Chapter 14
Arthropod Vectors and Their Growing Importance in Europe

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Abstract After the eradication of malaria in the middle of the past century, Europe felt relatively safe from vector-borne diseases due to the availability of effective insecticides and progress in medical diagnostics and treatment. In fact, except for Lyme disease, no vector-borne disease of cross-national distribution and far-reaching epidemiological relevance has been registered in Europe for decades. Nevertheless, not only have microorganisms with pathogenic potential increasingly been found to circulate among haematophagous arthropod populations but indigenous arthropods have also been demonstrated to possess vector competence for one pathogen or the other. Also, single cases and even localized outbreaks of mosquito-borne and further tick-borne diseases have occurred. But only in the last 10–20 years or so, probably as a consequence of ecological and climatic changes as well as of continuing globalization, some alarming vector- and vector-borne disease-related developments have taken place in Europe: the establishment and spread of invasive arthropod-vectors of disease, the importation of vector-associated pathogens, and outbreaks of emerging vector-borne diseases. The most striking examples of these incidents are the bluetongue disease epidemic in central Europe which started in 2006, and the chikungunya fever outbreak in Italy in 2007. In the first case, indigenous biting midges that had previously not been known to be vector-competent served as bluetongue virus vectors, while in the second case a human traveller carrying chikungunya virus infected vector-competent *Aedes albopictus* mosquitoes that had established in Italy some years before and had been spreading since then. In this contribution, major trends of the recent past concerning arthropod-vectors and the disease agents they transmit in Europe are

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reviewed. Because of their growing scientific importance and increasing public attention, the focus will be on mosquito, tick, sandfly and biting midge vectors.

14.1 Introduction

In the last half century or so, emerging infectious diseases have been on the rise globally, driven by socio-economic, environmental, ecological and behavioural factors. Zoonoses contribute significantly to them, and among these, vector-borne diseases play an important role (Jones et al. 2008). This is not only true for tropical and subtropical regions of the world but also for temperate and colder zones including the majority of the European territory. So, when discussing the growing importance of vector arthropods in Europe, it is necessary to mention changes in climate, in environment, and in human behaviour. Socio-economic factors may cause problems regionally, but are not relevant on a general European scale.

According to a report from the European Environmental Agency, European mean temperature has increased by about 1.2°C over the past 100 years. Global mean temperatures are projected to increase by 1.4–5.8°C until 2100, with larger increases in eastern and southern Europe (EAA 2003). Climate warming will have many effects on most arthropod vectors, such as expansion of distribution areas, acceleration of life cycles and reproduction rates, increase in biting frequencies and population sizes, and extension of seasonal activities. Several of these factors contribute to the vectorial capacities of potential vectors so that not only the nuisance caused by haematophagous arthropods but also the risk of acquiring a vector-borne disease after an arthropod's bloodmeal will be increased under a rising temperature scenario. Changes in environment may be climate-driven or man-made and include deforestation, construction of irrigation schemes, land fragmentation, loss of biodiversity and introduction of new species, just to mention some important elements. Environmental changes produce new habitats and improved living conditions for vector arthropods in many cases, and may facilitate the spread of present vectors or the establishment of new ones. Renaturation of river systems or rice cultivation, for example, are usually beneficial to arthropods with aquatic developmental stages such as mosquitoes, as new breeding sites are usually generated (e.g. Ponçon et al. 2007). The probability of contact with blood-feeding arthropods is, at least in part, dependent on human behaviour. An obvious modern change in human behaviour is that people increasingly spend their leisure time in natural environments where they are much more exposed to blood-feeding arthropods, such as ticks and mosquitoes. Enforcing this trend, urban sprawl is taking place with more and more people settling in those natural habitats (Bonnefoy et al. 2008). Most crucial for the introduction of new vector species and new vector-borne pathogens, however, is probably globalization. Technical progress in transportation and increasing global travel and trade in the past three decades have paved the way for outbreaks of vector-borne diseases in non-endemic regions of the world. During the last 50 years, air travel passenger numbers have grown by nearly 9%

annually, and shipping traffic has increased by some 27% since 1993 (Tatem et al. 2006a). Along with the passengers, animals and goods come the vectors and pathogens.

14.2 Mosquitoes (Diptera, Culicidae)

There are roughly 100 mosquito species in Europe including former malaria vectors, efficient virus vectors and vectors of filarial worms. While malaria is unlikely to become a health problem in Europe again in the foreseeable future, viral and filarial vectors seem to be spreading, followed by the pathogens.

14.2.1 Malaria

Endemic malaria was completely eradicated from Europe in the last century due to the comprehensive control programmes that had been implemented after the development of new and efficient insecticides and drugs. According to the WHO, the last autochthonous case of malaria was reported from Greek Macedonia in the early 1970s (Bruce-Chwatt and de Zulueta 1980). Mosquito populations have recovered since then, and several former malaria vectors, such as *Anopheles sacharovi, An. atroparvus* and *An. labranchiae*, are nowadays still widely distributed in Europe. Locally acquired cases of malaria therefore have continued to occur from time to time in various European countries (Sartori et al. 1989; Nikolaeva 1996; Baldari et al. 1998; Krüger et al. 2001; Cuadros et al. 2002; Kampen et al. 2002; Zoller et al. 2009). In view of the increasing travel activities to and from tropical regions where malaria is endemic and a growing number of *Plasmodium*-infected people entering Europe who may serve as infection sources for indigenous *Anopheles* mosquitoes, the number and frequency of autochthonous cases of malaria must be expected to rise in the future (Kampen and Maier 2008). A recurrence of endemic malaria, however, is rather unlikely, given the high standard of medical care in Europe.

Increasing air traffic might also lead to a rise in the frequency of inadvertent transport and importation of alien mosquitoes including *Plasmodium*-positive *Anopheles* (Karch et al. 2001; Tatem et al. 2006b). Being released at the place of destination, they may bite humans and cause cases of “airport malaria” or “baggage malaria” (Isaäcson 1989; Castelli et al. 1993; Thang et al. 2002).

14.2.2 Mosquito-Borne Viral Infections

Ten mosquito-borne viruses have been found circulating in Europe during recent decades. At least three of them are endemic and have pathogenic potential: West Nile virus, Sindbis virus and Ťahyňa virus (Hubálek 2008).

West Nile virus (WNV), a virus of the family Flaviridae and a member of the Japanese encephalitis virus complex, is generally considered an emerging pathogen although it was first observed in Europe in the early 1960s in the French Camargue (Panthier 1968). From then on, epidemics were noticed every now and then in the Mediterranean area, but intervals were long and disease symptoms generally mild. It was only in the 1990s that West Nile fever (WNF) became more and more associated with severe and neurological fatal disease, probably due to new and more aggressive virus strains entering Europe (Gubler 2007). Migratory birds are reservoir hosts to the virus, and these are responsible for spreading it over long distances and even transcontinentally. The virus is vectored by numerous mosquito species of several genera, most importantly *Culex pipiens*, that are indiscriminant between feeding on birds and on mammals (Reiter 2010). Humans and horses are especially susceptible to infections, but high numbers of dead crows may be a first indication of local virus transmission. Major WNF outbreaks in the Mediterranean basin during the past 15 years occurred in Algeria in 1994 (Le Guenno et al. 1996), in Romania in 1996 (Tsai et al. 1998), Tunisia in 1997 (Feki et al. 2005), Russia in 1999 (Platonov et al. 2001), Israel in 2000 (Green et al. 2005), France in 2000 (Murgue et al. 2001), and Italy in 2002 (Autorino et al. 2002). More recent European episodes including fatal human cases occurred in Italy in 2008 and 2009 (Macini et al. 2008; Barzon et al. 2009; Rizzo et al. 2009; Angelini et al. 2010).

Although in more northern European countries no cases of WNF have been diagnosed so far, there is serological evidence of viral infection in resident birds, for example in Great Britain and Germany (Buckley et al. 2006; Linke et al. 2007). It has been suggested that indigenous birds may be natural moderators of viral circulation as their immune system is able to cope with the infection (Pauli 2004; Reiter 2010). In North America, however, where a relatively virulent WNV strain encountered a naïve bird population in 1999, the virus was able to spread over the whole continent within a few years, with tremendous morbidities and mortalities among birds, horses and humans (Kramer et al. 2008).

Sindbis virus (SINV), a member of the western equine encephalomyelitis virus complex belonging to the family Togaviridae, is another mosquito-borne virus that is reservoired by birds. Among bird populations, it is transmitted by ornithiphilic *Culex* and *Culiseta* species whereas the bridge vector *Aedes cinereus* is mainly responsible for transmission to humans (Lundström 1999). The disease SINV causes comprises headache, myalgia, arthralgia, malaise, conjunctivitis, pharyngitis and rash. It has been named "Ockelbo disease" in Sweden, "Pogosto disease" in Finland and "Karelian fever" in north-western Russia. In Scandinavia (Sweden and Finland), thousands of human clinical cases were reported during the past decades but the virus has also been found to occur in eastern and southern Europe (Lundström 1999; Brummer-Korvenkontio et al. 2002). In Great Britain, seroconversion against SINV was demonstrated in sentinel chickens (Buckley et al. 2006) and, most recently, the virus was isolated from mosquitoes in Germany (Jöst et al. 2010).

Ťahyňa virus (TAHV) belongs to the family Bunyaviridae and is a member of the California encephalitis virus complex. It has been reported from many parts of Europe (Lundström 1999; Hubálek 2008) where it is transmitted by numerous mosquito species, predominantly *Ae. vexans*. Principal vertebrate hosts are lagomorphs, rodents and insectivores (Medlock et al. 2007, Hubálek 2008). Infections usually cause febrile illnesses in humans, sometimes accompanied by CNS involvement and bronchopneumonia.

In 2001, **Usutu virus** (USUV; Flaviviridae, Japanese encephalitis group) was detected for the first time in Europe when examining uncommonly high numbers of dead blackbirds in Austria (Weissenböck et al. 2002). Later, the virus was also found in Hungary (Bakonyi et al. 2007) and Spain (Busquets et al. 2008) while antibodies could be demonstrated in birds from Great Britain, Switzerland and Italy (Buckley et al. 2006; Weissenböck et al. 2007). USUV originates from Africa where it is transmitted mainly by *Culex* spec. among birds. Despite two human cases of neuroinvasive infection in immunocompromized patients in Italy (Cavrini et al. 2009; Pecorari et al. 2009), there is still some debate on its human pathogenic potential.

Although **Rift Valley fever virus** (RVFV; Bunyaviridae) has not yet appeared in Europe, the increasingly frequent occurrence of infections in endemic areas and its geographic expansion are being carefully observed by European epidemiologists. Originally, Rift Valley fever (RVF) was restricted to eastern and southern Africa but, since several outbreaks were reported from Egypt and the Arabian peninsula (Ahmad 2000; Gerdes 2004), a possible further spread and a leap into southern Europe is a matter for concern (Martin et al. 2008; Chevalier et al. 2010).

RVF is a serious disease of domestic animals and humans. Epidemics are often characterized by sudden abortion storms and close to 100% mortality in newborns. In older humans infection causes an influenza-like illness (Abdel-Wahab et al. 1978). A large range of mosquito species is capable of transmitting the virus, and historically outbreaks have often been associated with heavy rainfall, floods and the construction of dams. Some of the African vector species (Turell et al. 2008) also occur in Europe, where several of them are thought to be potential vectors or have been demonstrated to be susceptible to RVFV (Moutailler et al. 2008; Chevalier et al. 2010). A peculiarity with RVFV is that certain *Aedes* vector species in some African regions are at the same time the viral reservoirs, as the virus is transmitted vertically from one mosquito generation via the eggs to the larvae of the next generation (Gerdes 2004). Thus, vertebrate reservoir hosts are not necessary for the maintenance of the natural cycle, and the virus can remain endemic for a while without appearing in vertebrates (Linthicum et al. 1985).

14.2.3 Dirofilaria spec.

In the Mediterranean, various mosquito species of the genera *Culex*, *Aedes* and *Anopheles* (Pampiglione et al. 1995; Cancrini et al. 2003) also transmit the filarial worms *Dirofilaria immitis*, the etiological agent of heartworm disease, and *D. repens*, which parasitizes the subcutaneous tissue. Their natural hosts are canines and sometimes felines, but human infections with *D. repens* have lately been on the rise in France, Greece, Spain and Italy (Pampiglione et al. 1995; Muro et al. 1999; Pampiglione and Rivasi 2000; Simón et al. 2005). Also, the first cases of autochthonous infections in dogs have been reported from The Netherlands and Germany (Hermosilla et al. 2006; Overgaauw and Van Dijk 2009). In humans, an infection with *D. repens* may lead to subcutaneous and pulmonary nodules or parenchymal lesions. Climatic change, the spread of possible vectors, and increased movement of cats and dogs across Europe are supposed to be responsible for a continuing expansion of the geographic range of *Dirofilaria* parasites (Genchi et al. 2005, 2009).

14.2.4 Invasive Mosquitoes

Although there are numerous indigenous mosquito species in Europe that may become vectors of endemic or imported pathogens under certain circumstances, there are some mosquito species of tropical or subtropical origin that have been shown to be much more efficient in transmitting. Unfortunately, several of those have recently invaded Europe and some of them have even succeeded in establishing and spreading. The most important one undoubtedly is the Asian tiger mosquito ***Aedes albopictus***, which was introduced into southern Europe at least twice in the late 1970s and in the late 1980s through the used tyre trade (Sabatini et al. 1990; Adhami and Reiter 1998). During the second introduction, a mosquito strain was imported from the USA that was adapted to moderate climates and, in contrast to Asian *Ae. albopictus* strains, is now able to hibernate in southern Europe by egg diapausing. It successfully established populations in Italy and has started spreading northwards (Knudsen et al. 1996; Romi and Majori 2008). *Aedes albopictus* was also reported from France and Belgium in 2000 (Schaffner and Karch 2000; Schaffner et al. 2004), Serbia/Montenegro in 2001 (Petrić et al. 2001), Switzerland in 2003 (Flacio et al. 2004), Greece in 2003 (Samanidou-Voyadjoglou et al. 2005), Croatia in 2004 (Klobučar et al. 2006), Spain in 2004 (Aranda et al. 2006), The Netherlands in 2005 (Scholte et al. 2007), Germany in 2007 (Pluskota et al. 2008) and Malta in 2009 (Gatt et al. 2009). It had been imported into most places via the tyre trade (cf. Reiter 1998), but introductions via the lucky bamboo trade to greenhouses and via truck traffic also play a role (Flacio et al. 2004; Scholte et al. 2008). Fortunately, established outdoor populations of *Ae. albopictus* do not appear to exist at present in those more northern latitudes, but a further northward spread combined with an ecological adaptation cannot be excluded. *Aedes albopictus* is an efficient vector of at least 22 arboviruses including Dengue and yellow fever viruses (Mitchell 1995; Gratz 2004). In 2007, it was responsible for a chikungunya fever outbreak in northern Italy with more than 200 human clinical cases (Angelini et al. 2008). It was found later that a visitor from India who was unknowingly carrying chikungunya virus must have been the infection source to the local *Ae. albopictus* mosquitoes (Rezza et al. 2007).

In addition to *Ae. albopictus*, there have been further invasions of exotic mosquito species into Europe. The Asian rock pool mosquito ***Aedes japonicus japonicus***, an efficient vector of WNV and Japanese encephalitis virus, was found in France in 2000 (Schaffner et al. 2003), in Belgium in 2002 (Versteirt et al. 2009) and in northern Switzerland/southern Germany in 2009 (Schaffner et al. 2009).

Aedes atropalpus, a North American vector of WNV, was demonstrated in Italy in 1996 (Romi et al. 1997), in France in 2003 and 2005 (Adege-EID Méditerranée 2003, 2006), and in The Netherlands in 2009 (Scholte et al. 2009). It could, however, be completely eliminated by the control measures directed against *Ae. albopictus*.

Another mosquito species that is vector-competent to several arboviruses is the yellow fever mosquito, ***Aedes aegypti***, which was once widely distributed in subtropical southern Europe. It caused yellow fever outbreaks in the 18th and 19th centuries (Eritja et al. 2005), and a major dengue fever outbreak in the 1920s in Greece (Cardamatis 1929; Rosen 1986). It is not clear why it disappeared from Europe, but as it reappeared on the island of Madeira in 2004 (Almeida et al. 2007) and, although not European, on the Georgian Black Sea coast (Iunicheva et al. 2008), it is not unlikely that it will also reconquer the southern European continental areas, supported by climate warming.

14.3 Ticks (Acari, Ixodidae)

Next to mosquitoes, ticks are the most important group of arthropods that are agents of pathogen transmission. According to Süss and Schrader (2004) and Süss et al. (2004), there are 31 tick species in Europe from which viruses, bacteria and parasites have been isolated. Most of the pathogens are not very common but some are widely distributed, may be serious threats to health, or are just emerging, such as the *Borrelia burgdorferi* sensu lato complex, tick-borne encephalitis virus (TBEV), or *Babesia* spec., *Anaplasma phagocytophilum* and *Rickettsia* spec.

14.3.1 Spread of Ticks

Not only do several tick-borne pathogens seem to be emerging and spreading, but their vector ticks are spreading too (e.g. Hartelt et al. 2008; and chap. 16). The most common tick species in Europe is the hard tick ***Ixodes ricinus***, the main vector of *B. burgdorferi* sensu lato and TBEV. With few exceptions (e.g. regions of Scandinavia), this tick species is distributed over much of Europe and beyond (Gern 2005). In areas of central and northern Sweden, increasing population densities and a northwards distribution shift were observed between the 1980s and the 1990s (Tälleklint and Jaenson 1998) which has been attributed to climate change (Lindgren et al. 2000). In addition, an altitude shift from about 700–800 m above sea level to 1100 m and more has been registered for *I. ricinus* in the Czech Republic and Austria within the recent past, which has also been linked to a rise in temperature (Danielová et al. 2008; Materna et al. 2008; Holzmann et al. 2009).

There is also evidence for the spread of other tick species. For example, the taiga tick ***Ixodes persulcatus***, an efficient vector of TBEV, seems to be expanding its Asian distribution area westwards. It has recently been found in Finland, several hundreds of kilometres further to the northwest than previously recorded (Jääskeläinen et al. 2006). Another hard tick species, ***Dermacentor reticulatus***, the major vector of *Babesia canis* in Europe, is nowadays found at considerably more sites in Germany than only a few years ago (Heile et al. 2006; Dautel et al. 2006). In The Netherlands, questing specimens of this tick species were found in the field for the first time ever in 2006 (Nijhof et al. 2007). Environmental and climatic changes as well as an increase in blood host populations are among the causes being discussed. The former absence of *D. reticulatus* from Germany had in part been assigned to a lack of adequate humid biotopes such as swampy lowlands and floodplain forests (Enigk 1958).

Much more alarming would be a geographic expansion of ***Hyalomma marginatum***, as this tick species is the principal vector of Crimean-Congo haemorrhagic fever virus (CCHFV). It is a two-host tick that remains on the same host for up to 26 days, from the unfed larval stage through to the fed nymphal stage. Pre-mature stages of the subspecies *H. m. marginatum* are frequently imported by migratory birds from the tick's distribution areas in the southern European/North African Mediterranean and the southwestern Palaearctic regions into central and northern Europe (Hoogstraal et al. 1961; Papadopoulos et al. 2002). Laboratory studies on temperature requirements (Emelyanova 2005), however, suggest that they cannot survive and do not reach the adult stage under present central European conditions. Notwithstanding, a questing adult female of *Hyalomma m. marginatum* was found in southern Germany in 2006 (Kampen et al. 2007).

A further factor that needs to be considered in the context of pathogen transmission by ticks under changing environmental conditions is the extension of seasonal tick activity periods. Such an extension has in fact been observed in Sweden as a consequence of mild winters (Tälleklint and Jaenson 1998). In a German study, *I. ricinus* could even be collected throughout the winter (Dautel et al. 2008).

As with other ectoparasites, ticks may also take advantage of globalization and increased travel activities in terms of expanding their distribution area. The brown dog tick ***Rhipicephalus sanguineus***, for example, a thermophilic hard tick species and the major vector of *Rickettsia conorii* in Europe, is often imported while attached to, and feeding on, dogs. In recent decades, *Rh. sanguineus* has successfully established indoor populations in more northern European countries, such as Germany, the UK and Belgium (Gothe 1968; Fox and Sykes 1985; Sibomana et al. 1986).

14.3.2 Lyme Disease

The most significant tick-associated disease in Europe and worldwide is Lyme borreliosis (LB). At least four of the seven genospecies of the *B. burgdorferi* complex occurring in Europe are pathogenic to humans and are causative agents of LB: *B. burgdorferi* sensu stricto, *B. garinii*, *B. afzelii* and *B. spielmanii* (Baranton and De Martino 2009). In contrast to North America, it cannot really be said that LB or the spirochetes are spreading geographically in Europe (except for northern Scandinavia where its vector, *I. ricinus*, is spreading). *Borrelia burgdorferi* s.l. probably occurs everywhere where *I. ricinus* occurs, which by preference is in mixed and deciduous woods (Gern 2005), where borrelial reservoir hosts are available and where contact between ticks and humans is possible. Infection prevalences vary regionally as does the composition of the different genospecies (Hubálek and Halouzka 1997, 1998). There is evidence, however, that infection prevalences have been increasing within populations, possibly depending on tick and blood host densities (Kampen et al. 2004). In many countries, LB is not a notifiable disease and so disease incidences are hard to obtain. The symptoms are manifold, ranging from slightly feverish to skin lesions and the involvement of heart, joints and the nervous system (Strle and Stanek 2009).

14.3.3 Tick-Borne Encephalitis

Less frequent and regionally more focussed, but at the same time more critical with regard to human health and geographic spread, is tick-borne encephalitis (TBE). TBEV (family Flaviviridae) is endemic in central and eastern Europe, Russia and the Far East. It occurs in three subtypes, the far eastern (formerly RSSE = Russian spring-summer encephalitis), the Siberian, and the central European (formerly CEE = Central European encephalitis) (Gritsun et al. 2003). The far eastern and the Siberian subtypes are transmitted predominantly by *I. persulcatus*, the central European subtype by *I. ricinus*. An infection with the central European type often has a biphasic course (Haglund and Günther 2003). The first acute phase usually presents with fever, headache, joint and back pain, nausea and vomiting, whereas in the second chronic phase, following a short symptom-free interval, neurological signs occur and 20–30% of the patients suffer from meningoencephalitis. The fatality rate is ca. 1%. Infections with the far eastern subtype are regarded as much more severe than those with the other types, and case fatality rates of 20–60% have been described (Pogodina et al. 1986). *Ixodes persulcatus* often also reaches much higher virus infection prevalences than *I. ricinus*. While *I. ricinus* infection prevalences are mostly quoted as being about 0.5–5% (e.g. Dumpis et al. 1999; Randolph 2001; Süss et al. 2006), locally 30–40% of *I. persulcatus* may be found infected with TBEV (Smorodintsev 1958; Korenberg et al. 1999).

In Europe, TBE is endemic in many western and central countries and Scandinavia, particularly Austria, Croatia, Czech Republic, Estonia, Finland, Germany, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Sweden and Switzerland. Although incidences vary and reporting is not standardized internationally, an overall increase in case incidences during the past 30 years can clearly be seen (Süss 2005, 2007). This trend is generally thought to be related to global warming, as warmer weather leads to larger rodent populations and more active ticks. However, sophisticated models and analyses show that climate alone cannot explain the spatio-temporal heterogeneities in TBE epidemiology (Sumilo et al. 2007; Randolph 2008).

Incidences of TBE have not only risen but TBEV-positive ticks and human infections after tick bites have recently been recorded in areas and altitudes previously free of TBEV (e.g. Jääskeläinen et al. 2006; Skarpaas et al. 2004; Brinkley et al. 2008; Stefanoff et al. 2008; Fomsgaard et al. 2009; Holzmann et al. 2009).

14.3.4 *Babesia* spec., *Anaplasma phagocytophilum,* Rickettsiae

Tick-borne pathogens in Europe which, from a medical point of view, have been the subject of enhanced awareness in recent years and may become even more relevant in the future are *Babesia* spec., *Anaplasma phagocytophilum* and *Rickettsia* spec.

In Europe, the genus *Babesia* contains several species with zoonotic potential including *B. divergens*, *B. bovis, B. venatorum*, *B. microti* and *B. canis*. They are transmitted by various species of ticks, primarily *I. ricinus*, which may regionally reach infection prevalences of up to 20% (Halos et al. 2005). *Babesia divergens* and *B. ovis* have a reservoir in cattle, *B. microti* in mice, *B. canis* in dogs and *B. venatorum* in deer (Hunfeld et al. 2008). The majority of the human cases detected so far in Europe are traced back to *B. divergens* (Gorenflot et al. 1998), but cases of disease following infections with the other species have been described. *Babesia microti*, for example, formerly thought to occur only in North America (Homer et al. 2000), was recently diagnosed in humans in Switzerland and Germany (Meer-Scherrer et al. 2004; Hildebrandt et al. 2007). Additionally, a newly emergent species, *Babesia venatorum* (formerly *Babesia* EU1), was isolated from patients in Austria, Italy and Germany (Herwaldt et al. 2003; Häselbarth et al. 2007). Most patients infected with *Babesia* parasites were asplenic and immunocompromized. Symptoms were generally life-threatening and mortality rates high (Hunfeld et al. 2008).

Canine babesiosis is another growing problem in Europe, with an increasing number of cases in recent years (e.g. Bourdoiseau 2006; Matjila et al. 2005; Welc-Faleciak et al. 2009). The principal causative agent, *Babesia canis*, is transmitted mainly by *D. reticulatus* ticks, and the spread of *B. canis* is probably directly associated with the spread of its vector. In contrast to *B. canis*, *B. gibsoni* is supposed to be transmitted mainly by *Rh. sanguineus*. Recently, several cases of canine babesiosis caused by *B. gibsoni* (Asian genotype) have been found in Italy, Spain and Germany (Casapulla et al. 1998; Suarez et al. 2001; Hartelt et al. 2007).

Anaplasma phagoytophilum is the etiological pathogen of another emerging *I. ricinus*-borne disease in Europe, human granulocytic anaplasmosis (HGA;

Strle 2004). The first case of HGA was described in 1997 in Slovenia (Petrovec et al. 1997), but up to early 2003, 65 more patients were diagnosed with the disease, mostly in Slovenia and Sweden (Strle 2004). Isolated cases, however, occurred in other European countries. Clinical features are usually mild to moderately severe, but may be severe, particularly in the elderly, when there is a concomitant chronic illness (Bakken and Dumler 2000; Olano and Walker 2002). Small mammals have been identified as reservoir hosts for *A. phagocytophilum* (Liz 2002). Infection prevalences in ticks may be as high as 30% (Christova et al. 2001).

Mediterranean spotted fever caused by *R. conorii* was for a long time thought to be the only tick-borne rickettsiosis prevalent in Europe. During the last decade, however, several other rickettsial species transmitted by ticks, such as *R. aeschlimannii*, *R. slovaca*, *R. sibirica* subsp. *mongolitimonae, Rickettsia massiliae* and *R. helvetica*, have emerged (Brouqui et al. 2007; Dobler and Wölfel 2009). They are associated with different tick species and pathogenicities, but there are as yet no detailed European studies on their distribution and prevalences.

14.3.5 Crimean-Congo Haemorrhagic Fever

Together with the spread of *Hyalomma* ticks, the spread of Crimean-Congo haemorrhagic fever (CCHF) virus (family Bunyaviridae) is anticipated. CCHFV is enzootic in Africa, the Middle East, central and southwestern Asia (Hoogstraal 1978), and has also been shown to circulate in parts of southern and southeastern Europe, such as Bulgaria, Albania, Kosovo and Turkey (Ergönül 2006; Vourou 2009). Human infections may be coupled with severe haemorrhagic manifestations and case fatality rates of more than 30% (Charrel et al. 2004). CCHF has become a most severe public health problem in Turkey since 2002, with more than 3,000 fatal cases in Anatolia since 2007 alone (Yilmaz et al. 2009; Maltezou et al. 2010). The reasons for these dramatic developments are unknown, but it has been suggested that changes in land use have ameliorated the living conditions of both small and large mammals as potential tick blood hosts and, consequently, of the ticks themselves (Randolph and Ergönül 2008).

14.4 Sandflies (Diptera, Psychodidae)

14.4.1 Leishmaniasis

Sandflies are vectors of *Leishmania* parasites and several arboviruses. In Europe, they transmit *Leishmania infantum*, *L. tropica*, Toscana virus, sandfly fever Naples virus and sandfly fever Sicilian virus. Numerous species of sandflies occur in the Mediterranean, with some of them, such as *Phlebotomus perfiliewi* and *P. perniciosus*, spreading northwards (Kuhn 1999). *Phlebotomus perniciosus* and *P. mascittii* have sporadically been reported from northern France, the British island of Jersey, Belgium and Germany (Callot 1950; Naucke and Pesson 2000; Naucke and Schmitt 2004; Depaquit et al. 2005). The northernmost finding of a phlebotomine sandfly in Europe was that of *P. mascittii* in Rhineland-Palatinate, central-western Germany (Naucke et al. 2008).

Leishmania infantum zoonotic cutaneous and visceral leishmaniases are endemic in almost the whole Mediterranean, with major foci in Italy and Albania (Gramiccia and Gradoni 2005). *Phlebotomus perfiliewi* and *P. perniciosus* are reportedly able to transmit *Leishmania infantum* (Maroli and Khoury 1998), while *P. mascittii* has not definitively been proven to be a vector (Depaquit et al. 2005). A few years ago, two cases of *L. infantum* leishmaniasis were diagnosed in Germany, in a 15-month-old baby and in a horse that had never been outside of Germany (Bogdan et al. 2001, Koehler et al. 2002). Naucke et al. (2008) even reported 11 autochthonous *Leishmania* infections in Germany since 1991, mainly in dogs.

Anthroponotic cutaneous leishmaniasis caused by *L. tropica* sporadically occurs in Greece and probably in neighbouring countries where *P. sergenti* is likely to be the main vector. Because of migration and travelling, *L. tropica* has a high potential to be introduced into the rest of the EU (Ready 2010).

A particular problem with leishmaniasis and its potential spread in Europe is the significant increase in the movement of dogs together with their owners to endemic southern countries, and the exploding and often uncontrolled importation of dogs from those areas (Shaw et al. 2008; Menn et al. 2010). In some Mediterranean regions more than 50% of dogs are infected with *Leishmania* parasites (e.g. Brandonisio et al. 1992; Ciaramella et al. 1997), and imported and returning dogs are not necessarily medically examined. Since dogs are important reservoir hosts for the parasite, they may become infection sources to vector-competent sandflies occurring in non-endemic areas (Zahner and Bauer 2004; Mettler et al. 2005).

14.4.2 Sandfly Virus Fever

Toscana virus (TOSV; Bunyaviridae) is transmitted by sandflies in the European Mediterranean whereas sandfly fever Naples virus and sandfly fever Sicilian virus (both family Bunyaviridae), also referred to as "papatacci fever" viruses, have been reported from more eastern parts of the Mediterranean and some north African areas (Depaquit et al. 2010). Infections often present with influenza-like symptoms but, in the case of TOSV, can also lead to acute meningitis and meningoencephalitis. Important vectors are *P. perniciosus* and *P. ariasi* but potential vectors appear to be more widely dispersed than the viruses. At present, no reasons are known why the viruses should not extend over the entire distribution ranges of their vectors.

Little is known, however, about the vertebrate reservoirs and the impact of climatic factors on the viral replication in their vectors.

14.5 Biting Midges (Diptera, Ceratopogonidae)

14.5.1 Bluetongue Disease

Bluetongue disease (BTD), a viral infection of ruminants, in particular of sheep, cattle and goats, became endemic in southern Europe in the late 1990s (Purse et al. 2005). Prior to that, its main vector in its African and Asian distribution areas, *Culicoides imicola*, had been introduced and established in the Iberian peninsula and had spread to other European Mediterranean countries (Mellor et al. 1983; Purse et al. 2005). This ceratopogonid species has mainly been responsible for the transmission of five serotypes of the bluetongue virus (BTV; family Reoviridae) that have been circulating and causing BTD outbreaks in southern Europe. In August 2006, however, BTD unexpectedly broke out in central Europe (Belgium, The Netherlands, Germany, France, Luxembourg) from where it spread to numerous other countries of the continent during the following three years, thereby affecting tens of thousands of animal holdings and causing enormous damage to animal health and economic losses (Kampen and Werner 2010). Strangely, the newly emerging virus strain was serotype 8 (BTV-8) and different from the serotypes circulating in southern Europe. It later transpired that it was most closely related to a strain isolated in Nigeria in 1982 (Enserink 2006; Maan et al. 2008), but the way in which it entered Europe has remained obscure (Mintiens et al. 2008). Also, it has been demonstrated that the culicoid species responsible for BTV transmission in Europe so far, *C. imicola*, did not occur in the northern outbreak areas although a spread to the north had been observed (Purse et al. 2005). Instead, evidence has accumulated that indigenous *Culicoides* species, notably those of the Obsoletus complex, are the vectors of BTV in Europe north of the distribution area of *C. imicola* (Meiswinkel et al. 2007; Carpenter et al. 2008; Dijkstra et al. 2008; Hoffmann et al. 2009).

In addition to BTV-8, short episodes of BTV-6 and BTV-11 transmission occurred in late 2008 in a Dutch/German border region and in Belgium, respectively, and these are equally unsolved as regards their origin and background (De Clercq et al. 2009; Eschbaumer et al. 2009; Kampen and Werner 2010).

Last but not least, BTV-1 is spreading in Europe (Kampen and Werner 2010). This serotype jumped to the Iberian peninsula from northern Africa in 2007, and since then has caused disease outbreaks in Spain and Portugal, and, subsequently, France. During 2008, close to 5,000 animal holdings were affected in France, and despite the national vaccination programme several new cases occurred north of the restriction zone in 2009 (EU-BTNET 2009, 2010).

14.5.2 African Horse Sickness

BTD is only one of two dangerous viral animal diseases transmitted by *Culicoides* biting midges. African horse sickness (AHS) is even more devastating to equids than BTD is to ruminants. In AHS, mortality rates may exceed 90% in susceptible equids. The disease also originates from sub-Saharan Africa where Zebra are the reservoir hosts and where the same *Culicoides* species as in BTD, basically *C. imicola*, are the viral vectors (Mellor and Hamblin 2004). From 1959 to 1961, a massive AHS outbreak swept over the Arabian peninsula and the Middle East as far as India and Pakistan, with hundreds of thousands of horses dying (Anwar and Qureshi 1972). Another major epidemic beyond the sub-Saharan endemic zone was registered in North Africa and Spain in 1966 (Diaz Montilla and Panos Marti 1968). The Iberian peninsula was once again struck by an outbreak in 1987 after the introduction of subclinically infected Zebra to a zoological garden close to Madrid (Lubroth 1988). Because of the mild climate in southern Spain and Portugal and the vector activity throughout the year, the virus was able to overwinter and produce further incidents in 1988, 1989 and 1990 (Mellor and Hamblin 2004).

14.6 Conclusions

The BTV-8 epidemic is a remarkable, unprecedented and unique example of an emerging vector-borne disease and of the importance of public health preparedness in Europe. Prior to the BTD outbreak in 2006, entomologists had slowly disappeared from the European university scene as vector research was no longer thought to be sufficiently competitive and innovative (cf. Cuisance and Rioux 2004). At the time of the outbreak, hardly any of the few remaining entomologists dealt with ceratopogonids and so, when the disease broke out, specialists were not available and knowledge on the occurrence, distribution, biology, ecology and vector competence of biting midges, if present at all, was outdated. On the governmental side, a delusory feeling of safety, paired with ignorance concerning vector-borne diseases, had become commonplace. Interestingly, only shortly before the outbreak, a few reports and publications had explicitly pointed out the risk of BTD outbreaks in central and northern Europe (Wittman and Baylis 2000; Maier et al. 2003; Koslowsky et al. 2004).

The outbreak, disastrous as it was, resulted in some positive developments. Medical entomology has become attractive again and some research positions have even been established in Europe. As the epidemic was border-crossing, a fruitful international research network has been initiated and supported by the EU under the umbrella of the MedReoNet programme (Cêtre-Sossah 2010).

Since 2006, we have learnt much about European biting midges, but there are still tremendous gaps in our knowledge of breeding habitats, vector competences and overwintering, for example. Indigenous ceratopogonids cannot even be reared in the laboratory in order to conduct controlled experimental studies. Thanks to LB and TBE, there is a considerable body of knowledge on *I. ricinus*, but other tick species, mosquitoes and further groups of haematophagous arthropods have been recklessly neglected for a long time. Furthermore, we must recognize that we know a great deal more about alien and invasive potential arthropod vectors and vector-transmitted pathogens than about the indigenous ones. Both groups are important of course, and, depending on the ecological conditions, any combination between endemic or imported/invasive vector, and endemic or imported/invasive pathogen may be most efficient in causing vector-borne disease. A research gap that has accumulated over decades has to be filled, and this will only be possible with adequate personnel and research funds.

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