5.10 Human health

5.10.1 Introduction

Climate change is already contributing to the global burden of disease and premature deaths. Human beings are exposed to climate change through changing weather patterns (temperature, precipitation, sea-level rise and more frequent extreme events) and indirectly through changes in the quality of water, air and food, and changes in ecosystems, agriculture, industry, settlements, and the economy. At this early stage the effects are small but they are projected to increase progressively in all countries and regions (Confalonieri *et al.*, 2007).

Photo: © Pawel Kazmierczyk

There is emerging evidence of climate-change effects on human health. For example, climate warming in recent decades has altered the distribution of some infectious disease vectors, altered the seasonal distribution of some allergenic pollen species and increased the frequency and intensity of heat waves. In the longer term, many serious impacts on health may occur, including an increase in the number of people suffering from death, disease and injury from heat waves, floods, storms, fires and droughts, a change in the range of some infectious disease vectors, and an increase in the burden of diarrhoeal diseases from changes in water quality and quantity (IPCC, 2007b). In parts of Europe, there may be some benefits to health, including fewer deaths from cold. It is however expected that the benefits will be outweighed by the negative effects of rising temperatures worldwide.

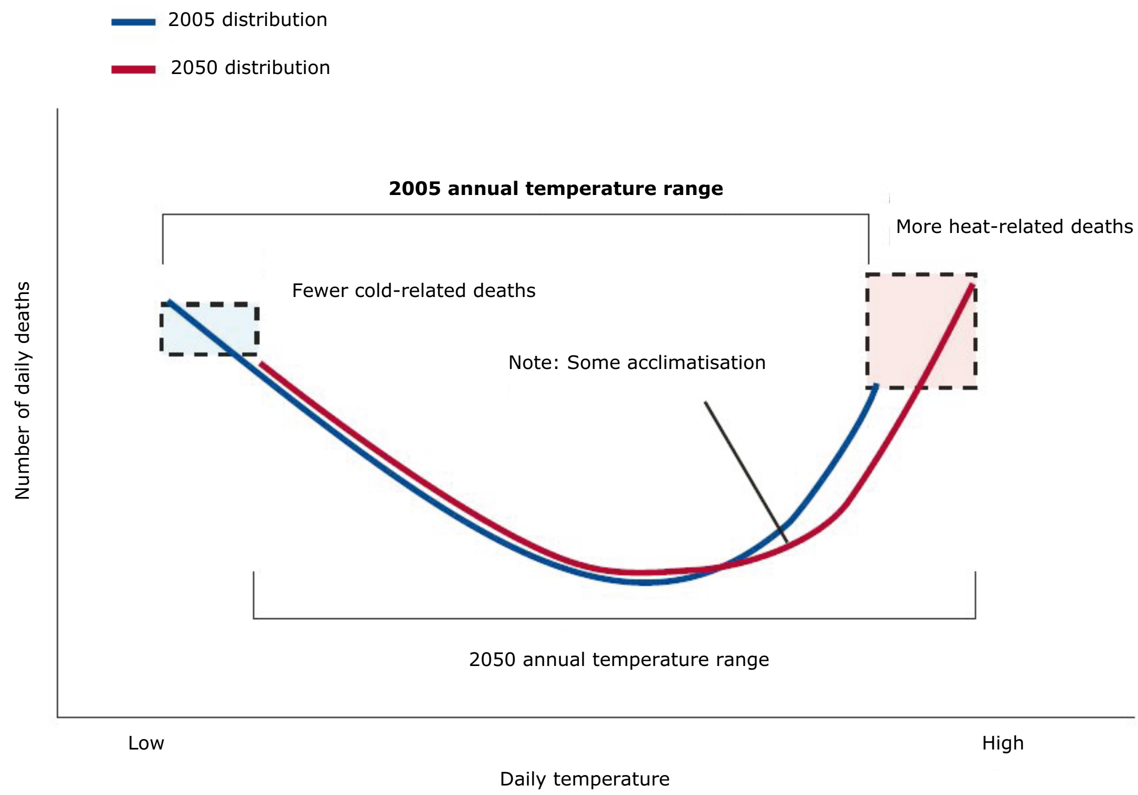
This chapter describes some of the climate-sensitive health outcomes in Europe. The information contained in this chapter is not merely indicator based but a collection of information from scientific publications. Epidemiological studies have been undertaken on the health impacts of individual extreme events (e.g. heat waves, floods), spatial studies where climate is an explanatory variable in the distribution of the disease or the disease vector, and temporal studies assessing the health effects of climate variability, including daily changes in temperature or rainfall. A very limited number of studies has been undertaken to investigate the effectiveness of public-health measures to protect people from future climate change.

5.10.2 *Heat and health*

Key messages

- Increasing temperatures are likely to increase the number of heat-related deaths. Mortality risk increases by between 0.2 and 5.5 % for every 1 °C increase in temperature above a location-specific threshold.
- Heat-wave events can have detrimental effects on human health. More than 70 000 excess deaths were reported from 12 European countries in the hot summer of 2003 (June to September). Long heat waves (more than 5 days) have an impact 1.5 to 5 times greater than shorter events.
- 86 000 net extra deaths per year are projected for the EU Member States for a high-emissions scenario with a global mean temperature increase of 3 °C in 2071–2100 relative to 1961–1990.

Figure 5.42 Relationship between number of temperature-related daily deaths and daily temperature



Note: Schematic representation of how an increase in average annual temperature would affect the annual total of temperature-related deaths, by shifting the distribution of daily temperatures to the right. Additional heat-related deaths in summer would outweigh the extra winter deaths averted (as may happen in some northern European countries). The average daily temperature range in temperate countries would be about 5–30 °C (McMichael, 2006).

Source: McMichael, 2006.

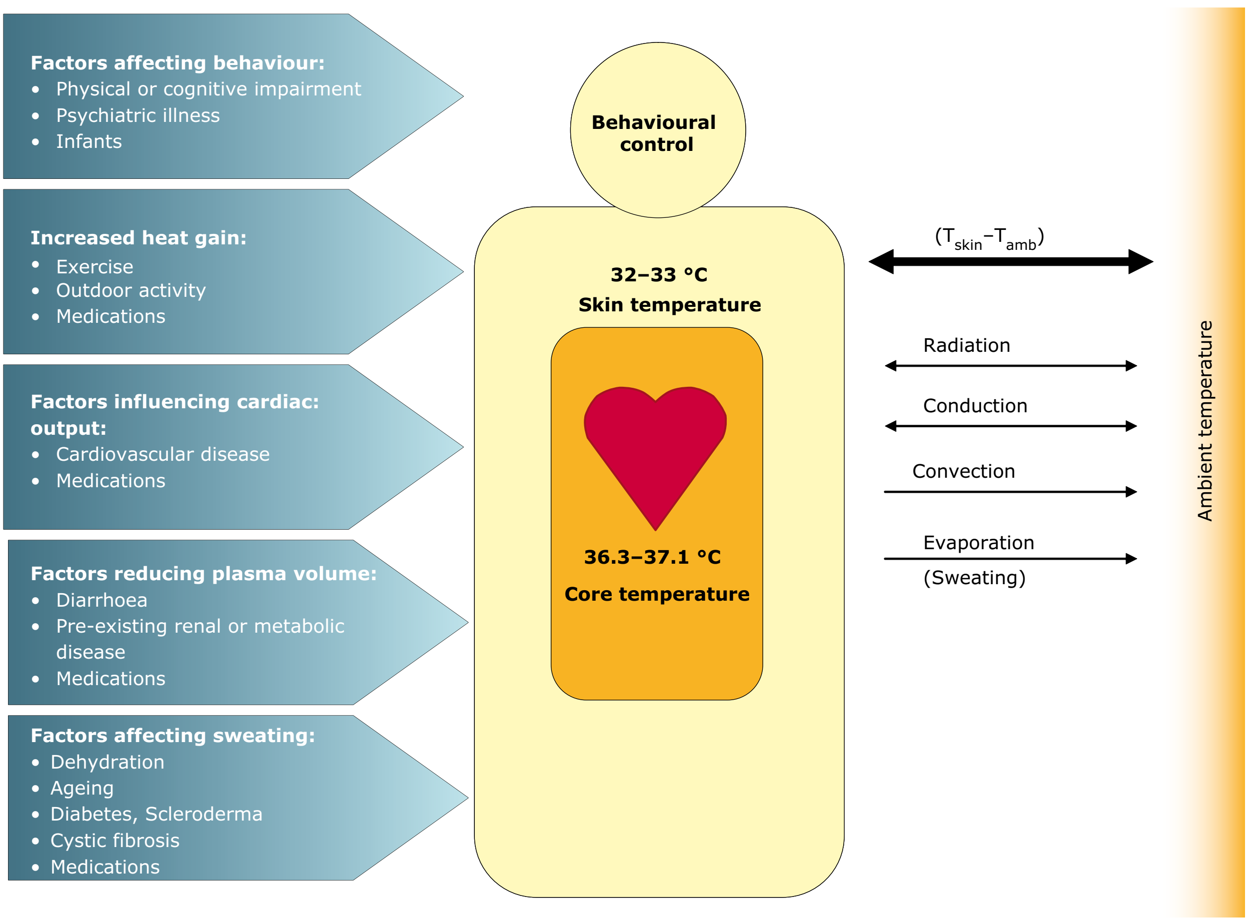
Relevance

Populations typically have an optimum temperature at which the (daily or weekly) death rate is lowest. Mortality rates rise at temperatures outside this comfort zone. Figure 5.42 shows a typical U/J-shaped relation theoretically, as well as in six European cities assessed in the PHEWE project. The trough represents the comfort zone; the steeper (right) arm of each line shows the mortality increase at high temperatures, and the left arm of each line shows the increase at low temperatures. Overall, the impact of hot weather and heat waves depends on the level of exposure, the size and structure of the exposed population, the population sensitivity, the preparedness of health systems, and the prevention measures in place. In temperate countries, there is a seasonal variation of mortality, with higher mortality in winter than in summer. There is uncertainty on whether some current observed reductions in winter mortality can be attributed to climate change (Confalonieri *et al.*, 2007). People with cardiovascular diseases are more at risk in winter, because of the cold-induced tendency of blood to clot.

Heat waves have caused significant mortality in Europe in recent decades. However it is difficult to compare the heat-wave effects across Europe and over time. Heat directly affects the human physiology: thermoregulation during heat stress requires a healthy cardiovascular system. When environmental heat overwhelms the heat-coping mechanism, the body's core temperature increases. This can lead to heat illness, or death from heat stroke, heart failure and many other causes (Figure 5.43).

Several medical factors can increase the risk of heat-wave mortality, including dehydration, drugs, ageing, and having a chronic disease that affects cardiac output and skin blood flow, as well as being confined to bed. Social factors, such as social isolation, may also be important, although there has been little research in Europe (see Figure 5.43; Bouchama, 2007). Many housing and urban factors have also been assessed, in particular for their role in high indoor temperatures (Kovats and Hajat, 2008). One special concern relates to indoor temperatures in health-care facilities and nursing homes. Increasing numbers of older adults in the population will increase the proportion of the population at risk (Confalonieri *et al.*, 2007). Health-system action will be needed to ensure adequate planning of locations for health care and nursing institutions, as well as for the thermal protection of their facilities.

Figure 5.43 Factors affecting human thermoregulation and the risk of heat illness



Source: Matthies *et al.*, 2008 (adapted from Bouchama, 2007).

The EuroHEAT project concluded that heat-related illnesses and deaths are largely preventable. In the long term, the most important measure is improving urban planning and architecture, and energy and transport policies. Such improvements should begin now, as the lead time for policy development is very long. Heat-wave effects can be reduced by keeping indoor temperatures low, keeping out of the heat, keeping the body cool and hydrated, and helping others. Health-system preparedness planning is essential, by collaborating with weather services in providing accurate, timely weather-related health alerts and developing strategies to reduce individual and community exposures to heat, especially among vulnerable populations, planning health and social services and infrastructure, and providing timely information to the population (Matthies *et al.*, 2008).

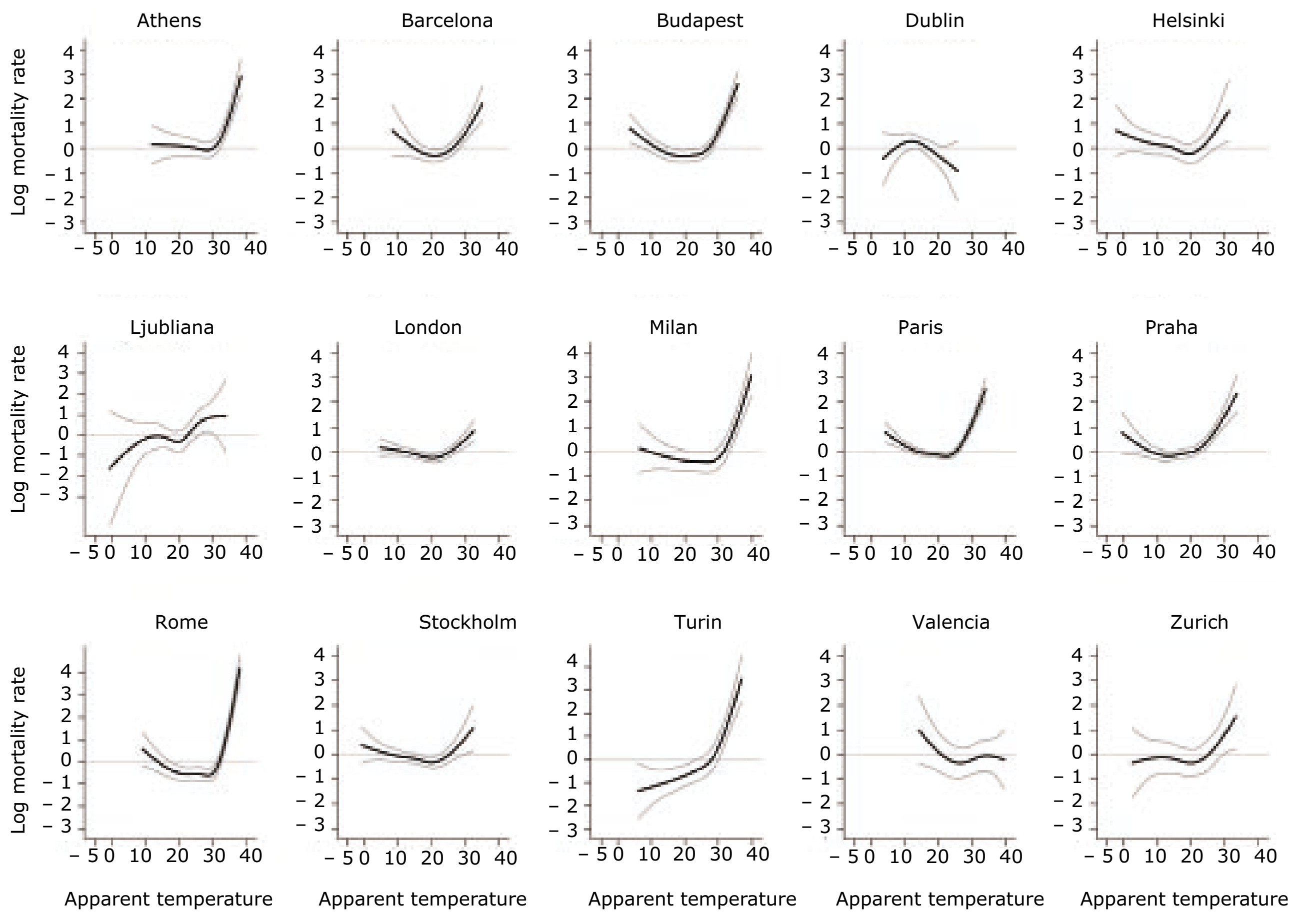
Past trends

Many epidemiological studies have quantified the impact of temperature on daily mortality. In all cities in Europe mortality increases over a certain threshold of temperature. This threshold is location-specific (see Figure 5.44).

The estimated change in mortality risk per degree temperature increase over the location-specific threshold ranges from 0.2 to 5.5 % (Kovats *et al.*, 2006; Baccini *et al.*, 2008).

Most European countries have between 5 and 30 % higher death rates in winter than in summer. Winter-related mortality in many European populations has declined since the 1950s (Kunst *et al.*, 1991; Lerchl, 1998; Carson *et al.*, 2006). Cold

Figure 5.44 Daily mortality rates in 15 European cities by apparent temperature in summer time



Note: City-specific estimates of the relevant parameters were obtained from 15 years (1990–2004) of data by specifying a marginal Poisson model for the daily count of deaths. Bayesian random effects meta-analysis models were used to combine the city-specific results.

Source: Baccini *et al.*, 2008.

days, cold nights and frost days have become rarer, but explain only a small part of this reduction: improved home heating, better general health and improved prevention and treatment of winter infections have played a more significant role (Carson *et al.*, 2006).

More than 70 000 excess deaths were recorded in 12 European countries from June to September 2003, compared with the 1998 to 2002 average (Robine *et al.*, 2007). Although this increase cannot be entirely attributed to the heat waves in 2003, in the absence of any other explanatory factors, most of these deaths are likely to have been caused by the several heat waves in that year. The timing, intensity and duration of heat waves have been shown to influence the amount of mortality. Impacts of heat waves characterised by longer duration were from 1.5 to 5 times higher than for short heat waves (Matthies *et al.*, 2008).

Major heat-wave events are also associated with other health hazards such as air pollution, wild fires, water, food and electricity supply failures, which also have implications for public health action. The combined effect of heat waves and peaks of air pollution due to ozone or particulate matter with a diameter under 10 μm (PM_{10}) increases mortality. There is growing evidence that the effects of heat-wave days on mortality are larger when ozone or PM_{10} levels are high, particularly among the elderly (75–84 years). In nine European cities the total daily number of deaths in the age group 75–84 years increased by 10.6 % during heat-waves when ozone levels were low but by 16.2 % when ozone levels were high; corresponding figures for PM_{10} were 10.5 % and 14.3 % (Analitis and Katsouyanni, in press). The mortality increase due to the combined effect of heat and air pollution can be reduced by decreasing exposure to ozone and PM_{10} on hot days.

Cold waves continue to be a problem if very low temperatures are reached in a few hours and extend over long periods. Accidental cold exposure in temperate and cold climates occurs mainly outdoors, among the socially deprived (alcoholics, the homeless), workers, and the elderly (Ranhoff, 2000). Living in cold environments in polar regions is associated with a range of chronic conditions in the non-indigenous population as well as acute risk from frostbite and hypothermia (Hassi *et al.*, 2005). In countries with populations well adapted to cold conditions, cold waves can still cause increases in mortality if electricity or heating systems fail.

Photo: © Waltraud Grubitzsch, dpa, 2003

Projections

Heat-related morbidity and mortality is projected to increase. Estimates of heat mortality have been made in several national assessments, using different climate scenarios and population and adaptation assumptions. In the United Kingdom, annual heat-related deaths are expected to increase from about 800 in the 1990s to about 2 800 in the 2050s and about 3 500 in the 2080s in the medium-high scenario. Annual cold-related deaths decrease from about 80 300 in the 1990s to about 60 000 in the 2050s and 51 200 in the 2080s in the same scenario (Donaldson *et al.*, 2001). In Germany, a 20 % increase in heat-related mortality is projected. This increase is not likely to be compensated by reductions in cold-related mortality (Koppe *et al.*, 2003). In Portugal, an increase in heat-related mortality from a baseline of 5.4 to 6 per 100 000 to a range of 19.5 to 248 per 100 000 by the 2080s is projected (Dessai, 2003).

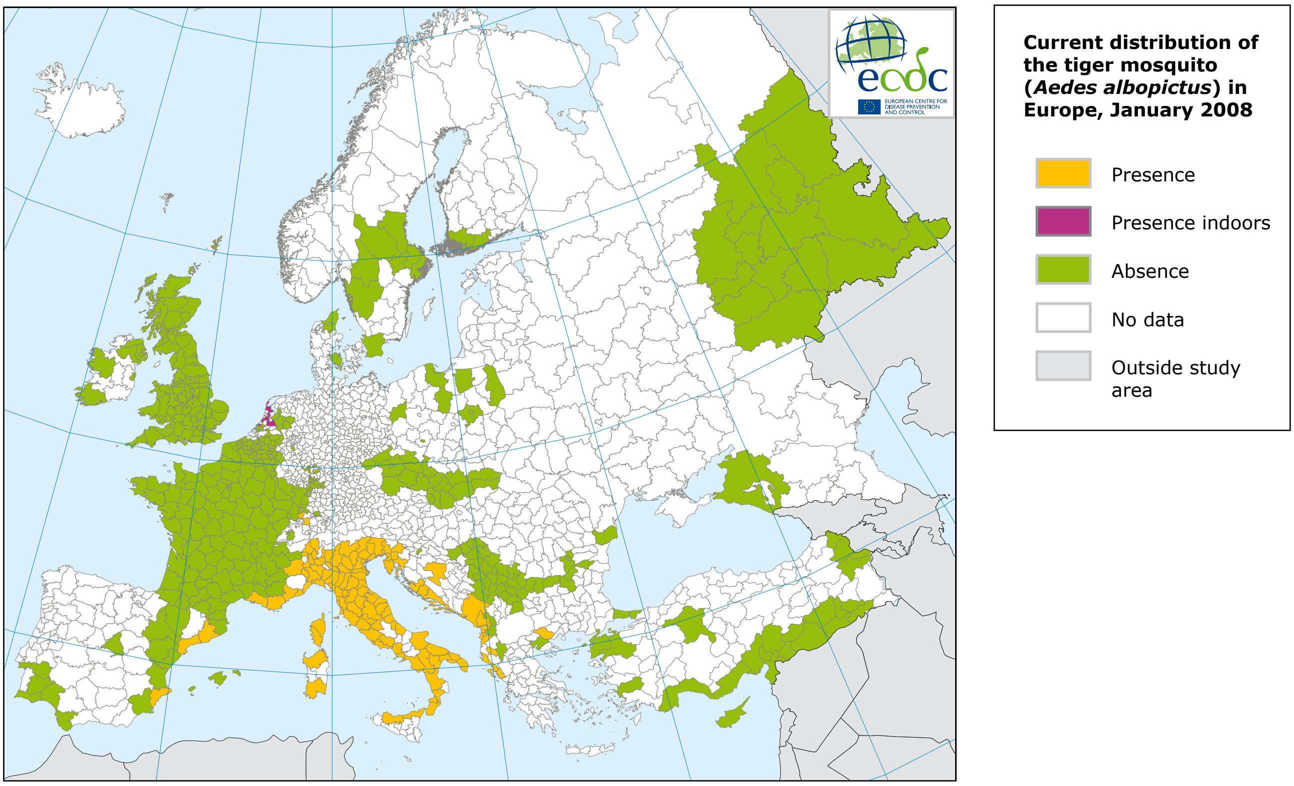
For the EU-27 Member States, the PESETA study projected almost 86 000 net extra deaths per year in 2071–2100, compared with the 1961–1990 EU-25 average, for a high emissions scenario (IPCC SRES A2, see Chapter 4) with a global mean temperature increase of 3 °C (EC, 2007). These results are preliminary, assume no physiological adjustment, and do not separate out the impact of non-climate changes (socio-economic changes in age structure or population movements). The study is based on assumptions of a mortality-temperature relationship that does not take into account the differences between the Mediterranean and northern European countries.

5.10.3 Vector-borne diseases

Key messages

- The tiger mosquito, a transmitter of a number of viruses, has extended its range in Europe substantially over the past 15 years and is projected to extend even further. There is a risk of additional outbreaks of Chikungunya and a potential for localised dengue to re-appear.
- Ticks and the associated Lyme disease and tick-borne encephalitis are moving into higher altitudes and latitudes.
- Changes in the geographical distribution of the sandfly vector are occurring in several European countries (high confidence) and there is a risk of human Leishmania cases further north.
- Projected temperature increases in the United Kingdom could increase the risk of local malaria transmission by 8 to 15 %; in Portugal a significant increase in the number of days suitable for the survival of malaria vectors is projected. However, the risk of localised malaria transmission is low.

Map 5.46 Presence of *Aedes albopictus* (the tiger mosquito) in Europe in January 2008



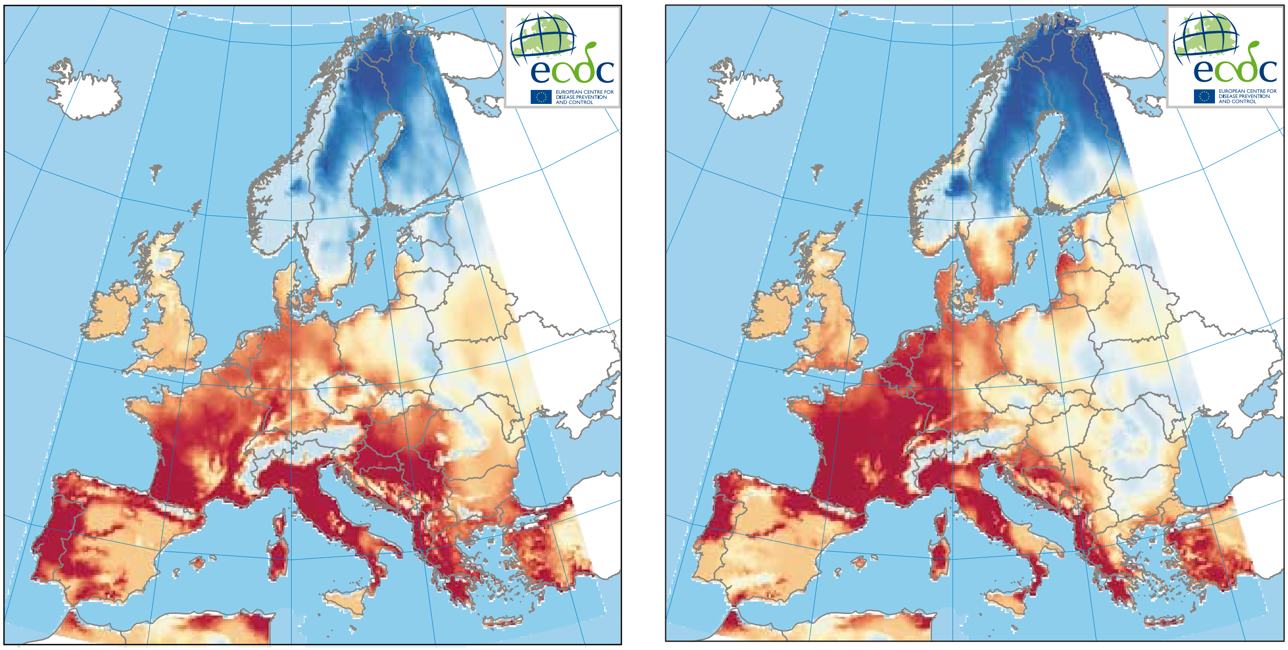
Note: Developed by Francis Schaffner (BioSys Consultancy, Zurich), in partnership with Guy Hendrickx/Ernst-Jan Scholte (Avia-GIS, Zoersel, Belgium) and Jolyon M Medlock (Health Protection Agency, UK) for the ECDC TigerMaps project. © European Centre for Disease Prevention and Control 2008.

Source: Based on Schaffner *et al.*, 2008.

Relevance

Climate change is likely to cause changes in ecological systems that will affect the risk of infectious diseases in Europe, including the seasonal activity of local vectors, and the establishment of tropical and semi-tropical species. Shifts in the global and regional distribution and behaviour

Map 5.47 Areas of possible establishment of *Aedes albopictus* (the tiger mosquito) in Europe for 2010 and 2030



Areas of possible establishment of *Aedes albopictus* (the tiger mosquito) in Europe for 2010 and 2030

Left: maximum-change scenario for 2010; right: minimal-change scenario for 2030

Less suitable areas — Most suitable areas

0 | 25.5 | 51 | 76.5 | 102 | 127.5 | 153 | 178.5 | 204 | 229.5 | 255

Note: Developed by Francis Schaffner (BioSys Consultancy, Zurich), in partnership with Guy Hendrickx/Ernst-Jan Scholte (Avia-GIS, Zoersel, Belgium) and Jolyon M Medlock (Health Protection Agency, United Kingdom) for the ECDC TigerMaps project. © European Centre for Disease Prevention and Control 2008.

Source: Based on Schaffner *et al.*, 2008.

of insect and bird species are early signs that biological systems are already responding to climate change (see also Section 5.7.5). The IPCC (2007a) projects that climate change will lead to significant changes in infectious disease transmission by vectors (such as mosquitoes and ticks) as a result of changes in geographic range, seasonality, disease transmission and absolute number of cases.

Patterns of infectious disease in Europe are and will be affected by the movement of people and goods, changes in hosts and pathogens, land use and other environmental factors. Personal risk factors such as the status of the immune system also play an important role. There are fears in Europe that new infectious diseases could be triggering population health problems, and that previously-existing diseases could re-emerge. Whether this happens will depend very much on the international, European and national surveillance systems in place for early detection and response, vector- and host-control measures, awareness of people and health professionals, and preventive measures such as vaccination and treatment. In many cases it will be necessary to revise integrated vector-control measures, increase international surveillance, strengthen collaboration between veterinary and public health services, and inform people on how to avoid potential risks.

Information is available, mainly from the climate change and adaptation strategies for human health (cCASHh) study, national assessments and global scenarios. The ongoing EDEN project and the ECDC expert consultation on magnitude and importance of vector-borne diseases in Europe (V-borne assessment) will further provide clarification and additional risk considerations in the next few years.

Vector-borne diseases in this report are grouped into mosquito-borne, tick-borne and sandfly-borne. Bacteria and parasites can be transmitted through these vector viruses.

Past trends

Mosquito-borne

Higher temperatures can contribute to higher virus replication rates in mosquitoes, increased mosquito populations, expansion of the mosquito distribution, and easier establishment and replication of vectors.

Chikungunya: *Aedes albopictus* (the tiger mosquito) has extended its range in Europe substantially over the past 15 years (Scholte and Schaeffner, 2007) and is now present in 12 European countries (see Map 5.46).

This mosquito can transmit a variety of diseases. The risk of local transmission of mosquito-borne viruses is the result of the simultaneous presence of the virus, competent mosquitoes, susceptible human hosts, and contacts between these three entities. In 2007, a cluster of cases of Chikungunya (a virus that is highly infective and disabling but not transmissible between people) was observed in the Emilia-Romagna Region of Italy. This is the first example in continental Europe of an imported human disease case being followed by sustained local mosquito transmission (ECDC, WHO, 2007; Menne *et al.*, 2008).

Dengue: *Aedes aegypti*, one of the many vectors that transmit dengue, closely follows the 10 °C winter isotherm and is extending its range. Currently, *Ae. aegypti* is absent in Europe, but was well-established until after World War II. Dengue is only one of a variety of diseases transmitted by *Ae. aegypti*. Today, dengue is frequently introduced into Europe by travelers returning from dengue-endemic countries. No locally-transmitted dengue cases have been reported; one can thus assume that the risk of locally-transmitted dengue is currently low, and any increase would depend on the re-introduction of *Ae. aegypti* into Europe. In addition, local transmission could occur if the dengue virus were introduced into the *Ae. albopictus* population (Semenza and Menne, 2008).

Malaria: Anopheles mosquitoes, the malaria vectors, are and have long been present in all European countries. In recent decades, conditions for the transmission of malaria in Europe have remained favorable, as documented by repeated rare autochthonous transmission of a tropical malaria strain by local vectors to a susceptible person. Currently, autochthonous malaria continues to pose a challenge in Turkey. However, the risk of local transmission depends on the simultaneous presence in a given area of anthropophilic, high-longevity and genetically-competent vectors, and human parasite carriers (Menne *et al.*, 2008; Ebi and Menne, 2006).

West Nile Virus (WNV): is primarily transmitted through bird-feeding mosquitoes (particularly *Culex* spp.). Climate change has been implicated in changes in the migratory and reproductive phenology (advances in breeding and migration dates) of several bird species, their abundance and population dynamics, as well as a northward expansion of their geographical range in Europe. There are two potential consequences: a) shifts in the geographic distribution of the vectors and pathogens due to altered distributions or changed migratory patterns of bird populations; b) changes in the life cycles of bird-associated pathogens due to a mistiming between bird breeding and the breeding of vectors, such as mosquitoes. Higher transmissions of WNV have been observed along major bird flyways. However human cases of WNV are rare in Europe and occur mainly in wetland and urban areas (Hubálek *et al.*, 2006).

Tick-borne

Climate change can increase tick survival and thus tick density, prolong the season of tick activity, prolong host activities, and shift ticks toward higher altitudes and northern latitude. Under climate change, a shift towards milder winter temperatures may enable expansion of the range of Lyme disease and tick-borne encephalitis into higher latitudes and altitudes. In contrast, droughts and severe floods will negatively affect the distribution, at

Aedes albopictus (the tiger mosquito)

Photo: © ECDC, www.world-television.se/world_television.se/mnr_stat/mnr/ECDC/431/index.php least temporarily. There is some observational evidence of northern or altitudinal shifts in tick distribution from Sweden and the Czech Republic. However, climate change alone is unlikely to explain recent increases in the incidence of tick-borne diseases in Europe, as there is considerable spatial heterogeneity in the degree of increase of tick-borne encephalitis (Daniel *et al.*, 2006).

Sandfly-borne

While there is no current compelling evidence that sandfly and visceral leishmaniasis distributions in Europe have altered in response to recent climate change, cCASHh analysis points to a considerable potential for climate-driven changes in leishmaniasis distribution. Sandfly vectors already have a wider range than the pathogen (*L. infantum*), and imported dogs infected with it are common in central and northern Europe. Once conditions make transmission possible in northern latitudes, the imported dog cases could act as a source of new endemic foci. Climate-induced changes in sandfly abundance may thus increase the risk of emergence of new diseases in the region (Lindgren and Naucke, 2006).

Projections

Projections of climate-change-related vector-borne diseases use different approaches to classify the risk of climate-sensitive health determinants and outcomes. For malaria and dengue, results from projections are commonly presented as maps of potential shifts in distribution (see Map 5.47). Health-impact models are based typically on climatic constraints on the development of the vector and/or parasite, and include limited population projections and non-climate assumptions. Models with incomplete parameterisation of biological relationships between temperature, vector and parasite often over-emphasise relative changes in risk, even when the absolute risk is small. Several modelling studies used the IPCC SRES climate scenarios, a few applied population scenarios, and none incorporated economic scenarios. Few studies incorporate adequate assumptions about adaptive capacity. The main approaches used are inclusion of current 'control capacity' in the observed climate–health function and categorisation of the model output by adaptive capacity, thereby separating the effects of climate change from those of improvements in public health (Confalonieri *et al.*, 2007).

The range of *Aedes albopictus* is projected to be further extended. Schaffner *et al.*, 2008 estimated areas of further *A. albopictus* extension for 2010 and 2030 (see Map 5.47). However, whether or not there will be outbreaks of Chikungunya in the next years will depend very much on the global circulation of the virus and global travel.

An empirical model estimated that, in the 2080s, 5–6 billion people would be at risk of dengue as a result of climate change and population increase, compared with 3.5 billion people if the climate remains unchanged (Hales, 2002). This projection includes an extension of the risk of dengue for Mediterranean countries.

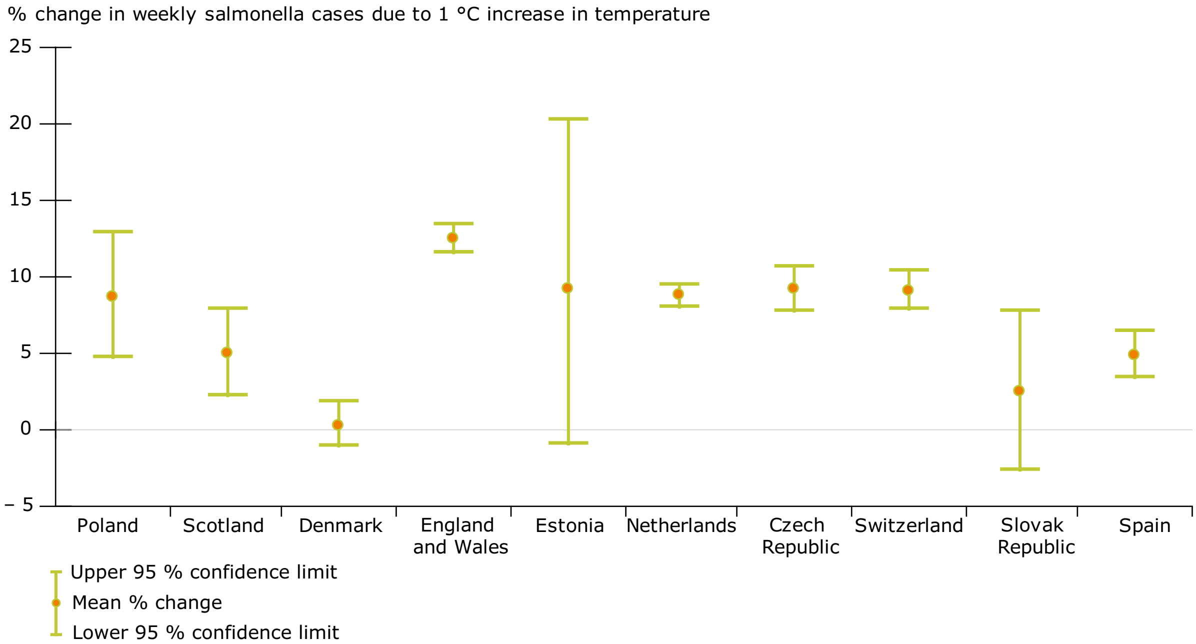
Several climate-change-related models project an increase in malaria risk: For example, in the United Kingdom it was estimated that, with temperature increases, the risk of local malaria transmission could increase by 8–15 % by 2050. In Portugal, the number of days suitable for survival of malaria vectors is projected to increase. Nevertheless, there is agreement that the risk of transmission of malaria related to localised climate change is very small. Risks are greater in countries where importation of malaria coincides with socioeconomic degradation, disintegration of health and social services, uncontrolled cross-border migration and lack of environmental management for mosquito control.

5.10.4 *Water- and food-borne diseases*

Key messages

- There has been a linear increase in reported cases of some food-borne diseases for each degree increase in weekly or monthly temperature over a certain location-specific threshold (medium confidence). Several thousand cases of salmonella are expected in future years, particulary in countries where food safety standards are poor.
- Changing frequency and intensity of precipitation events (and temperature) from climate change may result in outbreaks of water-borne diseases (high confidence) and could mobilise pathogens.
- In the Mediterranean additional salmonella problems from bathing water quality are projected, which would require proper monitoring and surveillance.

Figure 5.45 Percentage change of weekly salmonella cases by 1 °C temperature increase



Source: Kovats *et al.*, 2004.

Relevance

Four main issues should be considered when evaluating the relationship between health outcomes and exposure to changes in rainfall and water availability and quality: (1) links between water availability, household access to improved water and the health burden due to diarrhoeal diseases; (2) the role of extreme rainfall (intense rainfall or drought) in facilitating water-borne outbreaks; (3) effects of temperature and runoff on microbiological and chemical contamination of coastal, recreational and surface waters; (4) direct effects of temperature on the incidence of diarrhoeal and other diseases. Climate variability and change also change the risks of fires and pest and pathogen outbreaks, with negative consequences for food, fibre and forestry (Menne *et al.*, 2008).

Access to safe water remains an extremely important global health issue. The risk of outbreaks of water-borne diseases increases where standards of water, sanitation and personal hygiene are low.

Extreme precipitation events leading to floods or droughts can have direct and indirect health effects. Flooding can cause drowning, injuries (cuts, sprains, laceration, punctures, electric injuries, etc.), diarrhoeal diseases, vector-borne diseases (including those borne by rodents), respiratory infections, skin and eye infections, and mental health problems. Floods also have other effects with health consequences: damage to infrastructure for health care and water and sanitation, crops (and/or disruption of food supply) and property (lack of shelter), and disruption of livelihood and displacement of populations. Droughts or extended dry spells can impair provision of safe water leading to water-related health problems, for example through reducing the volumes of river flow, which may increase the concentration of effluent pathogens, posing a problem for the clearance capacity of treatment plants.

Climate change is also likely to affect the quality of coastal waters, by changing natural ecosystems or the quality of the waters draining into the coastal zone. This poses specific risks for the recreational use of bathing waters, particularly for transient tourist populations that may not have built-in resistance to endemic water-related diseases or may be faced with water quality that does not meet the stringent conditions imposed in the home country. The quality and safety of seafood is directly linked to the quality of the water in the coastal zone.

Intestinal infectious diseases that are transmitted through food or water are sensitive to climate and weather factors. Such diseases are the main causes of infectious diarrhoea and cause significant amounts of illness each year in Europe. Approximately 20 % of the population in western Europe is affected by episodes of diarrhoea each year (van Pelt *et al.*, 2003). Such infections have a significant economic impact in terms of treatment costs and loss of working time (Roberts *et al.*, 2003).

Various adaptation options are available, which include ensuring access to safe drinking water, providing sanitation services, and establishing common standards for surveillance systems and contingency plans for detecting and preventing water-borne disease outbreaks. Water-safety plans may need to be revised for changing climate conditions. Such plans will need to include ways of ensuring safe drinking water from source to tap through better risk assessment and management. Improved management of water demand in the context of fully-integrated planning for river-basin management will become imperative as a first coping mechanism, but is unlikely to satisfy all the needs created by demographic growth, rising living standards and economic development. Alternative strategies will need to be explored, including reusing treated wastewater, using grey water, harvesting rainwater and, where economically viable, desalination. Contamination of food products usually arises from improper practices at some point during the journey from farm to fork. Providing education and timely information on the best ways to handle food and avoid food-borne diseases to producers, food handlers and consumers is essential. Food-borne disease outbreaks can be prevented by using safe water and raw materials, keeping food clean and at safe temperatures, cooking food thoroughly, and keeping raw and cooked food separate.

Past trends

Access to public sources of drinking water in EU Member States is high. Heavy precipitation has been linked to a number of drinking-water outbreaks of Cryptosporidium (a pathogen causing a diarrhoeal illness) in Europe, due to spores infiltrating drinking water reservoirs from springs and lakes and persisting in the water distribution system (Lake *et al.*, 2005; Semenza and Nichols, 2007). In Germany, bacteriological and parasitic parameters spiked considerably during extreme runoff events (Kistemann *et al.*, 2002). New pathogens have also emerged in recent years. In Europe the risk of infectious disease outbreaks is relatively small due to the standard of water treatment and distribution infrastructure. While water-borne outbreaks have a rather large potential, the actual disease burden in Europe is difficult to estimate and is most probably underestimated. Examples of an increased risk of infectious disease outbreaks have been found in the United Kingdom (Reacher *et al.*, 2004), Finland (Miettinen *et al.*, 2001), Czech Republic (Kříž *et al.*, 1998) and Sweden (Lindgren, 2006).

Key food- and water-borne infections in Europe are monitored. The incidence of salmonella has been declining in many countries, but that of other pathogens is increasing. Several studies have confirmed and quantified the effects of high temperatures on common forms of food poisoning, such as salmonellosis (D'Souza *et al.*, 2004; Kovats *et al.*, 2004; Fleury *et al.*, 2006) (see Figure 5.45). These found an approximately linear increase in reported cases with each degree increase in weekly or monthly temperature over a certain threshold. Temperature is much less important for the transmission of Campylobacter (Kovats *et al.*, 2005; Louis *et al.*, 2005; Tam *et al.*, 2006). Contact between food and pest species, especially flies, rodents and cockroaches, is also temperature-sensitive. Fly activity is largely driven by temperature rather than by biotic factors (Goulson *et al.*, 2005).

Harmful algal blooms (HABs) produce toxins that can cause human diseases, mainly via consumption of contaminated shellfish. Warmer seas may thus contribute to more cases of human shellfish and reef-fish poisoning (ciguatera) and poleward expansions of these disease distributions (Lehane and Lewis, 2000; Hall *et al.*, 2002; Hunter, 2003; Korenberg, 2004).

Projections

Infections with *Salmonella* spp. increase by 5–10 % for each degree increase in weekly temperature, at ambient temperatures above 5 °C (Kovats *et al.*, 2004). Some emerging studies show that the disease burden in Europe could be significant (all else being constant) with potentially an extra 20 000 cases per year by 2030 and 25 000–40 000 by 2080 (EC, 2007).

Water stress over central and southern Europe is projected to increase. In the EU, the percentage of land area under high water stress is likely to increase from 19 % today to 35 % by the 2070s, by when the number of additional people affected is expected to be between 16 and 44 million. Furthermore, in southern Europe and some parts of central and eastern Europe, summer water flows may be reduced by up to 80 %. By 2025 it is projected that an additional 31 million people will be living in the coastal zone of the Mediterranean, and that 130 million more will visit the region each year.