

Review articles

The risk of arthropod vector configuration in Europe[1]

Elżbieta Lonc, Dorota Kiewra, Katarzyna Rydzanicz, Nina Król

Department of Microbial Ecology and Environmental Protection, University of Wroclaw, 63 Przybyszewskiego Street, 71-148 Wroclaw, Poland

Corresponding author: Elżbieta Lonc; E-mail: elzbieta.lonc@microb.uni.wroc.pl

ABSTRACT. In recent years several vector-borne, parasitic or zoonotic diseases have (re)-emerged and spread in Europe with major health, ecological, socio-economical and political consequences. The problem of increasing risk of vector-borne diseases in Europe is widely discussed at periodic international conferences like International Jena Symposium on Tick-borne Diseases or the conference organized by European branch of Society for Vector Ecology ESOVE. The problem takes also effect in establishment of international projects (e.g. EDEN, VBORNET). Mosquitoes and ticks are the most remarkable disease vectors transmitting microorganisms (viruses, bacteria, parasitic protozoans) or metazoan parasites (nematodes). In Europe mosquitoes have a strong effect on human life quality, tourism and economic development because of being a nuisance. However, the changing climatic conditions make mosquito-borne diseases which have already been eradicated, or newly appearing diseases, a threat to human health. Among tick-borne diseases in Europe, the most common is Lyme disease and tick-borne encephalitis, but the list of pathogens identified in ticks keeps increasing and it is expected to increase the number of cases of tick-borne infections. Assessment of vector-borne risk is enhanced by very helpful Geographic Information System – a notable technique for comprehensive analysis of both abiotic and biotic data.

Key words: vector, vector-borne diseases, mosquitoes, ticks

Introduction

Vector is defined as an organism – biological carrier which introduces invasive forms of pathogens to another host by sucking its blood [1]. Most vectors are haematophagous arthropods (ticks, mosquitoes, flies, sand flies, lice and fleas) transmitting microorganisms (viruses, bacteria, parasitic protozoans) or metazoan parasites (nematodes). Arthropods account for over 85% of all known animal species; they are the most important disease vectors which may affect humans either directly through bites and stings, or through infestation of tissues. The pathogen multiplies within the arthropod vector, to be transmitted when the arthropod takes its blood meal. Mechanical transmission of disease agents may also occur when arthropods physically carry pathogens from one place or host to another, usually on their body parts. The history of research on arthropods as transmitters of pathogens began at the end of the nineteenth century, but so far many of the most dangerous parasitic diseases in the world[2], i.e. malaria, still pose unsolved medical problems [2,3]. Since the 1970s there has been a worldwide resurgence of vector-borne diseases including not only malaria, but also leishmaniasis, sleeping sickness, dengue, yellow fever, louse-borne typhus, plague, West Nile encephalitis, Lyme disease, Japanese encephalitis, Rift Valley fever, and Crimean-Congo hemorrhagic fever.

[1] Presented at the 19th Wroclaw Parasitological Conference „Ewolucyjne i ekologiczne aspekty układu pasożyt-żywiciel" Wroclaw-Karpacz 2-4 June, 2011

[2] WHO's Report Tropical Diseases provides the most up-to-date estimates of the number of people infected by the most serious vector-borne diseases: malaria, 270 million; schistosomiasis, 200 million; lymphatic filariases, over 90 million; onchocerciasis, nearly 18 million; leishmaniasis, 12 million; dracunculiasis, over a million; and African trypanosomiasis, 25,000 new cases per year.

Many arthropod taxa play a role in spreading human diseases, but mosquitoes and ticks are the most remarkable disease vectors. Generally, the risk of vector-borne diseases for humans or animals is directly related to the size of the population of infected vectors in the environment in which potential victims are present. However, in practice the risk of vector-borne diseases is very difficult to estimate, because it depends on many factors which influence each other. Detailed analysis requires a thorough knowledge of the biology and ecology of the vectors and pathogens. As a result of ignorance of the vectors' ecology and because of globalization, potential vectors can be introduced in new places. Additionally, one vector individual can carry more than one pathogen (co-infection), and infected vectors can co-feed on one host. Although some pathogens share the same vector, they can have different ecological cycles and transmission patterns which influence the infection prevalence at different stages [4]. Human behaviour is also important. People are often not aware of the danger and therefore do not treat it seriously, which increases the risk of vector-borne diseases. To assess the risk, it is necessary not only to know the biology and ecology of the vectors, hosts, pathogens and their interrelationships, but also to be able to analyze environmental and climatic changes and human behavior.

Vector-borne diseases are prevalent in the tropics and subtropics; till recently they were regarded as less frequent in temperate zones. Now it is known that abiotic and biotic changes can create conditions suitable for outbreaks of many diseases in temperate regions. At the boundary of the 20th and 21st century in Europe, like in America and Eurasia, the research on the vector role of arthropods was intensified, as well as the activity of the Society for Vector Ecology (SOVE)[3]. The problem was so disturbing that in 2004 the European Commission created an Integrated Project called EDEN (Emerging Diseases in a changing European eNvironment). In recent years several vector-borne, parasitic or zoonotic diseases have (re)-emerged and spread in Europe with major health, ecological, socio-economical and political consequences. Most of these outbreaks are linked to global and local changes resulting from climatic changes, human-induced landscape changes or the activities of human populations. Because of that, EDEN's aims are to identify, evaluate and catalogue European ecosystems and environmental conditions linked to global change, which can influence the spatial and temporal distribution and dynamics of human pathogenic agents. The Project focuses on methods, tools and skills such as predictive emergence and spread models, early warning, surveillance and monitoring tools and scenarios, which can be used for risk assessment, decision support for intervention and public health policies. Part of EDEN's innovation is to combine spatial data (earth observation data, GIS, etc.) with epidemiological data (http://www.edenfp6project.net/).

New mosquito vectors in Europe

In Europe mosquitoes because of being a nuisance have a strong impact on human life quality, tourism and economic development. Apart from this, some of them can also transmit mosquito-borne diseases [5]. Therefore, scientists and the public are concerned with the increasing risk of vector-borne diseases in Europe, including Central Europe, both from the medical and epidemiological point of view. The changing climatic conditions make diseases already eradicated, or newly appearing, a threat to human health. It is necessary to inform the public of the potential risks of introduced or newly occurring infectious diseases or vector organisms on the base of realistic assessments in order to prevent the sensitive public from overreacting due to panic mongering.

Usually, malaria is mentioned in the media when climatic changes and the resulting epidemic threats are considered [6]. Although malaria is still the most important vector-borne disease in the tropics, it can be clearly stated that a revival of a malaria epidemic

[3] In 1968 the California Association of Vector Ecology (CAVE) was established. In 1971 it changed into the Society of Vector Ecology (SOVE), and eventually, in 1988 – to the Society for Vector Ecology (still SOVE). Another important organisation in this field is the European Centre of Disease Prevention and Control, which initiated the EVD Program (The Emerging & Vector-Borne Disease) aiming to create the database for vector distribution and special maps with updated distribution of different vector species (also known as Project VBORNET 2010). In the coming years, the scope of the programme of monitoring the spread of indigenous mosquito species in Central Europe will be expanded by close collaboration with European working groups and organisations, such as the European Mosquito Control Association (EMCA), European Society for Vector Ecology and the European Centre for Disease Prevention and Control (ECDC).

in the countries of Central Europe is very unlikely as long as high general hygienic and medical standards are maintained. In many European countries malaria infection has been on the decline for various reasons. The numbers of *Anopheles maculipennis* s.l. have been reduced through the elimination of its breeding sites. Improved health and sanitation, and prompt treatment of people infected with malaria parasites, all act to disrupt the infection cycle.

Major changes in agricultural practices particularly increase the risk of autochthonous malaria cases in Central Europe. In the past, due to high levels of organic waste, cesspools were not appropriate breeding sites for *An. plumbeus* (Stephens). However, through the abandonment of the use of cesspools and, instead, the installation of cisterns in which only slightly contaminated rainwater is collected, mass breeding areas for *An. plumbeus* were produced. *An. plumbeus* must be considered a potential risk factor not only because of its increasing population size, but also because it is a suitable vector for *Plasmodium falciparum* and *P. vivax*. It is anthropophilic and is often present in considerable numbers in rural residential areas. The changes in agricultural practices have a greater effect on the risk of malaria than an elevation in temperature of approximately 2°C. It should also be taken into consideration that there are already significantly higher temperatures in Southern Europe, where there have not yet been any malaria epidemics.

As a consequence of global climate change, we also face altering distributions of indigenous nuisance mosquito species [7]. Moreover, the potential vector capacity of European resident and invasive mosquito species appears to extend to both autochthonous and allochthonous viruses. Increased transcontinental mobility of humans and international trade facilitate dispersal and, in some cases, the establishment of exotic mosquito species into other countries with favorable climatic conditions. Therefore, new records of tropical Asian mosquitoes, emergence of new diseases or re-emergence of formerly endemic vector borne pathogens are currently increasingly reported at higher latitudes in Europe, including the Netherlands and Germany [8,9].

Within the Culicidae family, *Aedes aegypti* (Linnaeus) (*Stegomyia aegypti* sensu Reinert et al. [10]), *Ae. albopictus* (Skuse) and *Ochlerotatus japonicus japonicus* (Theobald) are notable for their dispersal potential and also for their significance as vectors of viral human diseases. Mosquito desiccation-resistant eggs and the ability to exploit a wide range of natural and artificial breeding places enable permanent establishment of viable populations [11]. Those three species are characterized by their high vector competence for arboviruses. *Aedes aegypti* and *Ae. albopictus* are the primary and secondary vectors of dengue fever (DF) and dengue hemorrhagic fever (DHF) which affects more than 40% of the human population worldwide, especially in mega-cities of the tropics [5]. *Ae. albopictus* is considered a serious threat to human health because of its potential to transmit at least 22 types of arboviruses [12] and other infectious agents including *Dirofilaria imitis* [13]. It is the most important vector for the Chikungunya virus [14]. Recently, *Ae. albopictus* was involved in the transmission of Chikungunya virus to humans in Italy in 2007 and, most probably, also in the first confirmed autochthonous dengue cases in France and Croatia in 2010 [14–17].

The Asian tiger mosquito, *Ae. albopictus*, originating from Southeast Asia (parts of China, Korea, Japan, and islands of the Western Pacific and the Indian Ocean) has expanded considerably in the last few decades [6]. With the increase in international trade in used tyres, this species has spread across very large distances and between continents [18]. In Europe it was first reported in Albania in 1979 [19], and later in Italy in 1990, where it was introduced through the import of used tyres from the USA into the port town of Genoa [20,21]. In the next few years, the species rapidly dispersed to other regions of Italy [7], and now it has been reported from France [22], Serbia and Montenegro [23], Belgium [24], Switzerland [25], Greece [26], Croatia [27], Spain [28] and the Netherlands [8].

The yellow fever mosquito, *Ae. aegypti*, has spread across almost all tropical and subtropical countries during the past four centuries. Its populations have increased especially in the areas where household water storage in containers is common and where waste disposal services are inadequate. Recently, *Ae. aegypti* has been found associated with the Nearctic *Ochlerotatus atropalpus* (Coquillett) (*Georgecraigius atropalpus* sensu Reinert et al. [29]) in used tyres, and *Ae. albopictus* has been detected in the Netherlands

[30]. This has been the first record of *Ae. aegypti* in the northern Europe for decades [31].

Ochlerotatus j.japonicus is an Asian species found in Japan, Korea, South China, Taiwan and the Russian Federation [5]. In 1998, it occurred for the first time in the USA: New Jersey and New York, and is now distributed in at least 22 other states. *Ochlerotatus j.japonicus* is a competent vector of several arboviruses, including West Nile (WN) virus and Japanese encephalitis (JE) virus, and is considered a significant public health risk. The primary dispersal mode of these three invasive mosquitoes by human activity was through transport of desiccation-resistant eggs in cargo that contained stagnant water. In Germany (as in Switzerland) *Oc. j.japonicus*, though mainly found in flower vases at cemeteries, is also present in used tyres and rainwater storage containers. The most important type of cargo is used tyres that have been stored outdoors [32]. Businesses processing or trading used tyres should be given high priority for monitoring of exotic fauna and flora. Another source of introduction is by ornamental plants, e.g. „Lucky Bamboo" (*Dracaena* spp.) from Southeast Asia. For example, „Lucky Bamboo", which is transported in containers with standing water making it an „ideal insectary in transit", was the primary reason for the introduction of *Ae. albopictus* from the Southeast Asia to California [33]. Similarly, multiple introductions of the Asian tiger mosquito to the Netherlands in commercial horticultural greenhouses were traced to intensive trade of this plant [8,30]. Due to high humidity and cool air temperature, the refrigerated transoceanic containers offer ideal conditions suitable for the transport of living insects [34]. Therefore, harbours/ports receiving transoceanic containers and inland air or road terminals receiving containers from infested countries should be routinely monitored. Rest areas and parking lots along highways originating in areas infested with exotic species can also serve as sites of introduction [9,25,35].

According to Becker et al. [7], the control of an invasive mosquito species should incorporate four major elements:

a) Evaluation of the pathways of introduction of exotic invasive species. The goal is to prevent further invasions of neobiota by governmental regulating agencies and in close cooperation with trading companies.

b) Increasing mosquito monitoring activities to assess the actual or suspected infestation areas of exotic species by routine site inspections and trapping.

c) Information to the public will be disseminated by regular press releases. Thorough information about the invasive mosquito species will be provided on the internet.

d) Development of control strategies to reduce or perhaps eliminate the invasive exotic mosquito species.

All tools should be employed as soon as an introduction is detected, including larviciding, adulticiding and an aggressive public education program encouraging community participation to reduce potential breeding sites.

During the European branch of SOVE (Euro-SOVE) Conference in Wrocław, Poland (2010) special attention was paid to the mosquitoes of the genera *Anopheles* and *Culex*, phlebotomine sand flies as the transmitters for such viral pathogens as West Nile virus, Sindbis virus (SINV), Batai virus, BATV [36]. In the Mediterranean region two species of *Phlebotus major* complex – *P. neglectus* and *P. syriacus* – are involved in transmission of medically important human pathogens. The first one is a proven vector of *Leishmania infantum* and *Phleboviruses*, the second is a probable vector of these pathogens. Researchers are trying to assess the distribution and intraspecific variability of these two species. The topic also often discussed concerns the bluetongue (BT), which is a viral infectious non-contagious disease transmitted by a vector from the Culicoides species that endangers mainly livestock.

European tick-borne diseases and their vectors

It should be emphasized that in Europe ticks are the most important vectors for various human and animals pathogens. The majority of tick-borne disease agents survive in nature by using animals as their vertebrate hosts; such diseases are therefore called zoonoses. Intermediate animal hosts (birds, rodents, game animals, foxes, cattle, sheep, goats, horses and dogs) often serve as reservoirs for the pathogens until susceptible human populations are exposed. The vector receives the pathogen from an infected host and transmits it either to an intermediate host or directly to the human host. The most common haematophagous vector parasites represent the genera: *Ixodes* (*I. ricinus*, *I. persulcatus*, *I. hexagonus*, *I. trianguliceps*, *I. uriae*), *Derma-*

centor (*D. reticulatus*, *D. marginatus*) and *Haemaphysalis* (*H. concinna*, *H. punctata*, *H. inermis*); they include also *Rhipicephalus sanguineus* and *Hyalomma marginatum.* Microbial pathogens transmitted by ticks are arthropod-borne viruses Flaviviridae (tick-borne encephalitis virus), Reoviridae, Bunyaviridae, Orthomyxoviridae; bacteria (*Borrelia burgdorferi* s.l., *Rickettsia* spp., *Anaplasma* spp., *Ehrlichia* spp., *Francisella tularensis*) and parasitic protozoans (*Babesia* spp., *Theileria* spp.).

The current problems were considered during the XI International Jena Symposium on Tick-borne Diseases 2011 involving scientists, physicians and epidemiologists dealing with pathogens and diseases transmitted by ticks. According to the conference materials the most frequently identified species of vector tick is *I. ricinus,* the most important vector for various human and animal pathogens in Europe. *I. hexagonus* and *Dermacentor reticulates,* which are also important tick species from the medical and veterinary point of view, were detected occasionally in Germany.

In Europe, the above-mentioned tick species can transmit many pathogens, but the majority of studies focus primarily on the most widespread diseases, i.e. Lyme borreliosis, the multisystem disordused by spirochetes of the *Borrelia burgdorferi* s.l. complex, rickettsiosis and anaplasmosis [37–40]. However, comprehensive studies on the prevalence of all relevant pathogens in ticks are scarce.

Summing up the abstracts of XI International Jena Symposium on Tick-borne Diseases 2011, we can conclude that ticks are infected mainly by *Borrelia burgdorferi* s.l. (43% of specimens, Slovakia) and *Rickettsia* spp. (67.4%, Germany) [41,42] – Table 1. However, the meta-analysis of prevalence of *B. burgdorferi* s.l. genospecies in *I. ricinus* in Europe indicates the overall mean prevalence of 13.6%: 10.1% nymphs and 18.6% adults and the highest rates of infection in the countries of central Europe [43]. Rauter and Hartund [43] also showed that *B. afzeli* and *B. garinii* are the most common *Borrelia* species in Europe, but the distribution of genospecies seems to vary in different regions. Other genospecies of *B. burgdorferi* s.l. which have been found in Europe are *B. burgdorferi* sensu stricto, *B. valaisiana*, *B. lusitaniae*, *B. spielmanii*, and *B. bissettii* [44]. The knowledge of the genospecies distribution is important not only from the ecological but also from the medical point of view: different genospecies can cause various clinical symptoms. Additional diagnostic difficulties may be caused by co-infection (one specimen can be infected with more then one pathogen) which interferes with the clinical picture. Another *Borrelia*, related to the relapsing fever spirochete *B. miyamotoi*, has been identified in Sweden, Germany, France, Poland, and the Czech Republic [44]. Other tick-borne bacteria which cause human diseases are *Rickettsia* spp., *Anaplasma phagocytophilum*, *Bartonella henselae* and *Bartonella quintana*, *Coxiella burnetii*, and *Francisella tularensis, Hepatozoon canis*, all of which show only relatively low prevalence rates for European ticks [45].

Researchers try to explain how ticks and tick-borne pathogens deal with unfavorable weather conditions because *I. ricinus* is very sensitive to desiccation. Weather conditions not only influence the tick development, but also the tick survival and behavior, and the chance of tick-host encounter. Infection by various tick-borne pathogens helps ticks to survive adverse weather conditions. This example shows how both ticks and microorganisms take advantage of each other [46]. In their unusual study on *I. ricinus* Dautel et al. [47] tested survival rate of ticks under water and after laundering. Their findings suggest that the main factor killing *I. ricinus* is the temperature, not the lack of oxygen. Thus, after visiting a forest or any other tick habitat, a bath is not the right method of getting rid of ticks, since they can spend from a few days to a few weeks under water. To be sure that the ticks die, we should wash our clothes at 60°C, because the ticks could survive laundering at 40°C.

Among tick-borne diseases, the most common next to Lyme disease is the tick-borne encephalitis (TBE) – a potentially fatal neurological infection affecting humans in Europe and Asia. *I. ricinus* is the principal vector for the European subtype of TBEV in Western Europe, whereas *I. persulcatus* is the vector for the Siberian and far-Eastern subtypes [48]. This viral disease is endemic in most European countries [49] and is a notifiable disease in 16 European countries, including 13 European Union Member States [50]. From 1974 to 2003, a 400% increase in TBE morbidity was observed in Europe and from 2004 to 2006, another increase was seen in a series of TBE-endemic countries, such as the Czech Republic, Germany, Slovenia, Sweden and Switzerland [50]. Besides the climatic changes, additional factors such as increased exposure, socio-economic and political changes and unknown

Table 1. Prevalence of tick infection by pathogens (based on abstracts from the XI International Jena Symposium on Tick-borne Diseases 2011)

Tick collection sites	Date	Parasite (host)	Number of specimens	Prevalence of tick infection by pathogens (%)				
				TBEV	***Borrelia* spp.**	***Anaplasma phagocytophilum***	***Rickettsia* spp.**	***Babesia* spp.**
Czech Republic	n/d	u/s / Plants	20056	0.48 [3]	12 [4,10]	–	–	–
Finland (Simo)	2009 (VI)	*I. persulcatus* (*Myodes glareolus*)	91	yes	–	–	–	–
Germany (Bavaria)	2009-2010	*I. ricinus* / Plants	5569	–	–	9	7.5 [5]	–
Germany (Bavaria)	2009-2010	*I. ricinus* / Plants	5791	–	–	–	–	0.5
Germany (Hannover)	n/d	*I. ricinus* (n/d)	1089	–	9.1 [18]	2.8 [7,18]	33.3	–
Germany (Ren-Men)	2009-2010	*I. ricinus* / Plants	12691	0.2 [1]	27.6 [2,10]	–	–	–
Germany (Thuringia)	2006-2007	*I. ricinus* (n/d)	1000	–	27	5.4	14.7	5
Germany	2009-2010	*I. ricinus* / Plants	b/d	yes	–	–	–	–
Germany	n/d	*I. ricinus* (Mammalia)[8]	1306	–	–	–	yes [9]	–
		I. hexagonus (Mammalia)[8]	555	–	–	–	yes [9]	–
Kazakhstan (West)	n/d	*I. persulcatus* (n/d)	241	2	40 [10]	2	–	–
Latvia	2009	*I. ricinus* (Aves)[11]	93	–	18.3 [10]	2.2	11.8 [9]	–
Lithuania and Norway	2006–2010	u/s (Aves)[11]	1336	–	9 [10,14]	7.2 [15]	32 [16]	–
Poland (North-East)	2004–2007	*I. ricinus* (Rodentia)[17]	b/d	–	–	–	–	7.4 [6]
Russia (Novosibirsk Oblast)	2010 (V–VI)	*I. persulcatus* / Plants	90	–	23.3 [13]	–	–	–
		I. pavlovskyi / Plants	60	–	36.7 [13]	–	–	–
Russia (Voronezh Oblast)	2008 (III–IV)	*I. ricinus* / Plants	26	0	19.2	–	–	–
		D. reticulatus / Plants	74	0	0	–	–	–
Slovakia (Martinske Hole)	2010	*I. ricinus* / Plants	n/d	–	43	1[12]	18	1
Switzerland	2006–2008	*I. ricinus* / Plants	2568	–	–	–	–	1.7

Explanations: n/d – no data; u/s – undetermined species; [1] – from 0 to 0.2% depending on location; [2] – depending on location: 3.8–14.7% in nymphs, 0–20% in males, 3.3–27.6% in females; [3] – 11278 individuals were tested; [4] – 11146 individuals were tested; [5] – 3851 individuals were tested; [6] – 1.7% in nymphs, 7.4% in females, studies conducted in the presence of *B. microti*; [7] – 391 individuals were tested; [8] – hedgehogs, deer, fox, raccoon, raccoon, mink, badger, brown hare, wild boar; [9] – research conducted for the presence of *R. helvetica;* [10] – research conducted for the presence of *B. burgdorferi* sl; [11] – Passerine (Passeriformes); [12] – research conducted for the presence of *Anaplasma* spp.; [13] – detected *B. garinni, B. afzelii, B. miyamoti*; [14] – 608 individuals were tested; [15] – studies were conducted on 668 individuals from Norway, in Lithuania there weren't detected ticks infected by *A. phagocytophilum*; [16] – studies were conducted only on ticks from Lithuania; [17] – bank vole, yellow necked mouse, common vole, Tundra vole; [18] – co-infected with *Rickettsia* spp.

factors are probably responsible for this increase [50]. The dynamics of number of TBE cases may also be affected by vaccination. For example, in Austria, about 2.800 TBE cases were prevented by vaccination in the years 2000 to 2006 [50].

I. ricinus is also a confirmed vector of *Anaplasma phagocytophilum*, causing human granulocytic anaplasmosis (HGA). In Asia, *A. phagocytophilum* is transmitted by *I. persulcatus* [51]. The prevalence of infected ticks in Europe ranges from 0.4% to 66.7% [52]. In Poland, among 76 specimens of *I. ricinus* removed from the skin of adult patients who reported to the Department of Infectious Diseases Emergency Room, Medical University of Białystok, 23.7% were infected by *A. phagocytophilum* [53]. Anaplasmea are transmitted from stage to stage as the tick moults (transstadially), but not transovarially and no anaplasmae have been detected in unfed larvae [52]. So far, the reservoirs of these bacteria have not been exactly determined, but in Europe rodents and some wild ungulates are considered as the reservoirs [54].

Pathogens being transmitted by *I. ricinus* in Europe include *Babesia* spp. *Babesia microti*, a protozoan parasite responsible for human babesiosis, has been recorded from northern, south-western, eastern and central Poland [55], while no cases of human babesiosis have been reported in Poland [56]. However, *I. ricinus* can transmit also other babesiae of medical and veterinary importance. *B. canis canis*, responsible for most infections in dogs throughout Europe, transmitted mainly by *Dermacentor reticulatus*, and *Babesia* EU1, known to infect humans, have been recently detected in *I. ricinus* collected by flagging in northern Poland [56].

The number of cases of tick-borne infections is expected to increase in Europe. The Lyme disease, like malaria, tends to produce a high disease incidence but does not cause major epidemics. Several studies have highlighted the influence of climatic changes and habitat on the risk of vector-borne diseases. For example, the problem of the *I. ricinus* infiltration into higher altitudes in Central Europe became important at the beginning of the 1990s, together with the increasing occurrence of tick-borne infections in new areas [57]. Nowadays infected ticks occur not only in forests, but also in urban parks, where they get with synanthropic animals [58,59]. Moreover, the risk assessment should take into account the spatial and temporal variation associated with long-term (predicting seasonal patterns or multi-year changes with regard to climate trends) and short-term (reflecting the weather conditions) prediction [60]. Assessment of vector-borne risk is enhanced by very helpful Geographic Information Systems. This notable technique for comprehensive analysis of both abiotic and biotic data [49,60,] was also used in our own research [61].

Conclusions

Reasons for the emergence or re-emerging of vector-borne diseases include not only changes of biology and ecology of vectors as a result of changing abiotic environment, climatic changes, changes in agricultural practices and deforestation. The cited examples of mosquito and tick species which have reestablished and gradually expanded its range into new regions are also the consequences of the development of insecticide and drug resistance; control of vector-borne diseases; prevention and deterioration of the public health infrastructure required to deal with these diseases, especially in the tropics, unprecedented population growth, wars, decreased resources for surveillance, uncontrolled urbanization and increased travel. Appropriate environmental education will increase not only public awareness of the threats, but also of the possible prophylaxis.

References

[1] Złotorzycka J. 1998. Słownik parazytologiczny. Polish Parasitological Society,Warsaw.

[2] Gubler D.J. 1997. Resurgent vector-borne diseases as a global health problem. *Emerging Infectious Diseases* 4: 442-450.

[3] Knap J.P., Myjak P. 2009. Malaria w Polsce i na świecie – wczoraj i dziś. Alfa Medica Press, Bielsko-Biała.

[4] Halos L., Bord S., Cotté V., Gasqui P., Abrial D., Barnouin J., Boulouis H. J., Vayssier-Taussat M., Vourc'h G. 2010. Ecological factors characterizing the prevalence of bacterial tick-borne pathogens in *Ixodes ricinus* ticks in pastures and woodlands. *Applied and Environmental Microbiology* 76: 4413-4420.

[5] Becker N., Petric D., Zgomba M., Boase C., Madon M., Dahl C., Kaiser A. 2010. Mosquitoes and their control. Springer, New York.

[6] Becker N. 2008. Influence of climatic change on mosquito development and mosquito-borne diseases in Europe. *Parasitology Research* 3: 19-28.

[7] Becker N., Huber K., Pluskota B., Kaiser A. 2011. *Ochlerotatus japonicus japonicus* – a newly established neozoan in Germany and a revised list of the

German mosquito fauna. *European Mosquito Bulletin* 29: 88-102.

[8] Scholte E.J., Jacobs F., Linton Y.M., Dijkstra E., Fransen J., Takken W. 2007. First record of *Aedes* (*Stegomyia*) *albopictus* in the Netherlands. *European Mosquito Bulletin* 22: 5-9.

[9] Pluskota B., Storch V., Braunbeck T., Beck M., Becker N. 2008. First record of *Aedes* (*Stegomyia*) *albopictus* Skuse (Diptera: Culicidae) in Germany. *European Mosquito Bulletin* 26: 1-5.

[10] Reinert J.F., Harbach R.E., Kitching I.J. 2004. Phylogeny and classification of *Aedini* (Diptera: Culicidae), based on morphological characters of all life stages. *Zoological Journal of the Linnean Society* 142: 289-368.

[11] Moore C.G., Mitchell C.J. 1997. *Aedes albopictus* in the United States: Ten-year presence and public health implications. *Emerging Infectious Diseases* 3: 329-334.

[12] Gratz N.G. 2004. Critical review of the vector status of *Aedes albopictus*. *Medical and Veterinary Entomology* 18: 215-227.

[13] Cancrini G., Frangipane di Regalbono A.F., Ricci I., Tessarin C., Gabrielli S., Pietrobelli M. 2003. *Aedes albopictus* is a natural vector of *Dirofilaria immitis* in Italy. *Veterinary Parasitology* 118: 195-202.

[14] Reiter P., Fontenille D., Paupy C. 2006. *Aedes albopictus* as an epidemic vector of Chikungunya virus: another emerging problem? *The Lancet Infectious Diseases* 6: 463-464.

[15] Beltrame A., Angheben A., Bisoffi Z., Monteiro G., Marocco S., Caller G. 2007. Imported Chikungunya infection, Italy. Emerging Infectious Diseases. Available from http://www.cdc.gov/EID/content/13/8/1264. htm.

[16] Schmidt-Chanasit J., Haditsch M., Schöneberg I., Günther S., Stark K., Frank C. 2010. Dengue virus infection in a traveller returning from Croatia to Germany. *Euro Surveillance* 15. Available online: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=19677

[17] Dengue fever in France. 2010. In: Health Protection Report 37. Available online: http://www.hpa. org.uk/hpr/archives/2010/hpr3710.pdf

[18] Reiter P. 1998. *Aedes albopictus* and the world trade in used tires, 1988–1995: The shape of things to come. *Journal of the American Mosquito Control Association* 14: 83-94.

[19] Adhami J., Reiter P. 1998. Introduction and establishment of *Aedes* (*Stegomyia*) *albopictus* Skuse (Diptera: Culicidae) in Albania. *Journal of the American Mosquito Control Association* 14: 340-343.

[20] Sabatini A., Raineri V., Trovato G., Coluzzi M. 1990. *Aedes albopictus* in Italia e possibile diffusione della specie nell'area Mediterranea. *Parassitologia* 32: 301-304.

[21] Dalla Pozza G.L., Majori G. 1992. First record of *Aedes albopictus* establishment in Italy. *Journal of the American Mosquito Control Association* 8: 318-320.

[22] Schaffner F., Karch S. 2000. Première observation d'*Aedes albopictus* (Skuse, 1894), en France métropolitaine. *Comptes Rendus de l'Académie des Sciences* 323: 373-375.

[23] Petrić D., Pajović I., Ignjatović-Ćupina A., Zgomba M. 2001. *Aedes albopictus* (Skuse 1895) a new mosquito species (Diptera, Culicidae) in entomofauna of Yugoslavia. In: Symposia of Serbian Entomologists 2001. Entomological Society of Serbia. Goč-Serbia. September 26–29 2001. Abstract book: 29.

[24] Schaffner F., Van Bortel W., Coosemans M. 2004. First record of *Aedes* (*Stegomyia*) *albopictus* in Belgium. *Journal of the American Mosquito Control Association* 20: 201-203.

[25] Flacio E., Lüthy P., Patocchi N., Guidotti F., Tonolla M., Peduzzi R. 2004. Primoritrovamento di *Aedes albopictus* in Svizzera. *Bollettino della Societa Ticinese di Scienze Naturali* 92: 141-142.

[26] Samanidou-Voyadjoglou A., Patsoula E., Spanakos G., Vakalis N.C. 2005. Confirmation of *Aedes albopictus* (Skuse) (Diptera: Culicidae) in Greece. *European Mosquito Bulletin* 19: 10-12.

[27] Klobucar A., Merdic E., Benic N., Baklaic Z., Krcmar S. 2006. First record of *Aedes albopictus* in Croatia. *Journal of the American Mosquito Control Association* 22: 147-148.

[28] Aranda C., Eritja R., Roiz D. 2006. First record and establishment of *Aedes albopictus* in Spain. *Medical and Veterinary Entomology* 20: 150-152.

[29] Reinert J.F., Harbach R.E., Kitching I.J. 2006. Phylogeny and classification of *Finlaya* and allied taxa (Diptera: Culicidae: Aedini) based on morphological data from all life stages. *Zoological Journal of the Linnean Society* 148: 1-101.

[30] Scholte E.J., Dik M., Schoelitsz B., Brooks M., Schaffner F., Foussadier, F.R., Brak M., Beeuke J. 2010. Introduction and control of three invasive mosquito species in the Netherlands. *Euro Surveillance* 15. Available online: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=19710

[31] Hansford K., Bennett E., Medlock J.M. 2010. Public health importance of the invasive mosquitoes of Europe. ECDC, VBORNET 2: 10-13 (www.ecdc.europe.eu).

[32] Knudsen A.B. 1995. Global distribution and continuing spread of *Aedes albopictus. Parassitologia* 37: 91-97.

[33] Madon M.B., Hazelrigg J.E., Shaw M.W., Kluh S., Mulla M.S. 2004. Has *Aedes albopictus* established in California? *Journal of the American Mosquito Control Association* 19: 298.

[34] Reiter P., Darsie R.F.Jr. 1984. *Aedes albopictus* in Memphis, Tennessee (USA): Anachievement of modern transportation? *Journal of the American Mosquito Control Association* 44: 396-399.
[35] Flacio E., Lüthy P., Patocchi N., Peduzzi R., Guidotti F., Radczuweit S. 2006. Bericht 2006 zur Überwachung und Bekämpfung der asiatischen Tigermücke, *Aedes albopictus*, im Kanton Tessin. *Jahresbericht 2006 Gruppo lavoro zanzare, Divisione della salute publica, 6501 Bellinzona*: 1-10.
[36] Rydzanicz K., Lonc E., Becker N., Zgomba M. 2010. Proceedings of the 17th *European Society for Vector Ecology Conference*. Conference Programme and Abstracts. Wrocław. September 13–17, 2010: 54.
[37] Dobler G., Hufert F., Pfeffer M., Speck S., Frey S., Essbauer S. 2011. Temporal dynamics of ticks and tick-borne encephalitis viruses in a natural focus in southern Germany during a period of two years. In: Programme and Abstracts XI International Jena Symposium on Tick-borne Diseases 2011: 39.
[38] Speck S., Scheid P., Perseke L., Szentiks C., Dobler G. 2011. The role of wildlife in maintenance of the *Rickettsia helvetica* life cycle. In: Programme and Abstracts XI International Jena Symposium on Tick-borne Diseases 2011: 64.
[39] Schicht S., Schnieder T., Strube C. 2011. Prevalence and species identification of *Rickettsia* spp. in the hard tick *Ixodes ricinus* in the area of Hannover (Germany). In: Programme and Abstracts XI International Jena Symposium on Tick-borne Diseases 2011: 139.
[40] Capligina V., Ranka R., Brangulis K., Keiss S., Salmane I., Baumanis V. 2011. Prevalence of tick borne pathogens in ticks collected from birds in Latvia. In: Programme and Abstracts XI International Jena Symposium on Tick-borne Diseases 2011: 81.
[41] Taragel'ová V., Derdáková M., Ciglerová I., Mydlová L., Špitalská E., Kazimirová M. 2011. Dispersal of tick-borne pathogens into the mountain ecosystem, Martinské hole mountain (Central Slovakia). In: Programme and Abstracts XI International Jena Symposium on Tick-borne Diseases 2011: 125.
[42] Silaghi C., Hamel D., Thiel C., Pfister K., Pfeffer M. 2011. Renatured areas as focal points for tick-borne pathogens in Saxony, Germany. In: Programme and Abstracts XI International Jena Symposium on Tick-borne Diseases 2011: 63.
[43] Rauter C., Hartung T. 2005. Prevalence of *Borrelia burgdorferi sensu lato* genospecies in *Ixodes ricinus* ticks in Europe: a metaanalysis. *Applied and Environmental Microbiology* 71: 7203-7216.
[44] Gern L., Douet V., López Z., Rais O., Morán Cadenas F. 2010. Diversity of *Borrelia* genospecies in *Ixodes ricinus* ticks in a Lyme borreliosis endemic area in Switzerland identified by using new probes for reverse line blotting. *Ticks and Tick Borne Disaeses* 1: 23-29.
[45] Reye A.L., Hübschen J.M., Sausy A., Muller C.P. 2010. Prevalence and seasonality of tick-borne pathogens in questing *Ixodes ricinus* ticks from Luxembourg. *Applied and Environmental Microbiology* 76: 2923-2931.
[46] Lise G. 2011. Facing bad weather: How ticks and tick-borne pathogens take up the challenge. In: Programme and Abstracts XI International Jena Symposium on Tick-borne Diseases 2011: 35.
[47] Dautel H., Gharbi A., Kleier S. 2011. Survival of *Ixodes ricinus* under water and after laundering in an automatic washer. In: Programme and Abstracts XI International Jena Symposium on Tick-borne Diseases 2011: 33.
[48] Mansfield K.L., Johnson N., Phipps L.P., Stephenson J.R., Fooks A.R., Solomon T. 2009. Tick-borne encephalitis virus – a review of an emerging zoonosis. *Journal of General Virology* 90: 1781-1794.
[49] Schwarz A., Maier W.A., Kistemann T., Kampen H. 2009. Analysis of the distribution of the tick *Ixodes ricinus* L. (Acari: Ixodidae) in a nature reserve of western Germany using Geographic Information Systems. *International Journal of Hygiene and Environmental Health* 212: 87-96.
[50] Suss J. 2008. Tick-borne encephalitis in Europe and beyond – the epidemiological situation as of 2007. *Euro Surveillance* 13. Available online: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=18916
[51] Ismail N., Bloch K.C., McBride J.W. 2010. Human ehrlichiosis and anaplasmosis. *Clinics in Laboratory Medicine*is 30: 261-269.
[52] Smrdel K.S., Serdt M., Duh D., Knap N., Zupanc T. A. 2010. *Anaplasma phagocytophilum* in ticks in Slovenia. *Parasites and Vectors* 3: 102.
[53] Grzeszczuk A., Stanczak J. 2006. High prevalence of *Anaplasma phagocytophilum* infection in ticks removed from human skin in north-eastern Poland. *Annals of Agricultural and Environmental Medicine* 13: 45-48.
[54] Adamska M. 2008. *Anaplasma phagocytophilum* as a tick-borne pathogen of humans and animals. In: *Stawonogi. Oddziaływanie na żywiciela* (Eds. A. Buczek, C. Błaszak). Akapit, Lublin: 231-237.
[55] Zygner W., Bąska P., Wiśniewski M., Wędrychowicz H. 2010. The molecular evidence of *Babesia microti* in hard ticks removed from dogs in Warsaw (central Poland). *Polish Journal of Microbiology* 59: 95-97.
[56] Cieniuch S., Stańczak J., Ruczaj A. 2009. The first detection of *Babesia* EU1 and *Babesia canis canis* in *Ixodes ricinus* ticks (Acari, Ixodidae) collected in urban and rural areas in northern Poland. *Polish Jo-*

urnal of Microbiology 58: 231-236.

[57] Daniel M., Materna J., Honig V., Metelka L., Danielová V., Harcarik J., Kliegrová S., Grubhoffer L. 2009. Vertical distribution of the tick *Ixodes ricinus* and tick-borne pathogens in the northern Moravian mountains correlated with climate warming (Jeseníky Mts., Czech Republic). *Central European Journal of Public Health* 17: 139-145.

[58] Gray J. S., Kahl O. 2001. Ticks as vectors of zoonotic pathogens in Europe. In: Acarology: Proceedings of the 10th International Congress. (Eds. R.B. Halliday, D.E. Walter, H.C. Proctor, R.A. Norton, M.J. Colloff). CSIRO Publishing, Melbourne: 547-551.

[59] Kiewra D., Lonc E. 2010. Mapping Lyme borreliosis risk in the Wrocław aera (Lower Silesia, Poland). In: *Stawonogi. Ekologiczne i patologiczne aspekty układu pasożyt-żywiciel.* (Eds. A. Buczek, C. Błaszak). Akapit, Lublin: 199-206.

[60] Daniel M., Zitek K., Danielová V., Kríz B., Valter J., Kott I. 2006. Risk assessment and prediction of *Ixodes ricinus* tick questing activity and human tick-borne encephalitis infection in space and time in the Czech Republic. *International Journal of Medical Microbiology* 296: 41-47.

[61] Kiewra D., Lonc E., Żyszkowska W., Rydzanicz K. 2008. Rozprzestrzenienie kleszczy *Ixodes ricinus* w Masywie Ślęży (Dolny Śląsk) – mapowanie i wizualizacja danych środowiskowych z zastosowaniem GIS. In: *Stawonogi. Oddziaływanie na żywiciela.* (Eds. A. Buczek, C. Błaszak). Akapit, Lublin: 81-86.

Received 16 October 2011
Accepted 24 November 2011