

Epilogue: emerging pests and vector-borne diseases are a reality

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Abstract

Historically, Europe has suffered pests and vector-borne diseases affecting man and domestic animals. Through advances in science and technology, measures were introduced that led to effective management and control, causing the eradication of several diseases (e.g. plague, typhus, malaria) or reduction of pests to levels where they no longer were harmful or damaging. In the last decades this situation has changed and a series of pests and diseases are resurging or emerging giving cause for serious concern, threatening both human and animal health. The reasons for this upsurge and emergence are being discussed, and actions are being proposed to reduce the incidence of diseases already present and to lower the risk of introduction of new ones. Suggestions for the control of pest organisms are being presented, using integrated control with emphasis on biological methods for insect control. Recommendations for the prevention of outbreaks of pests and vector-borne diseases associated with climate- and environmental change are proposed, including the establishment of early-warning systems and the development of pan-European contingency plans.

Keywords: remedial action, epidemiology, resistance, resurgence, climate change, Europe, biological control, environmental management

A growing threat

The preceding chapters demonstrate that in historic times pests and vector-borne diseases posed a huge health risk to humans and livestock in Europe. Notably malaria was highly prevalent, not only along the shores of the Mediterranean, but also in countries as far north as Norway and Sweden. Yellow fever was widespread in southern Europe and of course, plague caused devastating effects, notably in the 14th and 15th Centuries. Head lice and house flies were part of every household being rich or poor, and people had learnt to tolerate them until effective methods of control became available in the early 20th Century. With the discovery of parasite life cycles, drugs and insecticides the 20th Century provided prospects for real control of these pests and diseases, and it was widely expected that many of them could be eradicated. Indeed, yellow fever disappeared from Europe, most likely because of the disappearance of its vector *Aedes aegypti* (L.). It is peculiar that the reasons for the disappearance of this mosquito species from Europe are not known: the species is still widely common in the continental USA, China, South Africa and Brazil/Argentina, where it experiences a climate similar to that of southern Europe. By contrast, the disappearance of malaria from Europe is better understood, and is the result of targeted interventions using anti-malarial drugs, insecticides and environmental measures (Bruce-Chwatt and De Zulueta, 1980). Also, the prevalence of head lice infections decreased markedly by the middle of the 20th Century, presumably as a result of better hygiene and effective insecticides. Similarly, bed bugs were until recently, rarely considered a problem, even though they were highly prevalent before World War II. Few animal diseases in Europe were attributed to arthropods, directly or indirectly, although periodic outbreaks of African horse sickness and bluetongue, transmitted by *Culicoides* spp., were reported on the Iberian peninsula (Ortega *et al.* 1998).

What may have caused a change in these optimistic views? As this book shows, many vector-borne diseases are lingering on in Europe, and some new diseases, Usutu virus, Chikungunya virus and bluetongue virus have emerged in regions of Europe where they had never before been recorded. Also, there is a huge problem with several pest insects such as head lice, bed bugs and house flies: not only are these pests increasing in prevalence and abundance, they have also become resistant against conventional chemical treatments. Endemic vector-borne diseases like Lyme disease and tick-borne encephalitis (TBE) have increased in prevalence, and also seem to distribute across larger areas than before. On the livestock side, the 2006 emergence of BT serotype-8 in north-western Europe has shaken the livestock industry, and in poultry farms the emergence of multi-resistant housefly strains poses a serious economic problem for the poultry industry. Sheep scab is causing huge losses to the sheep industry in the UK, and because of acaricide resistance an effective solution for mite control is lacking. Finally, judging from the recent epidemics of SARS and avian influenza, there appears to be a genuine global dispersal of infectious diseases for reasons that are only partially understood. The resurgence and emergence of these diseases and pests is giving rise to considerable discontent in society and costs to the economy. Whereas until the late 1990s the people of Europe considered their continent 'free' of such diseases and pests, they now are confronted with regular news bulletins announcing the outbreak of a new disease or the nuisance caused by insects that cannot be sufficiently kept under control. Just in the summer of 2007, a renewed outbreak of bluetongue in north-western Europe has received much attention and the discovery of >150 cases of Chikungunya in Italy has made headlines.

Table 1 lists the most prominent of these diseases and pests, as well as their epidemiological status in Europe. Many diseases and pests on this list have been around in Europe for a long time, but changes in human and animal hygiene, arthropod control and the development of effective drugs have caused the low prevalence or indeed complete disappearance of them in Europe. Some diseases, such as West Nile virus and African horse sickness, return to Europe periodically from Africa, possibly cycling around host immune levels: when a sufficient level of herd immunity has been built up, the disease disappears to return in a year when this immunity has waned. Other diseases, like leishmaniasis, have never gone away. However, for as yet unexplained reasons, their distribution and prevalence are increasing. Some diseases like plague and typhus have disappeared and not been recorded any longer in Europe. This is attributed to hygienic and sanitary measures and a modified style of living. The pathogenic agents causing these diseases, however, are still present elsewhere in the world and an occasional (small) outbreak in Europe is considered possible. Finally, there is a series of 'new' diseases and pests that have not been seen in Europe until recently. Lyme disease was discovered only in the early 1980s, and has meanwhile become the most prevalent vector-borne disease of humans in Europe. The Asian tiger mosquito *Aedes albopictus* (Skuse) arrived in Albania around 1978, and has since enjoyed frequent introductions, and subsequent establishment in many countries. It is now one of the main nuisance species in northern Italy, and has recently become established in Southeast France and Northeast Spain.

Unlike vector-borne diseases, the prevalence of pest species is often not considered as emerging or associated with environmental and climate change. This is probably because their presence is often strongly dependent on human behaviour. For instance humans are the only host species of head lice, and the existence of this insect depends on the efficacy of control measures employed by its own host. Head lice control has become dependent almost exclusively on insecticides (Chapter 17), and the lice are rapidly developing resistance against these chemical agents. Other reasons for the increasing incidence of head lice are poorly understood, but may be associated with different cultural behaviours of families, providing renewed opportunities for head lice. In a similar vein

Table 1. Overview of the most prevalent vector-borne diseases and arthropod pests in Europe and their epidemiological status as eradicated/stable/emerging.

Disease	Arthropod vector or pest	Historical status	Epidemiological status	Emerging**
Plague	Flea	+++++	Disappeared	No
Malaria	<i>Anopheles</i> spp.	+++	(+)	No
Yellow Fever	<i>Aedes aegypti</i>	+	Disappeared	No
Dengue	<i>Aedes aegypti</i>	+	Disappeared	Possible
West Nile	<i>Culex pipiens</i>	??	++	Possible
Chikungunya	<i>Aedes albopictus</i> *	Not present	+	Yes
Usutu	<i>Culex</i> spp.	Not present	++	Yes
Leishmaniasis	<i>Phlebotomus</i> spp.	??	++	Yes
Typhus	<i>Pediculus humanus</i>	+++	Disappeared	No
Bartonella	<i>Ixodes ricinus</i> / <i>Pediculus humanus</i>	++	+	Yes
Q-fever	<i>Ixodidae</i> spp.	(+)	+	Possible
Human monocytic ehrlichiosis (HME)	<i>Ixodes ricinus</i>	??	+	Yes
Human granulocytic ehrlichiosis (HGE)	<i>Ixodes ricinus</i>	??	+	Yes
Lyme disease	<i>Ixodes ricinus</i>	(+)	+++	Yes
Rickettsia helvetica	<i>Ixodes ricinus</i>	??	+	Yes
Tick-borne encephalitis	<i>Ixodes ricinus</i>	(+)	+++	Yes
Tularaemia	<i>Ixodes ricinus</i>	(+)	++	Yes
Bluetongue	<i>Culicoides</i> spp.	Not established	+++	Yes
African horse sickness	<i>Culicoides</i> spp.	Not established	++	May become established
Pests				
Head louse	<i>Pediculus humanus capitis</i>	+++	++	Increasing in prevalence
Bed bug	<i>Cimex lectularius</i>	+++	+	Yes
Housefly	<i>Musca domestica</i>	+++	+++	Increasing in prevalence
Asian tiger mosquito	<i>Aedes albopictus</i>	Absent	++	Increasing in distribution and abundance
Sheep scab	<i>Psoroptes ovis</i>	+	++	Yes

* At the time of writing *Aedes albopictus* was suspect as the vector of Chikungunya virus in Italy; ** Emerging – Some diseases/pests have never been away, but are resurging and becoming widely prevalent. In that case we consider them as 'emerging'. Possible–environmental circumstances are suitable for its emergence and the disease is occasionally recorded.

+, ++, +++ increasing degree of prevalence; (+) historical presence unconfirmed

the resurgence of bed bugs may be seen: heavy use of pesticides to control bed bugs and other nuisance insects in the household has caused a rapid development of physiological resistance against a large number of chemicals. It may also be that a modern change in home care and control of indoor climate (wall-to-wall carpeting and central heating) favour the establishment and reproduction of bed bugs (Chapter 15). Another example of uncontrolled and intensive use of pesticides leading to resistance is the sheep ked in the British sheep husbandry. Here, measures are needed to develop alternatives to chemical control before the sheep ked can be brought under control (Chapter 13).

A threatening status

The examples of existing and new pests and vector-borne diseases listed in Table 1 are cause for serious concern. The emergence of Lyme disease in the 1980s was initially considered with curiosity and foremost a new challenge for the health care industry. Only when increasing numbers of patients were reported, and the disease was found to have a continental-wide distribution, became the authorities concerned. Today in many countries much research is funded for the development of diagnostic tools of Lyme disease, an effective drug treatment regimen and reliable epidemiological tools for risk assessment. This is done because no effective method for control of *Ixodes ricinus* L., the main vector species in Europe, is available. It is expected that under global warming the tick season will be extended in many countries, extending the transmission season possibly by several months each year. An additional threat is caused by the findings of other pathogenic agents being transmitted by *I. ricinus*: tick-borne encephalitis virus is the most important of these, having increased in incidence in Sweden and migrated into Norway (Lindgren and Gustafson 2001, Skarpaas *et al.* 2006) and spreading its distribution across Central Europe (Chapter 11). Other pathogens associated with *Ixodes ricinus* are *Anaplasma phagocytophilum* and *Ehrlichia chaffeensis*, *Rickettsia helvetica* and *Bartonella henselae*. Should the environmental conditions become more favourable for *I. ricinus*, as suggested in Chapter 22, then the incidence and geographic distribution of these diseases might increase further.

The discovery of the Usutu virus in Austria in 2001 has gone almost unnoticed in the scientific world. This is remarkable, given the high profile that the emergence of West Nile virus in the USA has received, and the numerous programmes that focus on Avian Flu (H5N1). In our opinion, Usutu virus has the potential of becoming more prevalent and more virulent if, by evolutionary force, the virus might enter different bird species or appear in a more virulent serotype. The virus has spread rapidly across Central Europe, possibly by several re-introductions or by birds emigrating from the index site in Austria. Being highly fatal for certain indigenous bird species in Austria, we should be alerted to the impact of the virus on other birds. Usutu virus has, therefore, the same potential as West Nile virus in the USA, by causing a kill-off of birds. In addition, humans develop disease symptoms following infection with Usutu virus, and the severity of these symptoms is still poorly understood.

Perhaps more dramatic, and certainly very serious, is the recent discovery of an epidemic of Chikungunya in Italy (Chapter 10). Whereas we do not yet know whether this epidemic has been brought under control (September 2007), it is worrying that it had been predicted following the recent and large epidemic of Chikungunya in the Indian Ocean and the Indian subcontinent (Bodenmann and Genton, 2006). This epidemic would most likely not have occurred if the vector *Ae. albopictus* had not been present in Italy. This mosquito was accidentally introduced there in 1990, and has since invaded most of northern Italy, thriving in both urban and rural ecosystems

(Chapter 14). This is an example where the introduction of an exotic vector species and an exotic arbo-virus have conspired into the scenario of a new disease aetiology. Chikungunya is a very serious disease, sometimes fatal, and nearly always causing a long convalescence of the patient (Pialoux *et al.* 2006).

On the livestock side we have seen frequent outbreaks of African horse sickness on the Iberian Peninsula. Each time, after the epidemic had run its course, the virus disappeared, to return some years later, possibly with *Culicoides* vectors, blown in by the wind from Africa across the Mediterranean sea. Bluetongue is another disease transmitted by *Culicoides* spp. The disease was, like African horse sickness, infrequently seen in Portugal and Spain. Only after the invasion of the African vector *Culicoides imicola* Kieffer in Italy in 1998 did bluetongue become permanently established in Europe. Italy has experienced bluetongue infections each year since 1998. The disease is usually absent during the winter, presumably because of unfavourable temperatures for the *Culicoides* vectors. However, in August 2006 bluetongue erupted in the Netherlands, Belgium, Germany, France and Luxemburg. The virus was new to Europe, and identified as BT serotype 8. *Culicoides imicola*, the main vector in southern Europe, was absent from northern Europe, and it was established that local, indigenous, *Culicoides* spp. were responsible for the transmission. During the winter of 2006/2007 no new infections were recorded, and it was hoped that the disease would die out. In July 2007, however, new cases of bluetongue were found in Germany, Belgium and the Netherlands (in that order of appearance), and by September 2007 several hundred farms had been affected. Moreover, unlike in 2006, the virus appeared to be more virulent, at least in the Netherlands, where hundreds of sheep died because of the infection. This resurgence of bluetongue in north-western Europe suggests that the virus had survived the winter of 2006/2007, either in the vector or in a vertebrate host. The latter is considered unlikely as laboratory studies had shown that the virus loses its infectiousness in vertebrates between 60 and 100 days (A. Elbers, personal communication).²⁷

A very different, but not less threatening, perspective for human and animal health is provided by the rapidly developing resistance to chemical pesticides in ectoparasites such as head lice, bed bugs, sheep ked and house flies. As we have seen, resistance against a large group of pesticides is already present in these organisms and widespread. Although these ectoparasites are not directly involved in disease transmission and rarely dangerous for humans, they nevertheless pose a serious problem for public health, causing economic damage (bed bugs, sheep ked and house flies) or socio-economic stress (head lice and bed bugs). In addition, at high densities, house flies may be involved in disease transmission, and sheep ked causes direct losses because of the health effect they have on sheep.

Cause of the observed change

The arrival of new vector-borne diseases, the resurgence of 'old' diseases and the increased prevalence of arthropod pests as described above are considered to be the result of environmental change and global warming. This explanation, although plausible, seems too simple and requires further details. For example, why was head lice in Europe successfully kept under control until the mid 1990s, and why has bluetongue virus not become established in Europe much earlier than 1998? When vector-borne diseases are being discussed, global warming is nearly always

²⁷ As this book went to press, it was confirmed that BT had emerged in the United Kingdom, and at least 5 farms had been infected by 28 September 2007.

mentioned as one of the reasons for resurgence or new outbreaks. However, global warming is a process that is taking place gradually, and the increased temperatures and associated changes in precipitation are unlikely to be the only factors that made these epidemics possible. In the last 50 years the world has witnessed a rapid increase in commerce and international travel. Thus, it has been proven that the continental spread of *Ae. albopictus* is largely caused by the trade in used tires and by shipment of ornamental plants (Chapter 14). *Aedes albopictus* is a competent vector of many arbo-viruses (Gratz 2004) and invaded the island of La Réunion in the 1950s. In the recent outbreak of Chikungunya on that island, *Ae. albopictus* was responsible for most of the virus transmission. This is only one example of an introduced mosquito becoming a vector of a deadly disease many years after its introduction.

In Italy, climatic conditions in the summer are favourable for transmission of bluetongue virus by *C. imicola*. It was therefore no surprise that the establishment of this vector species caused a rapid and intensive transmission of bluetongue virus in many parts of Italy. It is believed that the unusually high summer temperatures of 2006 in the Netherlands made an outbreak of bluetongue by indigenous *Culicoides* spp. possible: the high temperatures allowed for a rapid build-up of virus in the vector, so that virus transmission became possible. However, this hypothesis seems proven wrong by the ongoing transmission of bluetongue in 2007 in the Netherlands. The summer of 2007 has been much cooler and considerably more humid than that of 2006. These findings suggest, though, that environmental conditions, of which climate is an important component, are a strong factor in the epidemiology of bluetongue in north-western Europe.

Although malaria has not shown resurgence in continental Europe, the disease is still highly prevalent in parts of Asian Turkey. There is a huge amount of human movement between Turkey and countries of the European community. Thus it may be expected that healthy malaria parasite carriers are frequently arriving in regions where conditions for malaria transmission are favourable. The excellent status of health care is expected to intercept any malaria patient, but it is possible that a healthy parasite carrier, who is unaware of his condition, may serve as a reservoir of infection through the bite of anopheline mosquitoes. Indeed, several of such cases have been reported from northern Greece.

Arthropod pests such as head lice, bed bugs, house flies and the sheep ked are believed to increase in prevalence because of the widespread development of insecticide resistance. In poultry farms, where houseflies find numerous breeding sites in the manure and litter, large quantities of chemical pesticides have been used to reduce the nuisance caused by the flies. As a result, houseflies have developed resistance against most synthetic insecticides (Liu and Yue 2000, Pospischil *et al.* 1996). The same fate may await the head louse and the bed bug, as much of the control of these insects is conducted with synthetic chemicals. We have seen that the sheep ked can no longer be controlled with pesticides, and that alternative strategies must be sought for the control of this important group of pest organisms.

Remedial actions

Most European countries have only few effective programmes in place for the surveillance and control of existing vector-borne diseases, or for taking of measures to suppress or control ectoparasites. Yet, several tools are available to establish the incidence of disease and to control the vectors. In the case of vectors of Lyme disease, this is difficult as the most effective method would require treatment of the forest floor with pesticides (Chapter 23). This is highly undesirable

for environmental and political reasons. Development of alternative strategies for tick control may include biological products, which are less harmful to the ecosystem and cause no side effects. Indeed, in the USA promising experiments have been conducted with the entomopathogenic fungus *Metarhizium anisopliae* for the control of *Ixodes scapularis* Say (Benjamin *et al.* 2002), suggesting that such studies should be undertaken in Europe for assessment of field populations of *I. ricinus*.

Countries are even less prepared for the occasional immigration of a new disease. When environmental conditions are suitable and potential vectors are present, a new pathogen can become established, as happened with bluetongue in Italy, and now, possibly, also in north-western Europe including the Netherlands. In Italy, control of bluetongue is focused on vaccination and the occasional pesticide treatment of stables and other indoor resting sites of bluetongue vectors. In north-western Europe pour-on insecticides are being recommended when transporting animals from infected zones, but an effective method for *Culicoides* control is not available. Both aerial spraying and/or treatment of breeding sites with pesticides are not being used for lack of data on efficacy and for the assumed harmful effects on the environment. The recent outbreak of Chikungunya in Italy was reason for the launching of a large-scale mosquito control programme in the outbreak area using aerial spraying and treatment of breeding sites of mosquitoes with chemical and biological products. By contrast, the outbreak of Usutu virus in Austria has not given rise to vector control, presumably as human incidence of the disease was very low and of mild character. Yet, many indigenous birds died because of Usutu virus, and this poses a threat to biodiversity.

The control of ectoparasites is often easier than that of arthropod vectors. Head lice can be removed by simple measures such as wet combing (Chapter 17). Bed bugs will disappear by thorough cleaning of infested rooms/buildings, which measure can be aided by the addition of steam cleaning and/or fumigation with a chemical product (Chapter 15). House flies can be significantly reduced by mechanical removal of animal dung and covering of organic (household) waste. These methods can be augmented by the release of natural enemies that parasitise larvae and pupae (Meyer *et al.* 1990). For the control of the sheep ked such measures are hardly available. As long as insecticide resistance has not been detected, treatment of the herd animals with a pour-on acaricide might be the only strategic method available for the control of these ectoparasites (Chapter 13).

Most programmes for pest control and management of vector-borne disease still depend heavily on the use of pesticides. In only few cases non-chemical methods are being used, often with startling success (Becker and Schaedler 1998). Biological control products can be used on a much wider scale and it is encouraging to note that in many European countries mosquito control programmes are increasingly switching to the use of *Bacillus thuringiensis israeliensis* and *B. sphaericus* (Chapter 21). This is, however, not the case for the control of other vector groups, which are controlled with conventional pesticides or left uncontrolled for lack of an adequate intervention strategy.

In order to prepare for effective vector control, accurate data on the epidemiology of the disease should be available. Epidemiological models can assist in predicting the course and timing of an infectious disease, and be used as a tool to simulate the impact of intervention strategies. If combined with geographical information (GIS) and remote sensing (RS) systems, rapid advances can be made in demarcation of the potentially affected zones. In turn, this information can be

used by public health authorities to inform the public about the risk of the infection and for the planning of intervention strategies. In the case of sudden outbreaks of disease, this often happens on an ad-hoc basis, and is not part of the general public health studies. GIS and RS systems can be very useful in studies of the geographic distribution of vector species and for the identification of breeding sites. If linked to a meteorological satellite, GIS and RS are used for the preparation of risk maps, which will be useful for the planning of vector control operations. Epidemiology can also be used in predicting the potential establishment of a vector-borne disease in a country or region where the disease does not yet occur, but where environmental change may create conditions that are favourable for the disease. Using the basic reproduction number, R_0 , it is possible to obtain information about the likelihood of disease outbreak, which in turn can be used for the preparation of a strategic plan in the event of disease outbreak (Anderson and May 1992)

The spread of an infectious agent is often dependent on human behaviour. Ideally, any new infectious case should be confined to his/her residence for the duration of the infectious period, so that human-to-human contact is kept as little as possible and the pathogenic agent cannot be disseminated in the environment. However, this is difficult to arrange, and many parasite carriers are healthy and do not suffer from disease symptoms, so they are unaware of their condition. In the case of an animal disease, such as bluetongue, farmers are often obliged to keep their animals indoors and any animal movement between farms or to other areas are strictly prohibited. For a vector-borne disease one can question such regulations, as the vectors may acquire the pathogen or parasite and subsequently fly to a different place, taking the disease agent along. In the 2006-bluetongue epidemic in the Netherlands, Belgium, Germany, Luxemburg and France, vector dispersal may have been one of the reasons for the rapid spread of the disease, as animal transport had been banned immediately from the start of the outbreaks.

Vectors of infectious disease and pests can only thrive in environments that are suitable for the species. Areas with very cold winters are usually free of vector species that require the outdoor environment for disease transmission. However, the human domestic environment, which is artificially heated, often provides an excellent habitat for numerous pests and vectors. Bed bugs benefit from centrally-heated buildings, house flies thrive in poultry and pig farms, *Culicoides* species make use of grazing areas rich in animal dung for oviposition, and certain mosquito species lay their eggs in organically-rich septic tanks and basements. In many cases, the problems caused by these organisms can be solved by adaptations to the environment, so that breeding sites are being removed (mosquitoes), animal dung is being removed at frequent intervals (house flies) and home adjustments to central heating, ventilation and removal of wall-to-wall carpeting (bed bugs). For mosquito control in inundated areas, drainage or controlled irrigation may remove most mosquito breeding sites.

Conclusions and recommendations

This book is proof of the resurgence and emergence of many pests and diseases in Europe that were thought to have been eradicated or, at least, to remain far removed from the European continent. Examples are given of vector-borne diseases that have been circulating in Europe for many years (TBE, Lyme disease) or that have arrived recently (Usutu, bluetongue, Chikungunya). Other vector-borne diseases may arrive, and yet others are emerging. Harmful ectoparasites and pests are increasing in prevalence and abundance. The reasons for this surprising, and alarming situation are complex, and include human behaviour, climate change, environmental change, the development of insecticide resistance and increased international travel and trade. It appears to

be difficult to control indigenous diseases and pests, or eradicate incoming ones, and only when a disease outbreak remains within a defined area is effective eradication possible. Effective tools for disease control are lacking, not only because the aetiology of these vector-borne diseases is complex, but also because tools such as vaccines and sustainable insect control methods are lacking or inadequate. Europe is ill-prepared to meet the challenges posed by these diseases, and several steps should be taken urgently to prevent large-scale outbreaks of vector-borne disease. Similarly, blood-feeding arthropods can also cause huge problems because of their irritating, sometimes painful, biting behaviour. Especially in the livestock industry, these pests can lead to significant economic damage. Also, such pests may reduce the quality of living conditions and pose a serious threat for the tourist industry. For these reasons we propose that:

- Epidemiological units, preferably at country level, be established that monitor infectious vector-borne diseases and prepare predictive models to obtain insight in the spread and incidence of such diseases and to be prepared for the arrival of such diseases.
- Research units are created that study the ecology of vectors so that surveillance of the vectors can be increased.
- Tools are developed that can replace synthetic pesticides, and favour sustainable control based on integration of mechanical, cultural and biological methods (integrated pest and vector management).
- Disease control staff is being trained to apply GIS and RS technology for a rapid assessment of risk and to identify natural boundaries of the vector(s) and/or parasites and pathogens.
- Early warning systems are established in which the emergence and/or new arrival of vector-borne infectious diseases is being monitored to inform national and European authorities at the earliest opportunity of such developments.
- The European Centre for Disease Prevention (ECDC) and the World Organisation for Animal Health (OIE) act as reference centres for the provision of information of the status of vector-borne diseases in Europe associated with environmental change.
- The ECDC and OIE develop strategies for containment and control of pests and vector-borne disease so as to reduce health risks and the prevent disease and socio-economic damage caused by them.

References

- Anderson RM and May RM (1992) *Infectious Diseases of Humans - Dynamics and Control*. Oxford University Press, Oxford.
- Becker N and Schaedler P (1998) The use of entomopathogenic bacteria against mosquitoes. 6th Simposio de Controle Biologico 24.
- Benjamin MA, Zhioua E and Ostfeld RS (2002) Laboratory and field evaluation of the entomopathogenic fungus *Metarhizium anisopliae* (*Deuteromycetes*) for controlling questing adult *Ixodes scapularis* (Acari: Ixodidae). *J Med Entomol* 39: 723-728.
- Bodenmann P and Genton B (2006) Chikungunya: an epidemic in real time. *Lancet* 368: 258.
- Bruce-Chwatt LJ and De Zulueta J (1980) *The rise and fall of malaria in Europe, A historico-epidemiological study*. Oxford University Press, Oxford.
- Gratz NG (2004) Critical review of the vector status of *Aedes albopictus*. *Med Vet Entomol* 18: 215-227.
- Lindgren E and Gustafson R (2001) Tick-borne encephalitis in Sweden and climate change. *Lancet* 358: 16-18.
- Liu N and Yue X (2000) Insecticide resistance and cross-resistance in the house fly (Diptera: Muscidae). *J Econ Entomol* 93: 1269-1275.

- Meyer JA, Mullens BA, Cyr TL and Stokes C (1990) Commercial and naturally occurring fly parasitoids (Hymenoptera: Pteromalidae) as biological control agents of stable flies and house flies (Diptera: Muscidae) on California dairies. *J Econ Entomol* 83: 799-806.
- Ortega MD, Mellor PS, Rawlings P and Pro MJ (1998) The seasonal and geographical distribution of *Culicoides imicola*, *C. pullicaris* group and *C. obsoletus* group biting midges in central and southern Spain. *Arch Virol Suppl* 14: 85-91.
- Pialoux G, Gauzere BA and Strobel M (2006) Chikungunya virus infection: review through an epidemic. *Med Mal Infect* 36: 253-263.
- Pospischil R, Szomm K, Londershausen M, Schroder I, Turberg A and Fuschs R (1996) Multiple resistance in the larger house fly *Musca domestica* in Germany. *Pest Sci* 48: 333-341.
- Skarpaas T, Golovljova I, Vene S, Ljostad U, Sjursen H, Plyusnin A and Lundkvist A (2006) Tickborne encephalitis virus, Norway and Denmark. *Emerg Infect Dis* 12: 1136-1138.