported by Becker et al. (1999) from the Rhine Valley (49^{o} N). *Cx. p. molestus* is adapted to the urban environment and can develop in breeding sites that include cellars with a defective waste water system, or underground railway spaces (Rettich, 1983). *Ae. albopictus*, an aggressive introduced mosquito species and possible vector of a broad variety of mosquito-borne viruses, has recently adapted to urban environments in northern Italy and Albania to such an extent that its eradication is practically impossible (Velo, 2002; Bellini and Carrieri, 2002).

Malaria

After World War II mosquitoes in the European region decreased as important vectors of diseases. Malaria, which was common at that time, was eradicated from all European countries, except for Turkey. Prior to World War II, that malaria, both *Plasmodium vivax* and *P. falciparum*, posed an important health problem at relatively high latitudes in the United Kingdom, Germany, Czechoslovakia, Poland, and Sweden (to about 60^{o} north latitude) is well documented. In 1963, Dziuban, a Slovak vector ecologist, reported that until 1950 11.8% of the Slovak territory was considered as a malaria endemic area. At that time the mosquitoes, *Anopheles maculipenis* s.s. and *Anopheles atroparvus* were the major vectors, with a mean incidence of 4 cases of malaria per 1,000 people per year (0.4% of the human population).

The large-scale use of DDT since the late 1940s resulted in substantially decreased morbidity from malaria, and subsequent eradication of the disease in Europe. Turkey is the last country in the temperate climate zone on the edge of the European continent in which malaria (*Plasmodium vivax*) is prevalent at endemic and occasionally epidemic proportions. Prior to World War II, the incidence of malaria was as high as 100,000 cases per year. After the war, thanks to effective anti-malarial measures, this rate decreased to not more than several thousand cases per year, and this trend continued until the mid 1970s. Since 1976, owing to financial constraints and the interruption of malaria programs (Calgar and Alten, 2000), the morbidity from malaria dramatically increased to tens of thousands cases. For 2000, WHO (2002b) reports 17.51 cases of malaria per 100,000 people.

The malaria situation in the states of the former USSR is considered serious. During 2000, 1,526 cases of malaria were reported in Azerbaijan, and as many as 18,446 cases were reported in Tajikistan, which is not always considered to be a European country. In that country, 89%, 10.5%, and 0.5% of malaria cases were caused by *Plasmodium vivax, P. falciparum,* and *P. malariae*, respectively. The re-emergence of malaria in these countries is attributed to afflicted soldiers returning from Afghanistan. Quite recently a RBM/WHO expert has reported indigenous malaria in all Caucasian countries, and some cases in Russia, Moldavia, and Bulgaria. Approximately 70-80 million people would be at risk of malaria if the disease is reestablished in those European countries.

In recent years, the phenomenon of introduced malaria has been associated with Europeans traveling to regions where malaria is endemic. WHO data for 2000 indicate that 3.32, 3.62, 3.82, and 4.29 cases of imported malaria per 100,000 people were reported from Belgium, the United Kingdom, Denmark, and Switzerland, respectively. Globalization also gives rise to malaria in the vicinity of large international airports in temperate zones.

There are predictions of global warming resulting in a further resurgence of malaria in Europe. However, the warming by about 0.5°C, which has been confirmed so far, does not seem to be enough for a malaria comeback to Europe. Moreover, temperature may not be the only factor implicated if such a comeback occurs. Reiter (1999) pointed out that malaria was common in England in the 16th and 17th centuries, during the Little Ice Age. Even if localized outbreaks of malaria occurred now, modern health care authorities should be ready to intervene and take necessary measures to control the disease.

Mosquito-Borne Viruses

In the 1950s and 1960s, Czechoslovak vector ecologists and virologists isolated the endemic regions of several viruses: Tahyna, Calovo (Batai), and Lednice, which were named according to the respective localities within the country (Bárdoš and Danielová, 1959; Bárdoš and Cupková, 1962). In the 1970s, 1980s, and early 1990s, mosquito-borne diseases in the European region were not of major concern. However, the outbreak of West Nile fever in Romania in 1996 (Tsai et al., 1998) and the outbreak of West Nile fever in New York City in 1999 (Mostashari et al., 2001) indicated that it would be prudent to focus attention on mosquitoes as vectors of arboviruses throughout Europe.

Tahyna Virus. The Tahyna virus was isolated from mosquitoes in eastern Slovakia (then part of the former Czechoslovakia) in 1957. It is also known as Valtice fever, and belongs to the family Bunyaviridae, serogroup California. The Tahyna virus has been endemic in southern Moravia, in the southeastern part of the Czech Republic. In the 1960s it was found in 0.01 to 0.4% of the mosquito populations depending on whether the vector species was *Aedes vexans, Oc. cantans, Oc. caspius,* or *Ae. cinereus*. Danielová and Ryba (1979) demonstrated transovarial transmission of the virus in mosquitoes. Its reservoirs are small mammals. In the 1970s and 1980s, when mosquito populations became less abundant in the region, probably due to extensive water management and periods of drought, no cases of Tahyna virus were reported and the natural focus was considered inactive (Hubálek, 2001). The floods of 1997 affected 100 km^2 and inundated the Morava River area. The flooding led to large populations of mosquitoes, with biting rates ranging from 50-300 per minute for *Aedes* and *Ochlerotatus*. Hubálek (1999) detected the presence of Tahyna virus in 6 out of 117 breeding pools (5x *Ae. vexans*, 1x *Ae. cinereus*), and the mosquito positivity rate for Tahyna virus was 0.05%. In 1976, as many as 53.8% (N=619) of random blood

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serum samples tested positive for Tahyna virus. Tahyna virus incidence in different regions of Moravia was studied by local health authorities; the seropositivity rates in forestry workers near the towns of Lanzhot and Breclav was 63.9% to 85.7%. In the Šumperk region of northern Moravia, an area with a low incidence of mosquitoes, the Tahyna virus seropositivity rates reached only 2-4%.

West Nile Virus. The first isolation of the causative agent of West Nile virus in former Czechoslovakia was reported by Labuda (1974), and the first isolation from *Cx. p. pipiens* mosquitoes in 1997 in South Moravia (Czech Republic) was reported by Hubálek et al. (1998a, 1999a). West Nile virus-neutralizing antibodies were detected in 2.1% of 619 humans tested (hospitalized patients or outpatients at clinics during 1997), but only 5-13 seropositive individuals had symptoms compatible with West Nile fever. The clinical to sub-clinical ratio was about 1:1.6. No case of encephalitis was diagnosed. The area studied had a population of about 30,000 people, both urban and rural. The number of infected humans was probably 630, of whom about 240 might have had symptoms of the disease, albeit undiagnosed (Hubálek, 2001). This was the first isolation of West Nile virus in central Europe. An unprecedented West Nile encephalitis epidemic occurred in southeastern Romania involving the capital Bucharest (Tsai et al., 1998), with 352 reported cases and 17 deaths. During the post-epidemic period 1997-2000, 39 scattered human cases (5 fatal) were detected in the region (Ceianu et al., 2001). Serious West Nile fever outbreaks were reported later from Volha basin and Israel. The New York City epidemic during 1999 is another example of such an outbreak, which was completely unexpected (Mostashari et al., 2001). *Culex pipiens* mosquitoes were identified as vectors both in the Bucharest and in the New York City areas.

Mosquito Control

Intensive control of mosquitoes in natural areas to protect both urban and rural populations started in the late 1940s. The use of DDT resulted in eradication of malaria in most European countries. The DDT era was followed at the end of the 1950s and 1960s by an organophosphate era, followed by the era of pyrethroids. The European region was never at risk of serious mosquito resistance that would be a threat to mosquito control. However, DDT resistance was reported in *Anopheles sacharovi* in Greece and Turkey. Ultra-low-volume (ULV) adulticides, such as malathion or other organophosphates or pyrethroids, have never been widely used in most European countries, southern France being a major exception. They were used in the Czech Republic and Slovakia, too. Here ground-level ULV application of permethrin has been continued to treat urban peripheries. In the 1980s, soon after the discovery of mosquitocidal properties of the bacteria *Bacillus thuringiensis israelensis* (*Bti*) by Goldberg and Margalit (1977), *Bti*-based formulations started replacing relatively environmentally safe chemical insecticides, such as temephos or methoprene. The leading country in this regard is Germany, where *Bti* has been used exclusively since1981.

Latest Technical Achievement in *Bti* Use

In Germany a new technique of delivering microbial control such agents as ice granules to mosquito-breeding sites has been developed (Becker, 2000). Solutions of powder formulations of *Bti* or *B. sphaericus* are converted into ice pellets using specialized equipment. This new technique has these advantages: 1) *Bti* ice pellets melt at the water surface, releasing the active agents (proteinous protoxins); 2) the active agent remains inside the ice pellets and is not lost by friction in the spraying equipment; and 3) increase in the size of the swath being sprayed significantly reduces the cost of application. In large pilot field tests, ice granules were applied at dosages of 5 and 10 kg per hectare, added with 100, 200, and 400 grams of 3,000 ITUs/mg potent product

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against larvae of *Aedes vexans*. Mortality rates of 91-98 % were achieved. The production costs for ice granules are much lower than those for sand and commercially available corncob granules. In 2001, the water level of the Rhine River was extremely high, causing widespread floods and breeding of *Aedes vexans*. This situation could have been easily handled by treating more than 12,000 hectares successfully with ice granules. 20,000 hectares have been treated this way, with substantial cost-savings of several hundred thousand dollars compared to *Bti* sand granules (Becker, 2002). Control of *Cx. pipiens* domestic mosquitoes in Germany is mainly carried out by building tenants. Each year about 1 million *Bti*/*B.sphaericus* "fizzi" tablets are distributed for use especially in rainwater containers (Becker, 2000). The tablets are effective in water containers over a period of several weeks.

Sandflies. The sandflies *Phlebotomus* spp. and *Lutzomyia* spp. are fierce biters and important vectors of leishmania parasites and the causative agents of a wide spectrum of human and animal diseases. Leishmaniases affect about 12 million people world-wide, with 367 million people at risk in 67 countries. The most important disease transmitted by sandflies in Europe is visceral leishmaniasis, caused by *Leishmania infantum*. It is a zoonosis and affects mainly dogs. Canine leishmaniasis is prevalent in all countries of the Mediterranean region, and dogs serve as reservoirs of the disease. Visceral leishmaniasis is a threat to all age-categories, but children are the most affected. Recently this parasite has been associated with AIDS cases. Among causative agents of opportunistic diseases, *L. infantum* is considered as a major contributor to the fatal outcome. Leismaniasis vectors are *Phlebotomus perniciosus* in Italy, France, and Spain; *P. ariasi* in France; and *P. neglectus* in the eastern Mediterranean, including Greece and Turkey. Dog collars impregnated with deltamethrin have been successfully tested in France and Italy; the efficacy lasts throughout the season of *Phlebotomus* (Killick-Kendrick et al., 1997).

Cutaneous leismaniases caused by *L. major* and *L. tropica* are endemic in the Near East European countries (Turkey, Israel). *L. tropica* has been typically transmitted from human to human in the cities via its anthropophilic vector *Phlebotomus sergenti*. *L. major* circulates among semidesert rodents; man is its accidental host, its vector being *P. papatasi*, a highly opportunistic species. Both *P. sergenti* and *P. papatasi* are endophagous, feeding on a wide spectrum of hosts (Volf et al., 2002).

Influences on Vector Control in Europe in the Last Decade

In the early 1990s more than ten central and eastern European countries, comprising about half of the European territory, started to undergo important political and socio-economic changes. These changes, such as from planned to market economies, and the opening of commercial and political boundaries, have greatly impacted vector control in Central and East European countries. In the Czech Republic these changes have resulted in the availability of a wider spectrum of insecticidal agents; almost 300 of these agents have been authorized in 2002. State pest control companies were privatized, leading to higher competition between the manufacturers with subsequent advances in application techniques and better service to customers. However, after full implementation of the Biocide Directive in the EU countries, the choice of vector/pest control products may decline again.

Changes related to vectors are due mainly to the spread of exotic vector species resulting from trade globalization, air transport, climate changes, unusual incidence or behavior of vectors caused by warming, such as unusually abundant ticks in the central European region in winter, ornitophilous *Cx. pipiens* conversion to facultative anthropophily in regions north of the 50th parallel, or domestication of initially wild animal species. There is a complex relationship between the status of vectors in urban and rural areas in the European region. The cities are expanding, and people prefer building their houses in rural areas. Thus, the population is getting closer to the areas harboring abundant vectors, such as ticks, mosquitoes, and blackflies, and the disappearance of wildlife and vector biotopes, such as mosquito breeding sites. For example urbanization led to disappearance of an extensive breeding site of *Oc. caspius* in Hradec Králové, Eastern Bohemia. Large water works may create suitable conditions for more abundant occurrence of anopheline vectors, such as shallow artificial lakes in southern Moravia (Vanhara, 1985) or new dams and irrigation projects in Turkey (Calgar and Alten, 2000), or may be helpful in *Aedes* mosquito control, such as the Danube waterworks in Bratislava, Slovakia.

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