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Lyme borreliosis in Europe: influences of climate and climate change, epidemiology, ecology and adaptation measures

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CASH

ABSTRACT

Stockholm University and WHO, within a project funded by the European Commission (EVK2-2000-00070), reviewed the impacts of climate change and adaptation on Lyme borreliosis (LB) in Europe.

LB is the most common vector-borne disease in Europe. The highest incidence is reported from Austria, the Czech Republic, Germany, and Slovenia, as well as from the northern countries bordering the Baltic Sea. LB is a multi-system disorder that is treatable with antibiotics, but may lead to severe complications of the neurological system, the heart, and the joints.

LB is caused by a spirochete (*Borrelia burgdorferi* s.l.), which is transmitted to humans by ticks, in Europe mainly the species *Ixodes ricinus*. Reservoir animals are small rodents, insectivores, hares and birds.
Ticks may live for more than three years and are highly sensitive to changes in seasonal climate. Daily seasonal climatic conditions directly impact tick survival and activity. Indirectly, climate affects both tick and pathogen occurrence through effects on habitat conditions and reservoir animal density. In addition, climate-induced changes in land use and in recreational behaviour influence human exposure to infected ticks and thus disease prevalence.

Since the 1980s, tick vectors have increased in density and spread into higher latitudes and altitudes in Europe. It can be concluded that future climate change in Europe will facilitate a spread of LB into higher latitudes and altitudes, and contribute to increased disease occurrence in endemic areas. In some locations, where climate conditions will become too hot and dry for tick survival, LB will disappear.

There is a need to strengthen preventive measures such as information to the general public, surveillance activities within a pan-European network and to use standardized methods to provide data for future research activities.

Keywords

BORRELIA BURGDORFERI
LYME DISEASE - diagnosis - epidemiology
TICK-BORNE DISEASES - prevention and control
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1. Introduction

1.1. The scope and framework of the cCASHh project

Climate and weather are important determinants of human health and well-being. Important changes in climatic conditions are predicted and these will have implications for human health in Europe.

The project "Climate Change and Adaptation Strategies for Human Health" (cCASHh) was funded by the European Commission within its fifth framework programme under Thematic Programme: Energy, Environment and Sustainable Development (EESD-1999) and the Key action: Global change, climate and biodiversity. The project started on 1 May 2001 and ended on 31 July 2004. The assessment mainly includes all 25 countries of the European Union.

The overall objective of the cCASHh project is:

- to identify the vulnerability to adverse impacts of climate change on human health;
- to review current measures, technologies, policies and barriers to improving the adaptive capacity of populations to climate change;
- to identify for European populations the most appropriate measures, technologies and policies to successfully adapt to climate change;
- to provide estimates of the health benefits of specific strategies or combinations of strategies for adaptation under different climate and socioeconomic scenarios.

To this end several health impact assessments, adaptation assessments, cost–benefit analysis and integrated assessment modelling (health futures) were carried out. The main health outcomes that were investigated in the cCASHh project are:

- health impacts of thermal stress
- health impacts of floods
- foodborne diseases
- vector- and rodent-borne diseases.

This document presents the results of an extensive literature review on Lyme borreliosis (LB) combined with input from leading experts in this field.

1.2. Lyme borreliosis

LB is the most common vector-borne disease in temperate zones of the northern hemisphere. About 85 000 cases are reported annually in Europe (estimated from available national data). However, this number is largely underestimated as case reporting is highly inconsistent in Europe and many LB infections go undiagnosed. In the United States between 15 000 and 20 000 cases are registered each year and the disease is currently endemic in 15 states (Steere, 2001).

LB is transmitted to humans during the blood feeding of hard ticks of the genus *Ixodes*: in Europe mainly *Ixodes ricinus,* and to a lesser extent *I. persulcatus*. The symptoms of LB were described almost a century ago by the Swedish dermatologist Arvid Afzelius, but the disease was not identified until 1977, in the area of Lyme in the United States – hence the name Lyme disease. Following the discovery in 1982 of the spirochete (spiral-shaped bacterium) *Borrelia burgdorferi* s.l. as the causative agent of LB, the disease emerged as the most prevalent arthropod-borne infection in northern temperate climate zones around the world. In Europe the disease is nowadays commonly called LB. LB is a multi-system disorder that is treatable with antibiotics. Neither subclinical nor symptomatic infections provide immunity. If early disease manifestations are overlooked or misdiagnosed, LB may lead to severe complications of the neurological system, the heart and the joints. Spirochetes are maintained in nature in ticks and in the blood of certain animal species: in Europe particularly insectivores, small rodents, hares and birds. Humans as well as larger animals, such as deer and cattle, do not act as reservoirs for the pathogen.

Current knowledge of the impact of different climatic factors on vector abundance and disease transmission is rather extensive. Climate sets the limit for latitudinal and altitudinal distribution of ticks. In addition, daily climatic conditions during several seasons (as ticks may live for more than three years) influence tick population density both directly and indirectly. The pathogen is not in itself sensitive to ambient climatic conditions, except for unusually high temperatures, but human exposures to the pathogen – through tick bites – may be influenced by weather conditions.

During the last decades ticks have spread into higher latitudes (observed in Sweden) and altitudes (observed in the Czech Republic) in Europe and have become more abundant in many places (Tälleklint & Jaenson, 1998; Daniel et al., 2003). These tick distribution and density changes have been shown to be related to changes in climate (Lindgren et al., 2000; Daniel et al., 2004). The incidences of LB and other tick-borne diseases have also increased in Europe during the same time period. In some places this may be an effect of better reporting over time. However, studies from localized areas that have reliable long-term surveillance data show that such incidence increases are real, and that they are related to the same climatic factors that have been shown to be linked to changes in tick abundance (Lindgren, 1998; Lindgren & Gustafson, 2001; Daniel et al., 2004).

2. Geographical distribution

2.1. Distribution

The geographical distribution of LB worldwide correlates with the known distribution of the ixodid vectors (Fig. 1). In Europe, the distribution of *I. ricinus* overlaps with the distribution of *I. persulcatus* in the coastal regions east of the Baltic Sea and further south along that longitude into middle Europe, from where the range of *I. persulcatus* stretches to the Pacific Ocean. Where the two species overlap there are microclimatic conditions separating their distribution. *I. persulcatus* is more flexible and less sensitive to hydrothermal changes in the environment than *I. ricinus* (Korenberg, 1994). Recent studies of the Baltic regions of the Russian Federation showed for example that 11.5% of *I. ricinus* ticks (development stages not stated) were carriers of *B. burgdorferi* s.l. in contrast to 26.3% of *I. persulcatus* (Alekseev et al., 2001). In addition, a large number of other tick species have been reported as carriers of *B. burgdorferi* s.l., but this does not necessarily mean that these ticks are effective in transmitting the disease.
Seasonal climatic conditions limit the latitude and altitude distribution of ticks in Europe (Daniel, 1993; Lindgren et al., 2000; Daniel et al., 2003, 2004). Both altitude and latitude distribution limits of *I. ricinus* have changed during recent years in Europe, as described in detail

in Section 5. Ticks are now found in abundance up to 1100 m above sea level (a.s.l.) in the Czech Republic (Daniel et al., 2003), up to 1300 m a.s.l. in the Italian Alps (Rizzoli et al., 2002), and along the Baltic Sea coastline up to latitude 65°N in Sweden (Jaenson et al., 1994; Tälleklint & Jaenson, 1998). At high northern latitudes, where the inland climate generally is too harsh for ticks to survive, small tick populations can be found in locations where the landscape characteristics help in modifying the climatic conditions. That is, close to large bodies of water, i.e. in river valleys, around inland lakes and along the coastlines (Lindgren et al., 2000).

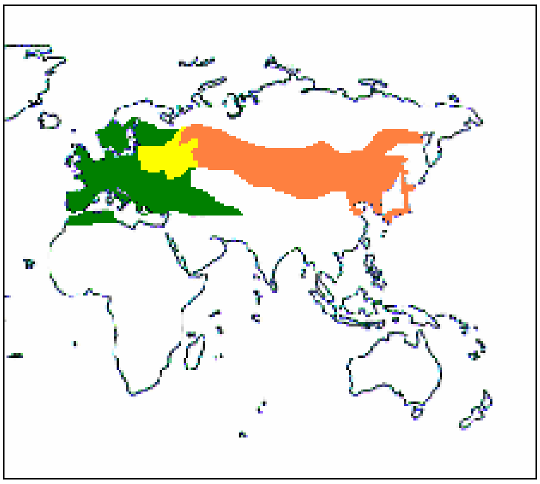

Figure 1. **Distribution of *I. ricinus* (green) and *I. persulcatus* (orange).**
Yellow indicates areas where both tick species are present. *Source*: based on several sources.

2.2. Incidence

Surveillance in Europe varies and does not allow direct comparison between countries. In some regions the general public is not aware of the risk, and as the symptoms of LB are easily neglected — especially if the characteristic skin rash called erythema migrans does not occur initially — LB may go undetected. In addition, data obtained from various European laboratories are often not directly comparable because of different serological tests used to detect antibodies to *B. burgdorferi* s.l. (Santino et al., 2002). Even if LB is diagnosed, there is often a lack of reporting as few countries have made LB a compulsorily notifiable disease. Despite these caveats, it appears that both disease incidence and antibody prevalence are higher in the central and eastern parts of Europe than in the western parts (Table 1). A gradient of decreasing incidence from south to north in Scandinavia and from north to south in Italy, Spain and Greece has also been noted (e.g. Epinorth, 2003; EUCALB). The highest incidences of LB in Europe are found in the Baltic States and Sweden in the north, and in Austria, the Czech Republic, Germany, Slovenia and central Europe (Figures 1, 2a and 2b).

In much of Europe, the number of reported cases of LB has increased from the early 1990s (e.g. the Czech Republic, Estonia, Lithuania; see Fig. 2), and the geographic distribution of cases has also expanded. This is partly due to an increased level of awareness in the general population and among medical personnel, and to better reporting. However, studies from the Czech Republic and Sweden show changes in vector abundance as well as changes in latitudinal or altitudinal distribution of ticks during the same time period (Tälleklint & Jaenson 1998; Daniel et al., 2003). The possible factors underlying these reported changes will be discussed in the sections below.

Table 1. **Incidence and annual number of cases of LB, and seroprevalence of antibodies (in human blood) in different European countries**

Country	Incidence per 100 000 population (annual average)	Annual number of cases (average)	Antibody prevalence (in human blood)[a]
Austria	300	14–24 000	1997: General 7.7% [1]
Belgium	No data	500	No data
Bosnia and Herzegovina	LB is prevalent		
Bulgaria	55	3500	No data
Croatia		>200 (LB absent in southern parts) [2]	
Czech Republic	27–35 (Fig. 2a)	3500	No data
Denmark	0.8 (Table 2)	<50	No data
Estonia	30–40 (Fig. 2b)	<500	1997: Risk pop. 2.7% [1]
Finland	12.7 (Table 2)	<700	1995: Risk pop. 16.9% [3] 1998: High risk area 19.7% [4]
France	16.5 40 (Berry-Sud)	7–10 000	1997: Risk pop. 15.2% [5]
Germany	25 111 (Wurzburg) [6]	15–20 000	1997: General 5.6% [1]
Greece	No data	No data	1997: General 1–3% [1] 2000: Young males 3.3% [7]
Hungary	Neuroborreliosis 2.9 (Baranya) [8]	No data	No data
Iceland	*B.garinii* present in *I.uriae* [9]		
Ireland	0.6	<50	1998: General 3.4% [10]
Italy	~17 (Liguria)	<20 (Central Italy)	1997: General: 1.5–10% [1] 1998: Risk pop. 27% [11]
Latvia	15.6 (Table 2)	<400	No data
Lithuania	25–35 (Fig. 2c)	<1300	1994: General 4–32% [12]