Climate change as a threat to health and well-being in Europe: focus on heat and infectious diseases

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Key messages

- The severity of the current and projected impacts of climate on health in Europe call for a stepping up of action in both mitigation of and adaptation to climate change.

- Heatwaves cause the largest number of deaths among weather- and climate-related events in Europe. Over the next few decades, more frequent extreme heat episodes and increasing vulnerability of the population to extreme heat will lead to a substantial increase in morbidity and mortality unless adaptation measures are taken.

- Increasingly frequent, long and intense heatwaves in combination with an ageing population and growing urbanisation mean that more vulnerable populations are exposed to high temperatures, particularly in southern and central Europe. The location of many schools and hospitals in areas experiencing the urban heat island effect, further exacerbating high temperatures, calls for urgent adaptation of those facilities.

- Increasing temperatures in Europe also affect occupational health and safety, with an average annual loss of 16 hours per worker (compared with the 20th century baseline) in highly exposed sectors, with the largest losses in southern Europe.

- Climatic conditions across Europe are becoming more suitable for emergence and transmission of climate-sensitive infectious diseases, which may particularly affect those working in agriculture, forestry or emergency services (through higher exposure) or the elderly, young children and those with compromised immune systems (through higher vulnerability).

- The projected lengthening of the transmission season and wider distribution of mosquito species that act as vectors for malaria and dengue, combined with the growing number of travel-imported disease cases, increases the likelihood of local outbreaks.

- Higher temperatures increase the risk of West Nile fever outbreaks in central, eastern and southern Europe and expand the risk of transmission to previously unaffected areas of northern and western Europe.

- The warming sea waters are increasingly suitable for the dangerous Vibrio bacteria, in particular along the Baltic Sea coastlines.

- Reducing the health impacts of heat requires implementing a wide range of solutions, including effective heat health action plans, urban greening, appropriate building design and construction, and adjusting working times and conditions. Effective monitoring of vectors and disease surveillance enable the development of early warnings and targeting of vector control or vaccination.

- Cross-sectoral collaboration between public health and the built environment, spatial planning and employment sectors is needed to prevent climate threats where people live and work. Interventions aimed at reducing exposure to heat or diseases should prioritise vulnerable groups, as well as people and locations that are particularly exposed.

- Adapting to the existing and emerging health threats arising from climate change requires better preparedness of the health sector through increasing awareness, improving knowledge and widening engagement of public health and healthcare professionals; improving the resilience of healthcare facilities to climate hazards; and ensuring that health systems have the capacity to respond to increased demand for patient care or diagnostics.

- The need to better understand and address the impacts of climate change on human health and well-being is increasingly recognised in EU and national policies, albeit the subject is covered to a greater extent in policies focused on adaptation than those focused on health. At the local level, the engagement of health or social care stakeholders with climate adaptation planning remains low.

Executive summary

Climate change poses multiple threats to human health and well-being in Europe. Extreme weather events, such as devastating floods, extensive wildfires or intense and long-lasting heatwaves, that are more likely and more severe due to the changing climate have become part of our reality in recent years. The greatest direct climate-related threat to human health in Europe is heat, and the large number of excess deaths attributable to extremely high temperatures and prolonged heatwaves during the summer of 2022 is a case in point.

Despite high average living standards, Europe's ageing society and prevalence of chronic diseases make its population particularly vulnerable to heat. The exposure of vulnerable groups to heat is increasing, driven not only by more frequent and intense heatwaves but also by ongoing urbanisation and the associated urban heat island effect, the fact that buildings and cities in most of Europe have not been constructed to protect people from high temperatures, or outdated work practices that ignore the dangers of heat exposure to human health. Vulnerable socio-economic groups are particularly affected by heat. This high vulnerability, combined with the projected substantial global warming, creates a dire picture of a future with growing numbers of heat-related deaths and ailments, as well as reduced labour productivity, affecting well-being and prosperity across Europe.

Climate-sensitive infectious diseases are another type of emerging threat discussed in this report. The increasing suitability of the climate for various pathogens or their vectors may translate into higher likelihood of disease transmission in larger parts of Europe. The arrival of travellers and goods into Europe from regions where dengue or malaria is endemic, combined with the increasing suitability of climate conditions for the mosquitoes that carry those diseases becoming permanent in parts of Europe, increases the probability of disease outbreaks.

The key finding of the report is the marked increase in the scale and geographical extent of heat and infectious diseases that pose a threat to human health. This is corroborated by both the trends over past decades and the projections for the future.

Another aspect is the regional differences in the presence of threats. The current and projected exposure to heat is highest in southern Europe, resulting in increasing mortality rates and negative impacts on labour. Central and eastern Europe emerge as having the highest current climatic suitability for the transmission of dengue, malaria and West Nile virus. The population's vulnerability to high temperatures is highest in northern and western Europe as a result of high levels of urbanisation and high proportions of the elderly in the population. These two regions have also recorded the highest increase in climatic suitability for dengue, malaria and West Nile virus over the past few decades, which potentially has contributed to the expansion of those diseases to previously unaffected regions. The risk of *Vibrio* infections is highest around the Baltic Sea coastlines. These regional differences necessitate the development of specific strategies addressing both the established and the emergent climate-related health threats.

In addition, the report draws attention to social inequalities as drivers of vulnerability and exposure to climate-related health threats. Most of those at risk from heat are older people or those with pre-existing health conditions; in addition, the health of elderly people and young children can be more seriously affected if they contract an infectious disease. Low-income groups tend to be overrepresented in dense, urban environments and poor-quality housing prone to overheating. People on the lowest incomes tend to work in manual jobs that are often performed in hot indoor environments or outside, exposing them to high temperatures or infection risk through contact with vectors.

Nearly all deaths associated with high temperatures are preventable in the European context. Prevention of and better preparation for outbreaks of climate-sensitive infectious diseases can lessen the health implications. Therefore, the report also looks at measures to reduce the health impacts of heat and infectious diseases in Europe. The monitoring and surveillance of climate-related threats is an effective measure and the most frequently mentioned in national health or climate adaptation strategies. It is essential to develop early warnings: swift, well-organised and effective actions as part of heat health action plans and providing appropriate information to the public can reduce the risk of disease transmission.

The adaptation measures planned by the EEA member and collaborating countries emphasise the need to raise awareness of the health threats associated with the changing climate among the population (particularly vulnerable and exposed groups in terms of both working and living conditions) but also among public health and healthcare professionals. Inclusion of the topic of climate change in medical schools' curricula and the training of healthcare workers is key. Furthermore, improving the resilience of healthcare facilities across Europe is necessary to both the direct impacts of heat (especially given the high proportion of hospitals in areas experiencing the urban heat island effect) and the pressure on their capacity to deliver patient care during heatwaves or diagnostics during outbreaks of climate-sensitive infectious diseases.

However, involving actors beyond the health sector when planning responses to climate-related threats is also essential. Preventing the negative impacts of heat on health can be achieved by climate-proofing buildings to ensure thermal comfort during heatwaves or by integrating green spaces into urban planning and redevelopment. Changing work schedules and applying heat-aware working conditions and facilities can reduce heat stress at work, especially for outdoor workers. To successfully plan and implement such measures needs cross-disciplinary collaboration between the health sector and the built environment, planning or employment sectors.

The recent recognition of the climate-related threats to human health and the call for action in political fora such as the G7, in the EU policy framework or by professional associations in the sphere of public health can help to push the subject up the political agenda of the EEA member countries. This occurs predominantly at the national level, where monitoring and surveillance actions are decided, early warnings may be activated and decisions are made about the roll-out of vaccination programmes. Nonetheless, the local implementation of actions — such as information and check-up services for the elderly during heatwaves, targeted urban greening activities or raising awareness of the threat of disease outbreaks — is key to the successful reduction of health threats associated with heat or climate-sensitive infectious diseases. Thus, addressing the complex problem of climate change impacts on human health requires a systemic approach to problems and a collaborative way of planning and implementing measures that involves all levels of governance.

The EU, while having limited competences in the area of health, can support Member States by facilitating knowledge development and sharing through research programmes, including the EU Mission for adaptation to climate change, and through specific initiatives such as the European Climate and Health Observatory or the Health Emergency Preparedness and Response Authority. Furthermore, regulatory proposals such as that on serious cross-border threats to health can strengthen the role of the EU in developing early warnings and addressing the threats associated with climate change.

1 Introduction

Climate change is increasingly recognised as a threat to human existence (Kemp et al., 2022). In Europe, despite the predominantly temperate climate and relatively prosperous socio-economic situation in comparison with other world regions, the climate change threats to human health and well-being are becoming increasingly severe. Alongside the intensification of efforts to mitigate climate change, adaptation to climate change is an urgent necessity, not just to protect a healthy standard of living but also to prevent loss of life and reduce health impacts associated with extreme weather events and ongoing climate change.

The climate change threats to human health and well-being are increasingly severe. Alongside the intensification of the efforts on climate mitigation, adaptation to climate change is a necessity.

The aim of this report is to highlight two particular threats to human health associated with climate change. First, the report focuses on high temperatures, which are already responsible for the largest number of fatalities associated with natural hazards in Europe and are projected to increase substantially because of anthropogenic climate change. Second, the report covers infectious diseases as an emerging threat in Europe. The COVID-19 pandemic highlighted that everyone's well-being can be threatened by infectious diseases and drew attention to diseases spreading through global travel and originating from complex interactions between people, biodiversity, environmental degradation and climate change. Both climate-sensitive infectious diseases and heat consistently emerge in various policy analyses as the most frequently tackled topics in European countries (IANPHI, 2021; WHO, 2021; European Climate and Health Observatory, 2022a).

The report draws on the knowledge collated and developed for the European Climate and Health Observatory under its 2021-22 work plan, which has an explicit focus on high temperatures and climate-sensitive infectious diseases. The knowledge includes the set of indicators developed by the Lancet Countdown in Europe and the Copernicus Climate Change Service, case studies undertaken in various European countries, and national policy analyses. These are supplemented in the report with additional scientific evidence.

Chapter 2 provides a brief overview of the policy frameworks at EU, national and local levels that consider climate change threats to human health. The chapter shows the increasing interest in this area, but it also highlights the lesser integration of health into adaptation policies at subnational levels than at national and EU levels.

Chapter 3 examines the vulnerability and exposure of the European population to high temperatures, considering the characteristics of the population and the geographical distribution of hazards. It also looks at the impacts of heat on mortality and on labour supply and productivity. Finally, it discusses the solutions that can be applied to mitigate heat stress.

Chapter 4 explores climate-sensitive infectious disease threats in Europe, in particular the changing climatic suitability for the transmission of four selected diseases (dengue, malaria, West Nile fever and vibriosis). It also identifies the groups in society that are particularly vulnerable or exposed to diseases and provides an overview of preventive actions.

The report closes with Chapter 5, which draws conclusions on the state of play in policy and practice and recommends opportunities for action.

2
Climate change impacts on health in the policy framework in Europe

Key messages

- The need to better understand and address the climate change threats to human health and well-being is increasingly reflected in EU policies, with an emphasis on better preparedness and collaboration among Member States.
- Most national adaptation policies across Europe cover the climate threats to human health and propose countermeasures. However, national health strategies less frequently focus on climate threats. Furthermore, the actions proposed in both types of document are largely explorative or preparatory, rather than practical.
- At the local and subnational levels, adaptation efforts rarely engage health or social sector stakeholders and are primarily driven by environmental or urban design agendas. There is a great need to focus on health in local adaptation plans, in particular in relation to vulnerable groups.

2.1 European policies

The need to better understand and urgently address the impacts of climate change on human health is becoming increasingly recognised in both national and European policies. The European Green Deal (EC, 2019) aims to protect, conserve and enhance the EU's natural capital and 'to protect the health and well-being of citizens from environment-related risks and impacts'.

Article 5 of the European Climate Law (EU, 2021a) makes adaptation to climate change a legal obligation for EU institutions and Member States, requiring them to 'ensure continuous progress in enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change in accordance with Article 7 of the Paris Agreement'. In addition, Member States' adaptation policies 'shall take into account the particular vulnerability of the relevant sectors', integrate 'adaptation to climate change in a consistent manner in all policy areas', and 'focus, in particular, on the most vulnerable and impacted populations and sectors'. The new EU strategy on adaptation to climate change (EC, 2021a) states the need for a deeper understanding of the climate risks to health. Key to this strategy is the European Climate and Health Observatory. In accordance with the European Climate Law (EU, 2021a), the Observatory was launched to 'better understand, anticipate and minimise the health threats caused by climate change'.

The European Climate and Health Observatory was launched to better understand, anticipate and minimise the health threats caused by climate change.

To strengthen the preparedness and the coordination of responses to health threats, the 2013 Decision on serious cross-border threats to health (EU, 2013) (including climate change) is proposed to be replaced by a regulation (EC, 2020a). With this stronger and more comprehensive legal base, the EU will be able to react rapidly and trigger preparedness and response measures.

The European Health Union (EC, 2020b) builds on the EU's joint effort to reconcile the relationship with the natural environment by engaging in different and more sustainable patterns of economic growth, including mitigating carbon emissions, and finding ways to adapt to climate change. Set up in 2021, the European Health Emergency Preparedness and Response Authority (HERA) takes EU preparedness and response capacity to serious cross-border health threats to a new level and will be a key element in establishing a stronger European Health Union. The EU4Health programme (EU, 2021b) is the biggest EU health funding programme to date, which intends, among other things, to 'contribute to tackling the negative impact of climate change and environmental degradation on human health'. In parallel, the EU supports knowledge developments in the area of climate change and health. Horizon Europe, the EU's key funding programme for research and innovation that will run until 2027, offers numerous funding opportunities for work on the health effects of climate change.

In addition, the World Health Organization (WHO) Regional Office for Europe has been advocating action on climate-related health threats since the 1990s, including through the European Environment and Health Process. Climate change and health is one of the seven priority areas of the 2017 Ostrava Declaration of the Sixth Ministerial Conference on Environment and Health (WHO Europe, 2017a), in which the 53 Member States of the WHO European Region committed to developing national portfolios of actions on environment and health. The WHO 'Zero Regrets' (WHO Europe, 2021b) initiative aims to scale up action on climate change mitigation and adaptation for health. It addresses policymakers, particularly from the health sector, to raise awareness about the links between health and climate change. The initiative provides relevant evidence, offers areas for policy action that can maximise health benefits and promotes collaboration across sectors and actors.

More detail on the European policies and activities relevant to climate threats to human health can be found on the European Climate and Health Observatory web pages.

2.2 National policies

National adaptation strategies, plans and climate risk assessments emerge as the national policies most relevant to addressing climate change impacts on health at the country level. Climate change impacts on health are more commonly addressed in national adaptation strategies than in national health strategies. Health impact assessments and response strategies are often integral parts of national adaptation policies. Only a few countries have a specific sectoral climate adaptation strategy for health. The climate hazards most frequently covered in national adaptation and health policy documents are heatwaves and drought; heavy precipitation and flooding; general rise in temperature; increasing threat of pathogens and infectious diseases; and more intense and frequent storms. The most frequently planned interventions to address climate change impacts on health are monitoring and surveillance, including early-warning systems; awareness-raising campaigns for the general public; and continued research into climate change impacts on health. For a comprehensive analysis of the national adaptation policies and national health strategies, see the European Climate and Health Observatory (2022a).

Only a few countries have a specific sectoral climate adaptation strategy for health.

2.3 Local and subnational policies

According to the EU adaptation strategy (EC, 2021b), the local level is the bedrock of adaptation. Most European countries recognise the crucial role of local authorities in implementing national adaptation strategies (EEA, 2020a). In addition, local authorities have the best knowledge of local population characteristics, locally occurring climate-related hazards and opportunities for engagement with local communities. Therefore, embedding health in planning and implementing adaptation measures matters most at the subnational and local levels.

Health is the fourth most frequently targeted sector for local adaptation actions (EEA, 2020a), and the risks to vulnerable people such as the elderly, children and those in poor health are increasingly recognised in local adaptation plans (Reckien et al., 2022). Yet the local authority departments responsible for implementation of the planned adaptation actions are most often those dealing with spatial planning, urban design, open spaces or architecture, followed by those concerned with environment or sustainability. In contrast, very few actions are implemented by social care or health and housing departments. In addition, the engagement of stakeholders from the health and social care sectors is minimal at the local level. As a result, many climate adaptation measures focus on technological interventions, without accounting for the social characteristics of cities, and thus fail to address the climate impacts on health. For example, projects and policies targeted at the most vulnerable groups were listed only 12th among the types of climate adaptation actions reported by cities across Europe. Thus, at the local level, the policy link between adaptation and health needs to be reinforced (EEA, 2020a). In over half of European countries, health is at least partially or fully included in the competences of local authorities (CEMR, 2011), thereby lending itself to closer links with local adaptation actions.


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3
Heat as major threat to human health in Europe

Key messages

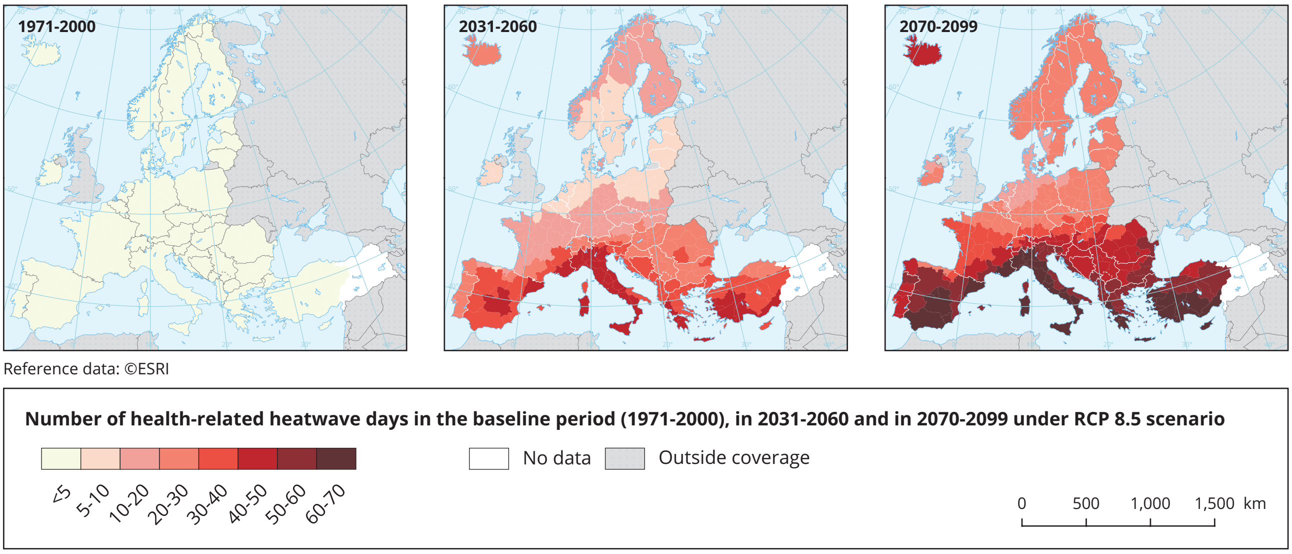
- Europe is warming fast. The duration and intensity of heatwaves dangerous to human health are increasing and are projected to further increase substantially across Europe under all climate scenarios, especially in southern Europe.
- Vulnerability to heat exposure associated with ageing, prevalence of diseases and urbanisation is highest in northern Europe, while between 1990 and 2019 the largest increase in vulnerability was observed in central and southern Europe.
- Across Europe, 1.21 billion person-days of exposure to heatwaves among people over 65 years old were estimated in 2020. The exposure of elderly people to heatwaves has particularly increased in parts of central and southern Europe.
- The exposure of people to heat is driven by the characteristics of the built environment and their occupation, which tends to put lower socio-economic groups at a disadvantage.
- Nearly half of hospitals and schools in European cities are in areas with strong urban heat island effects (>2°C), meaning that their vulnerable users and staff are exposed to high temperatures.
- Heat-related mortality has been increasing across Europe since the beginning of the 21st century, particularly in southern Europe. Under a scenario of 3°C global warming, without adaptation measures, 90,000 Europeans could die from extreme heat every year.
- Increasing temperatures resulted in an estimated annual loss of 16 working hours per person employed in high-exposure jobs in the period 2016-2019 compared with 1965-1994. The largest declines in working hours occur in parts of southern Europe.
- Reducing the health impacts of heat requires the implementation of different solutions, including effective heat health action plans, urban greening, climate-proofing of buildings, and changing working times and conditions.
- Interventions should prioritise vulnerable groups (e.g. elderly, children, those in poor health and outdoor workers) and facilities (e.g. hospitals and schools), as well as people particularly exposed to heat.

3.1 Increasing hazard of high temperatures in Europe

Europe is warming faster than the global average. Between 2017 and 2021, the average temperature in Europe has increased by around 2°C above late 19th century values (C3S, 2022a). Much of Europe has experienced intense and recurrent heatwaves since 2000 (EEA, 2022c). The conditions dangerous to human health — hotter days, higher night-time temperatures and an increasing number of humid heatwaves — have become more frequent in Europe over the past few decades and are projected to increase (EEA, 2021a). While the summer of 2021 was the warmest in Europe on record (ESOTC, 2021), it was trumped by summer 2022, with the average temperatures during June, July and August 0.4°C higher than those in 2021 (Copernicus, 2022c). In summer 2022, during the subsequent heatwaves, several temperature records were broken; Spain, Italy and France in particular experienced long spells of exceptionally high temperatures (Copernicus, 2022a).

Land temperature in Europe is projected to increase by up to 3.4°C under RCP 2.6 scenario (a low greenhouse gas emissions scenario) and by up to 8.5°C under RCP 8.5 scenario (a high-emissions scenario) by the end of the 21st century, compared with the period 1981-2010 (EEA 2022c). Accordingly, the frequency, duration and intensity of hot periods are projected to increase in the future. The number of hot days is expected to double and almost quadruple during the 21st century under the medium- and high-emissions scenarios (RCP4.5 and RCP8.5), respectively, with more limited increases expected under the low-emissions scenario (RCP2.6) (EEA, 2021a). Southern Europe may experience up to 100 'tropical nights' (with a minimum temperature over 20°C) per year by the end of the century under a high-emissions scenario. Prolonged waves of extreme heat, as well as an increase in the duration of extremely humid and hot conditions particularly dangerous to human health, are projected to increase substantially across Europe under all climate scenarios, especially in southern regions (EEA, 2022c). With climate change, the number of health-related heatwave days (a prolonged period of extremely high temperature and humidity) is projected to increase. While in the baseline period nowhere in Europe had more than five such days per year, by the end of the century, under the high-emissions scenario, in parts of southern Europe the annual number of health heatwave days will exceed 60 per year (Map 3.1).

Map 3.1 Number of health-related heatwave days in the baseline period (1971-2000), 2031-2060 and 2070-2099 under RCP 8.5 scenario



Notes: A health-related heatwave is a period of at least two consecutive days on which the maximum apparent temperature (Tappmax) exceeds the 90th percentile of Tappmax and the minimum temperature (Tmin) exceeds the 90th percentile of Tmin. The apparent temperature is a measure of relative discomfort due to combined heat and high humidity. Health-related heatwaves are calculated for June, July and August.

Source: Climate-ADAPT (2022a).

While this report focuses solely on the direct impacts of high temperatures on human health, the European Climate and Health Observatory also includes web pages focused on the health impacts of wildfires and air pollution combined with heat.

3.2 Population vulnerability to extremes of heat in Europe

The vulnerability of a population to heat-related morbidity and mortality is influenced by individual factors and socio-economic characteristics. Elderly people, children, pregnant women, outdoor workers, people with pre-existing health conditions (such as cardiovascular disease, respiratory disease, diabetes and mental health disorders; see Box 3.1) and marginalised or underresourced people are among the most vulnerable to extreme heat (WHO Europe, 2021a).

Older people in particular are at a higher risk of death from cardiac and respiratory disease during heatwaves. Population ageing in Europe will continue over the next couple of decades. In 2021, one fifth of the EU population was aged 65 years or over (Eurostat, 2022). In 2040, when 155 million Europeans will be over 65 years, the incidence of cardiovascular diseases is set to increase (MedTechEurope, 2020). In addition, the current number of people with diabetes (61 million) is expected to 69 million by 2045 (IDF, 2021), further increasing the population vulnerability to extreme heat.

Box 3.1 Impacts of high temperatures on mental health

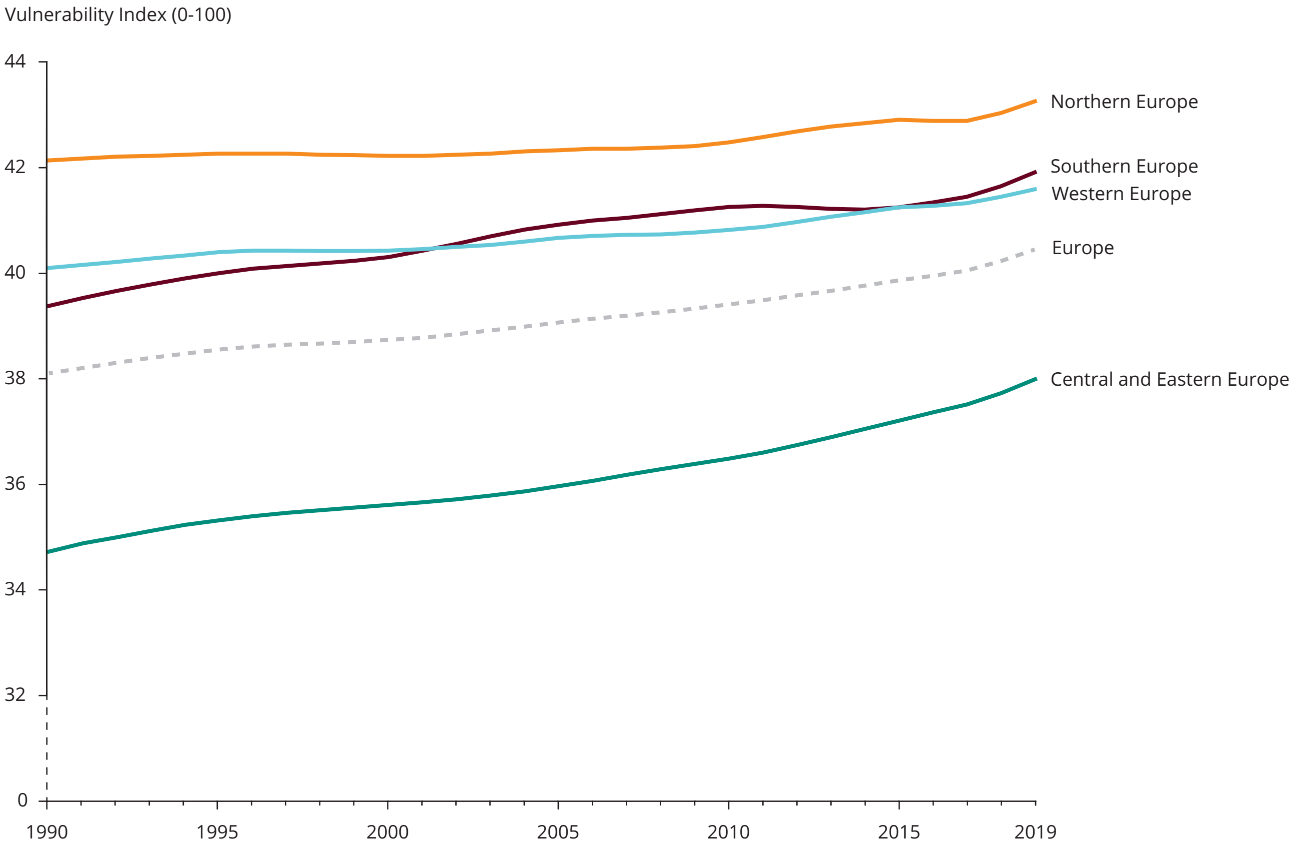
High temperatures and heatwaves are associated with mood and behavioural disorders, including increases in aggressive behaviour and crime. Links between high temperatures and an increase in suicide risk were found, particularly for men, as well as in the risk of mental health-related admissions and emergency department visits (Thompson et al., 2018).

A specific group vulnerable to the effects of extreme hot temperatures are people with pre-existing mental health conditions (Page et al., 2012; Palinkas and Wong, 2020), for whom heat is associated with psychological distress, worsened mental health, increased psychiatric hospitalisations, heightened suicide rates and higher mortality rates (Charlson et al., 2021). The interaction of heat with diuretics and psychotropic drugs increases the risk of dying for people with mental health problems during hot periods (Page et al., 2012).

For more information, see European Climate and Health Observatory (2022d).

The vulnerability of European populations to heat due to ageing, urbanisation and disease prevalence has been increasing steadily since 1990 (European Climate and Health Observatory, 2021a). While northern Europe is the most vulnerable region, given its high urbanisation level and the high proportion of elderly people in the population, the highest relative increase in population vulnerability (9.8% since 1990) has been observed in central and eastern Europe (Figure 3.1).

Figure 3.1 Trends in vulnerability to heat by European region, 1990-2019, in EEA member and cooperating countries



Notes: Heat vulnerability index (ranging from 0 to 100) was calculated for the period 1990-2019 based on the proportion of the population over 65 years, proportion of urban populations, and chronic disease prevalence (diabetes and kidney diseases, cardiovascular diseases and respiratory illnesses). Central and eastern Europe includes Albania, Bulgaria, Czechia, Estonia, Croatia, Hungary, Lithuania, Latvia, North Macedonia, Poland, Romania, Slovenia, Slovakia. Northern Europe includes Denmark, Finland, Iceland, Norway, Sweden. Southern Europe includes Cyprus, Greece, Spain, Italy, Malta, Portugal, Türkiye. Western Europe includes Austria, Belgium, Switzerland, Germany, France, Ireland, Luxembourg, Netherlands, United Kingdom.

Source: van Daalen et al. (2022).

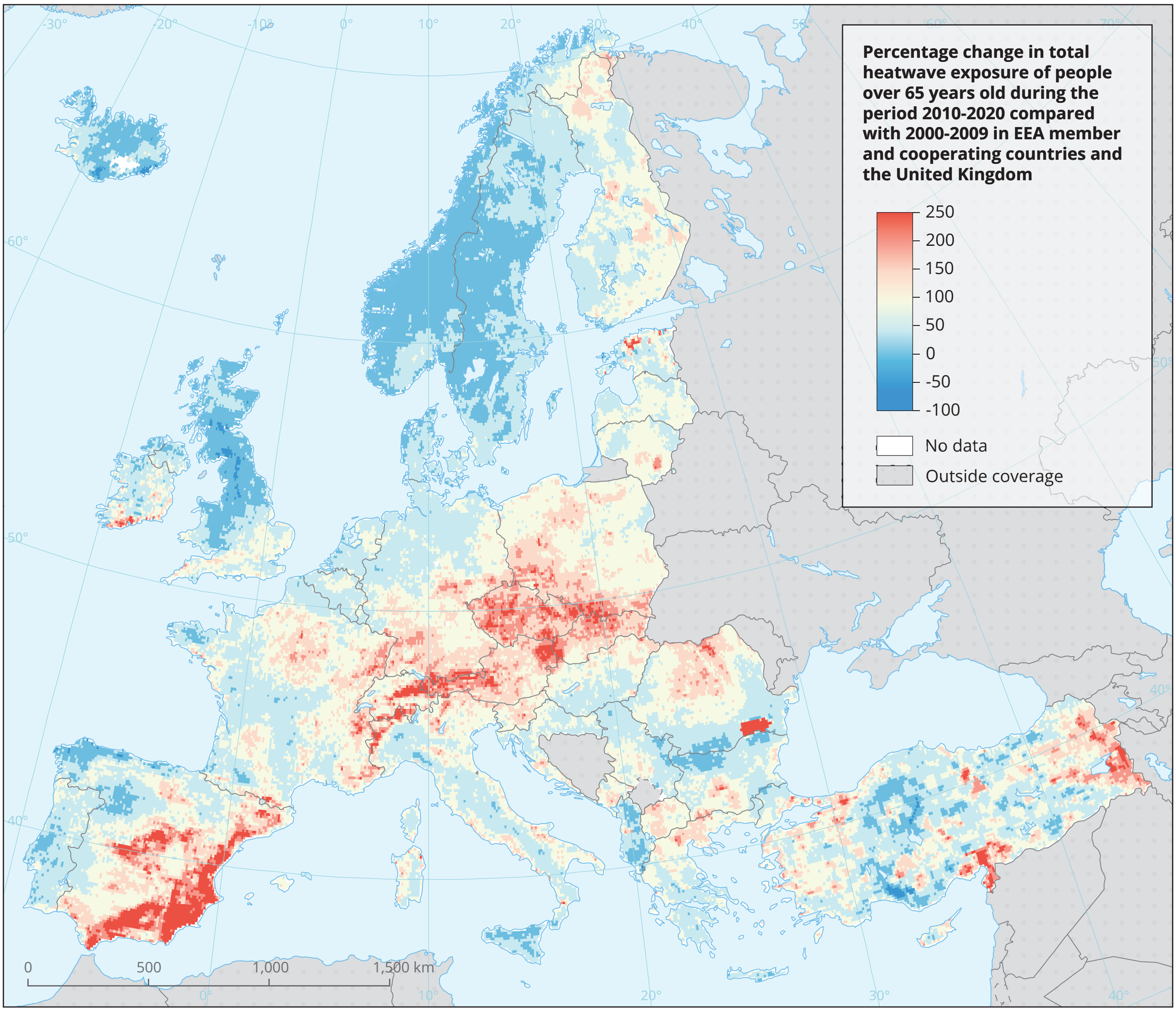
3.3 Exposure of population to heatwaves and high temperatures in Europe

3.3.1 Exposure of vulnerable groups across Europe

Southern Europe consistently emerges as the region with the greatest and fastest-increasing risk of high temperatures to human health (EEA, 2021a). In addition, many regions affected by high temperature are characterised by populations with low socio-economic status. For example, parts of Bulgaria, Croatia, Greece, Italy and Spain are among the European regions most affected by both long-term unemployment and high temperatures. In addition, the areas with a large number of hot days ([1]) tend to have higher proportions of elderly people in their populations, for example Greece, Italy, Portugal and parts of Spain (EEA, 2018).

The increasing number of people over 65 years old in Europe, combined with the higher temperatures in summer, has resulted in a substantial increase in the overall exposure of elderly people to heatwaves since 1980 (European Climate and Health Observatory, 2021b). According to modelling that includes the number of infants under 1 year old as a vulnerable group alongside elderly people, the decade 2010-2019 had heatwave exposure 64.4% higher (yearly mean of 1.07 billion person-days) compared with 2000-2009 (0.65 billion person-days). In 2020, 1.21 billion vulnerable person-days of heatwave exposure were calculated. This was principally driven by the exposure of the over-65s. However, 3.1 million person-days were related to the heatwave exposure of infants. Furthermore, increases in specific locations may be significantly higher than average. Particular hot spots for increased heatwave exposure are in central and eastern Spain and central Europe (van Daalen et al., 2022; Map 3.2).

Map 3.2 Percentage change in total heatwave exposure of people over 65 years old during the period 2010-2020 compared with 2000-2009 in EEA member and cooperating countries and the United Kingdom



Reference data: ©ESRI

Notes: The indicator has been calculated by multiplying the number of heatwave days by the vulnerable population count (i.e., those aged 65 years and over), producing an indicator of 'person-days' reflecting both the change in frequency and duration of heatwaves. Heatwaves are defined as periods of 2 or more days on which both the minimum and the maximum temperatures are above the local 95th percentile (defined using the 1986-2005 baseline).

Source: van Daalen et al. (2022).

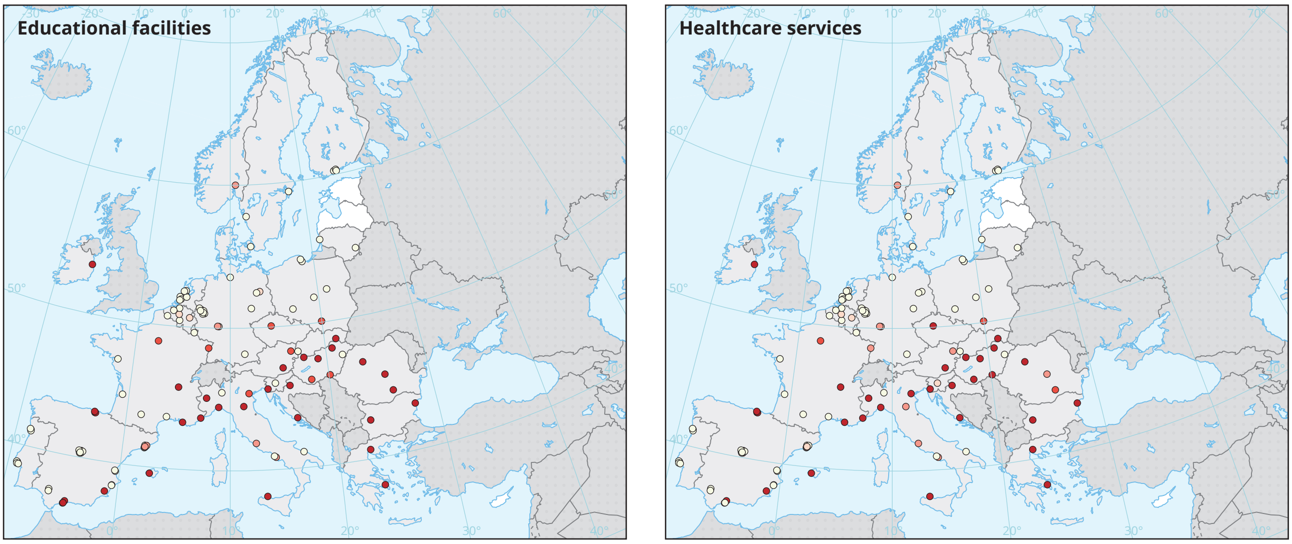
([1]) Days on which maximum temperature exceeds 35°C.

3.3.2 Exposure to heat at home, work and school

In urban areas, where most Europeans live, exposure to heat may be compounded by the urban heat island (UHI) effect, whereby the urban structure, its materials and its landscapes tend to increase ambient temperatures and reduce night-time cooling (EEA, 2021a). In many European countries, it is the more vulnerable communities that tend to live in dense, urban environments and, therefore, may be exposed to higher temperatures because of the UHI effect (EEA, 2018). In addition, the quality of the built environment, which substantially affects the indoor thermal comfort, tends to be the lowest among lower socio-economic status groups, which also may not be able to afford mechanical cooling in their homes (EEA, 2018). Consequently, in nearly all European countries, the lowest-income households are less able to keep cool during summer than wealthier households. In Bulgaria, Greece, Spain and Italy, those on the lowest incomes are twice as likely to be uncomfortably hot in their home as those on the highest incomes (Eurostat, 2012). This requires urgent adaptation actions targeted at housing inhabited by people in low-income groups (see Section 3.5.3).

An analysis of the distribution of hospitals and schools in relation to UHIs in 100 European cities found that almost half are in areas at least 2°C warmer than the average for that city (European Climate and Health Observatory, 2022b). Hospitals and schools are particularly exposed to intense UHIs (>4°C in comparison with the city average) in Greece, Italy, Romania and Spain (Map 3.3). This may pose heightened heat-related threats to schoolchildren or hospital patients, as well as teachers and health workers. The risk of losing electricity supply in hospitals during periods when the power grid is overused may not only disrupt care, but also reduce or remove air conditioning capacity and expose highly vulnerable people to high temperatures (Patel et al., 2022). The COVID-19 pandemic showed that the healthcare workforce can be particularly at risk of occupational exposure to heat through the use of special protective equipment (Jegodka et al., 2021), emphasising further the need for the urgent adaptation of healthcare facilities.

Map 3.3 Percentage of educational facilities (left) and healthcare services (right) in areas experiencing the urban heat island effect greater than 2°C in 100 European cities



Reference data: ©ESRI

Percentage of educational facilities (left) and healthcare services (right) located within Urban Heat Island Effect greater than 2°C in 100 European cities

- <20
- 20-40
- 40-60
- 60-80
- >80

Outside coverage

No data

0 500 1,000 1,500 km

Source: European Climate and Health Observatory (2022b).

People who perform physical work, use protective equipment or clothing, work outdoors exposed to the sun or work in poorly cooled buildings with machinery that generates heat are disproportionately exposed to high temperatures (Pogačar et al., 2018; WHO Europe, 2021). Many agricultural workers' tasks need to be performed to a fixed schedule, sometimes requiring the most physically demanding tasks to take place during either the hottest part of the day or the hottest time of year. Construction workers in cities are also exposed to the UHI effect. Low-income workers exposed to heat stress through their jobs tend also to be more exposed on the way to work (e.g. on foot or commuting in vehicles without air conditioning), in their homes (due to poor insulation, lack of air conditioning and inability to afford mechanical cooling) and in their neighbourhoods (e.g. urban areas are highly susceptible to the heat island effect) (Narocki, 2021).

3.3.3 Projected exposure of European population to high temperatures

The projected increase in the intensity, frequency and length of heatwaves will result in a strong rise in the number of people exposed to extreme heat. Even if global temperatures are stabilised at 1.5°C above pre-industrial levels, by the end of this century more than 100 million people annually in the EU and United Kingdom are expected to be exposed to a present 50-year heatwave intensity ([2]), compared with nearly 10 million per year under the baseline climatic conditions (1981-2010). The number of people exposed to a present 50-year heatwave intensity grows to 172 million per year at the end of the century with a global temperature increase of 2°C above pre-industrial levels and to nearly 300 million per year with unmitigated climate change (3°C warming in 2100). This means that in 80 years more than half of the European population could be exposed each year to a present 50-year heatwave (Naumann et al., 2020).

In addition, continued urbanisation in Europe will increase the number of people exposed to extreme heat conditions due to the UHI effect. Europe's level of urbanisation is projected to increase to approximately 83.7% in 2050. Built-up areas are likely to expand by more than 3% between 2015 and 2030, constituting 7% of EU territory by 2030 (Perpiña Castillo et al., 2019). Smid et al. (2019) project increased exposure to heatwaves in all capital cities across Europe, but particularly those in southern Europe.

With regard to exposure to heat at work, in large parts of Europe future heat exposure will exceed critical levels for physically active people far more often than in today's climate. This may result in substantially reduced labour productivity in southern Europe (Casanueva et al., 2020; see Section 3.4.2).

3.4 Health impacts of heat

3.4.1 Heat-related mortality

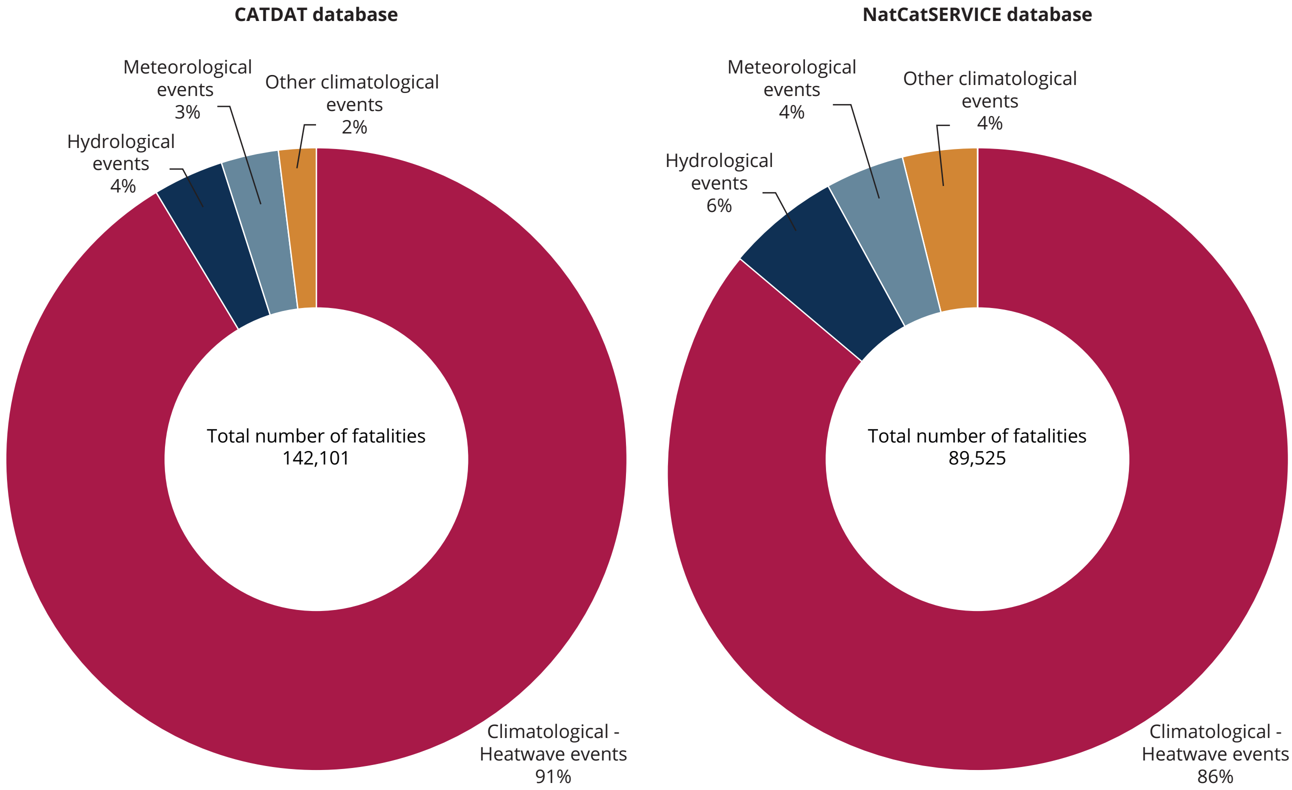
High temperatures can cause heat stress, which increases the risk of death from heat exhaustion and heatstroke. Moreover, indirect heat impacts on cardiovascular and respiratory systems and the exacerbation of existing health conditions by heat are another cause of increased mortality during hot weather (WHO Europe, 2021a). High temperatures also affect mental health and may increase the mortality risk of people with mental health problems (see Box 3.1). These direct and indirect impacts of heat have been recognised in over half of the national adaptation policies and health strategies across the 33 EEA member countries and six cooperating countries (EEA-38) (European Climate and Health Observatory, 2022a).

No consistent reporting of heat-related mortality exists in Europe. According to information held by various databases on natural disasters and catastrophes, heatwave events are responsible for 86-91% of fatalities caused by weather- and climate-related extreme events in EEA member countries (1980-2020), which corresponds to 77,000-129,000 deaths over that period (EEA, 2022d) (Figure 3.2). The death toll from the 2003 European heatwave alone is believed to have exceeded 70,000 (Robine et al., 2008). An early indication of the mortality associated with the 2022 heatwaves in Europe is given in Box 3.2.

No consistent reporting of heat-related mortality exists in Europe.

([2]) A heatwave that has a 2% probability of occurring every year (i.e. on average that would happen every 50 years).

Figure 3.2 Fatalities associated with natural disasters and catastrophes in EEA member countries in the period 1980-2020 based on CATDAT (left) and NatCatService (right)



Source: EEA (2022d).

Box 3.2 Deaths associated with heatwaves in summer 2022

The summer of 2022 was the summer of heatwaves. In 2022, the first high temperatures dangerous to human health were already experienced in southern Europe in the second half of May; these continued into June, peaking on 17 June (Copernicus, 2022a). Subsequently, July was the warmest on record in south-western Europe in terms of average maximum temperatures. Around mid-July, heatwave conditions affected most of western Europe (Copernicus 2022b). During the July heatwave, temperatures exceeded 40°C in France, 45°C in Spain and 46°C in Portugal (ECMWF, 2022). The average temperatures in August were the highest on record (0.8°C higher than in 2018) (Copernicus, 2022c).

At the time of publishing this report, it was too early to have a robust overview of the deaths related to the heatwaves; in addition, the information disclosed by national authorities on the deaths associated with high temperatures varies. However, in June, July and August 2022, Spain alone recorded over 4,600 deaths attributable to temperatures exceeding 40°C (MoMo, 2022). In Germany, in July, 9,130 (or 12%) more deaths were recorded than the median of the years 2018 to 2021 for this month (Federal Statistical Office, 2022). In Portugal, over 1,000 extra deaths had been reported by 18 July (Reuters, 2022). In the Netherlands, in week 29, the authorities recorded 559 non-COVID-19 excess deaths compared with the previous 5 years (Politico, 2022).

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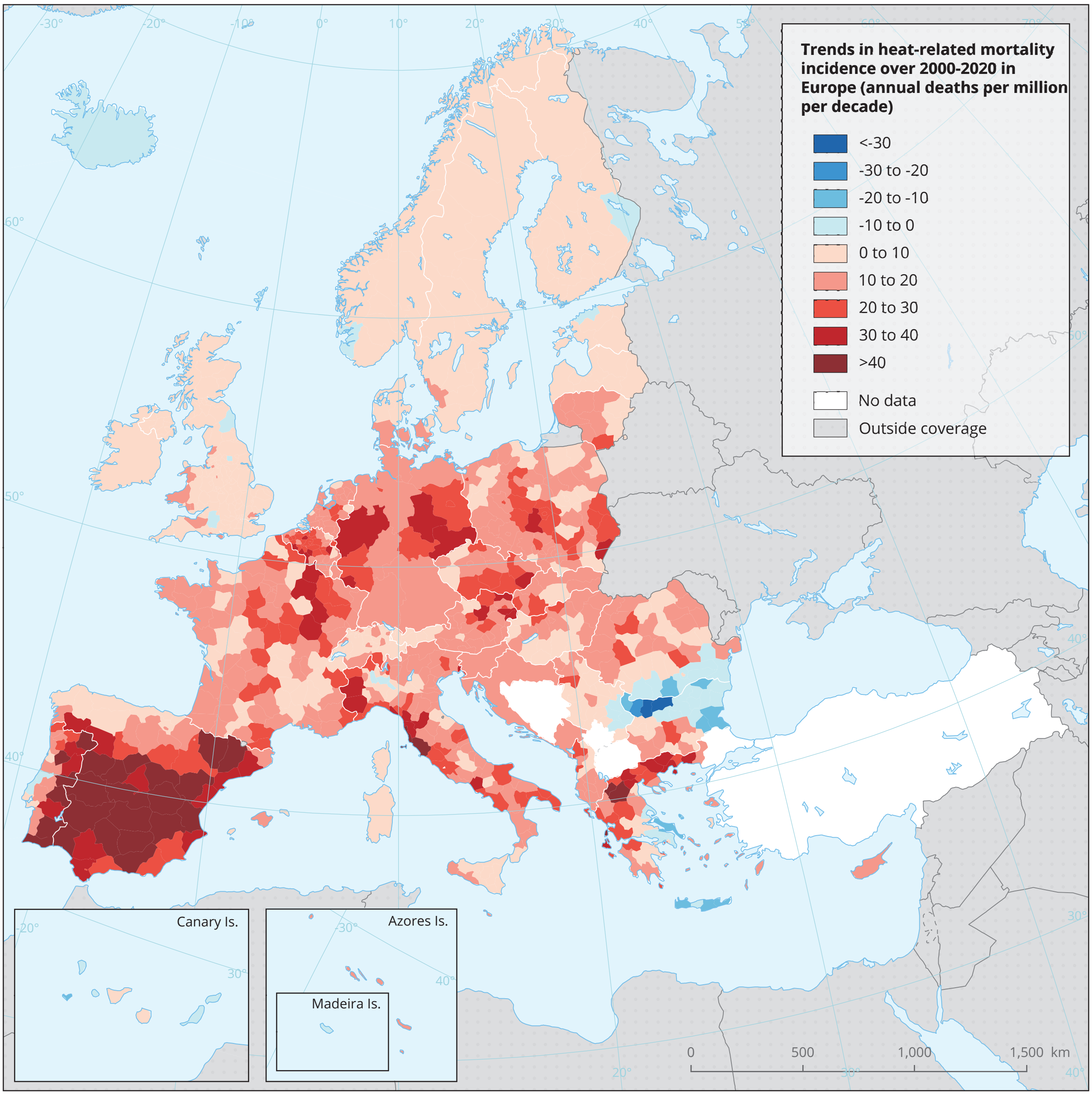
In the paucity of consistently recorded heatwave mortality, the modelling utilising weekly mortality and temperature data suggests an increase in heat-related mortality between 2000 and 2020 in 94% of the 990 European regions assessed. An overall average increase of 15.1 (95% confidence interval (CI): -1.51 to 31.6) annual deaths per million inhabitants per decade for the general population is estimated (Map 3.4). This upwards trend in heat-related deaths has been more pronounced in southern Europe, especially in Spain and Portugal. Country-level values range from the average of 30.6 (95% CI: 6.32 to 54.9) annual deaths per million per decade in Spain to -1.53 (95% CI: -6.33 to 3.27) in Iceland (van Daalen et al., 2022).

Map 3.4 **Trends in heat-related mortality incidence over 2000-2020 in Europe (annual deaths per million per decade)**



Reference data: ©ESRI

Notes: Epidemiological models were combined with with weekly temperature and mortality data to estimate the number of heat-related deaths over the period 2000-2020. A linear trend was fitted to the yearly time series of heat-related mortality incidence, whose slope represents the indicator expressed as annual deaths per million inhabitants per decade. The smallest regions possible were used, depending on the spatial resolution of the mortality data in a given country, ranging from NUTS ([3]) to countries. Data were not available for Türkiye, Bosnia and Herzegovina, Kosovo (under UN Security Council Resolution 1244/99) and North Macedonia.

Source: van Daalen et al. (2022).

([3]) NUTS (French Nomenclature des unités territoriales statistiques) is a hierarchical system for dividing up the territory of the EU for the purpose of collecting, developing and harmonising European statistics, carrying out socio-economic analyses of the regions and framing EU policies. NUTS 3 are areas with 150,000-800,000 inhabitants (Eurostat, 2015).

However, the above calculations do not consider the adaptation measures present (heat health action plans, improvements in health services, better insulated buildings that provide cooling; see Section 3.5) or human adaptability to higher temperatures, which may mean that the increasing temperatures do not directly translate into increased mortality. For example, in Spain, the minimum mortality temperature (i.e. temperature above which mortality increases) has increased in parallel with the general increase in the temperatures over the past decades (Achebak et al., 2019; Follos et al., 2021), indicating a level of population acclimatisation and possibly reducing the temperature effect on mortality.

Over the following decades, accelerating climate change may lead to a substantial increase in morbidity and mortality unless adaptation measures are taken. Without adaptation measures, and under a scenario of 3°C global warming by 2100, 90,000 Europeans could die from extreme heat annually. With 1.5°C global warming, this is reduced to 30,000 deaths annually (Naumann et al., 2020). In addition, according to the sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC), the number of deaths from and people who may experience heat stress in Europe will be double or treble at the end of the century at a global warming level of 3°C compared with a 1.5°C level (IPCC WGII, 2022a). The projected decrease in mortality associated with exposure to low temperatures will be much smaller and will not offset the increase in mortality from high temperatures (Naumann et al., 2020; Martínez-Solanas et al., 2021). Therefore, climate mitigation and adaptation measures are both necessary and urgent. According to Díaz et al. (2019), in the case of Spain, the number of deaths in the second half of the 21st century could be nearly 10 times smaller using a comprehensive set of adaptation measures than in a scenario without adaptations.

3.4.2 Heat impacts on labour

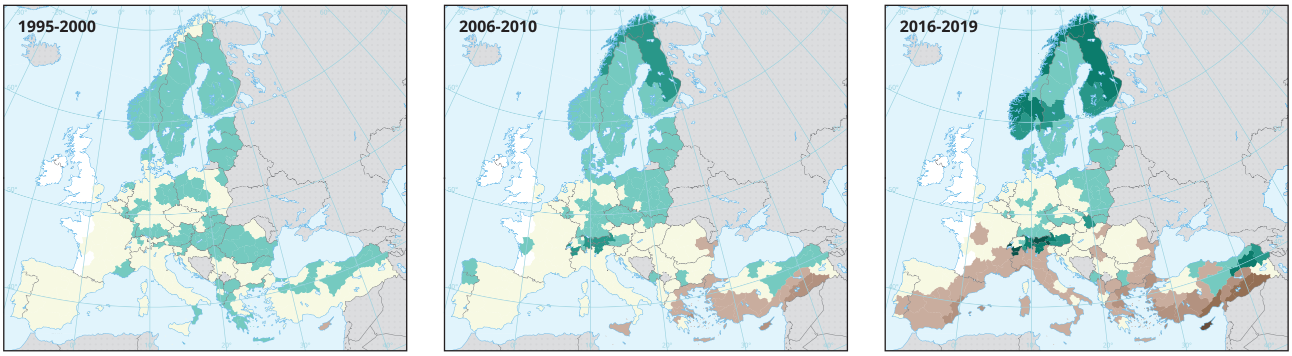
While Europe has been relatively less affected by heat stress in the work environment than other parts of the world, the increasing temperatures have nevertheless already had adverse effects on the European labour force, especially on workers in highly exposed sectors such as agriculture and construction (van Daalen et al., 2022). Heat stress in the working environment can cause dehydration, which in turn may reduce concentration and speed of reflexes, increasing the risk of work-related injuries (Narocki, 2021). For office workers, increasing temperatures impact cognitive abilities, negatively affecting concentration and decision-making capacity. Therefore, warming directly affects labour supply (number of working hours, i.e. the amount of time people allocate to work) and reduces performance during working hours (labour productivity), as workers need to slow the pace of work under heat stress and take additional breaks to rehydrate and cool down (Dasgupta et al., 2021; Ioannou et al., 2021; Szewczyk et al., 2021).

The relationship between temperature and labour is non-linear, with labour supply and productivity declining beyond certain optimal thresholds (Dasgupta et al., 2021; Schleypen et al., 2021). The optimal annual mean temperature beyond which labour supply in Europe declines has been estimated to be 9.3°C (95% CI: 7.9°C to 10.6°C) for high-exposure work conditions (in agriculture, forestry, mining and quarrying, and construction) (van Daalen et al., 2022). In these four high-exposure sectors, the increased temperature caused a 0.23% decline in the number of working hours in the period 1995-2000, compared with the reference period of 1965-1994. This amounts to just over 4 hours per worker per year. In the period 2016-2019, a 0.98% decline (equivalent to 16 hours per worker per year) was observed in comparison with the same baseline. The largest declines in working hours are estimated to be in Cyprus, the South Aegean in Greece and the Balearic Islands in Spain. Northern European countries generally show small gains in labour supply (van Daalen et al., 2022; Map 3.5).

According to the International Labour Organization (ILO, 2019), by 2030, 0.03% of total working hours could be lost as a result of heat stress in Europe and Central Asia, the equivalent of around 103,000 full-time jobs. In the worst-case scenario, European labour productivity losses could be around 0.3%, 0.8% and 1.6% by the 2020s, 2050s and 2080s, respectively, with southern Europe experiencing the highest losses (Szewczyk et al., 2021). Effective labour (the combination of the number of working hours and output during these working hours) in southern Europe is expected to decrease by up to 13.6 percentage points under 1.5°C of warming (2030-2050), 18.2 percentage points under 2.0°C of warming (2050-2070) and 28.5 percentage points under 3.0°C of warming (2070-2090) (Dasgupta et al., 2021).

Heat stress in the working environment can cause dehydration, which in turn may reduce concentration and speed of reflexes, increasing the risk of work-related injuries.

Map 3.5 **Percentage change in labour supply due to temperature change in high-exposure sectors (agriculture; forestry; mining and quarrying; construction) in relation to the baseline period 1965-1994**



Reference data: ©ESRI

Percentage change in labour supply due to temperature change in high-exposure sectors (agriculture; forestry; mining and quarrying; construction) for three periods (1995-2000; 2006-2010; 2016-2020) in relation to the baseline period 1965-1994

<-8 | -8 to -6 | -6 to -4 | -4 to -2 | -2 to 0 | 0 to 2 | 2 to 4 | 4 to 6 | >6

No data | Outside coverage

0 | 500 | 1,000 | 1,500 km

Notes: This indicator uses longitudinal data controlling for non-linear mean annual temperature and total annual precipitation as climatic stressors. The dependent variable is the log of the number of working hours at the NUTS 2 level. The econometric estimates are combined with temperature deviation from the 1965-1994 average to estimate the impact of temperature change on the number of hours worked in each NUTS 2 region.

Source: van Daalen et al. (2022).

The projected impacts of high temperatures on effective labour supply are likely to have negative implications for both economic growth and poverty in Europe. Over the period 1981-2010, the average European loss of gross domestic product (GDP) associated with heatwaves was 0.2%, amounting to 0.3-0.5% GDP in years with substantial heatwaves (2003, 2010, 2015 and 2018), with southern Europe experiencing up to 1% loss of GDP (García-León et al., 2021). By 2050 the construction sector in Europe is projected to suffer a loss of about EUR4.7 billion, followed by transport (EUR2.8 billion) and agriculture (EUR2.4 billion) (Flouris et al., 2017). Other industries such as tourism and manufacturing will also be affected, albeit to a lesser extent.

3.5 Reducing the health impacts of heat through adaptation measures

Heat-related health impacts will increase across Europe if adequate adaptation efforts are not implemented (WHO Europe, 2021a). Heat prevention requires a portfolio of actions at different levels, across different sectors and over different time-frames. According to the IPCC, adaptation options to manage heat risks in Europe include behavioural change combined with building interventions, space cooling and urban planning (IPCC WGII, 2022a).

Adaptation options to manage heat risks in Europe include behavioural change combined with building interventions, space cooling and urban planning.

The effectiveness of public policies aimed at reducing the health impacts of heat can be exemplified by the difference in heatwave fatalities in France: while the 2003 heatwave caused an estimated 15,000 deaths, the June 2017 heatwave caused only 580 additional deaths nationally (Mairie de Paris, 2018), and around 2,000 deaths were associated with the heatwaves of 2018 and 2019 (Adélaïde et al., 2022). The actions taken include the introduction of the national heatwave plan to increase awareness among the population about the risks associated with high temperatures, the establishment of more green areas in cities and the provision of cool rooms (CSMonitor, 2019; EEA, 2020a).

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However, little is yet known about the effectiveness and efficiency of the specific adaptation measures, leading to calls for the development of knowledge on the subject and the effective sharing of information (EEA, 2020a). In addition, the actions taken to date may not constitute the most efficient approach, given the increasing frequency and intensity of recurring climatic events and the disproportionate impact of these on vulnerable populations (Mairie de Paris, 2018). The following sections discuss some of the approaches to reducing heat impacts on health.

3.5.1 Heat health action plans including early warnings

Heat health action plans (HHAPs) that incorporate early-warning and response systems emerge as a key tool for reducing extreme heat threats to human health (WHO Europe, 2021a; IPCC WGII, 2022b). HHAPs offer short-term responses: to heat-health threats associated with heatwaves and extreme heat events. They comprise early-warning meteorological systems ensuring timely alerts, which trigger national-, regional- or city-level actions; define institutional responsibilities and coordination mechanisms; and list measures to be deployed. Well-designed and well-implemented heat action plans can successfully reduce mortality from extreme temperatures (EEA, 2020a).

HHAPs can be applied in urban and other settings to target both the general population and vulnerable groups, such as the elderly or those working outside (IPCC WGII, 2022b). The iteratively updated response strategies incorporate weather-based alerts and timely public and medical advice, as well as improvements to housing and urban planning, while ensuring that healthcare and social systems are ready to act in the case of an extreme heat event (Climate-ADAPT, 2021). The measures in heat action plans include informing vulnerable individuals about the risk and preventive measures, accompanied in many cases by the provision of cooling rooms and medical support (EEA, 2020a). Communicating risks and giving behavioural advice are essential components of an HHAP to improve the population's awareness of health-related threats and prevention measures (WHO Europe, 2021a).

WHO Europe (2008) guidance on heat health action planning names eight elements for the successful implementation of an HHAP:

1. agreement on a lead body;
2. accurate and timely alert systems;
3. a heat-related health information plan;
4. a reduction in indoor heat exposure;
5. particular care for vulnerable population groups;
6. preparedness of the health and social care system;
7. long-term urban planning;
8. real-time surveillance and evaluation.

According to a 2021 World Health Organization (WHO) Europe survey, HHAPs at national or federal level have been confirmed in 16 EEA member and collaborating countries ([4]); eight countries responded that they did not have an HHAP in place ([5]) (WHO Europe, 2021a). Specific state, regional, provincial or municipal HHAPs are listed by 10 countries: Austria, Belgium, France, Germany, Italy, North Macedonia, Portugal, Spain, Sweden and Switzerland. In the 16 countries with HHAPs, five of the eight elements (agreement on a lead body, accurate and timely alert systems, a heat-related health information plan, a reduction in indoor health exposure, and particular care for vulnerable population groups) have been either fully or partially implemented. Among the countries with HHAPs, all but one have implemented alert systems. The least commonly implemented items were real-time surveillance, long-term urban planning and preparedness of health and social care systems (Sanchez Martinez et al., 2022).

Among the countries with HHAPs, France, Germany, Italy and the Netherlands, at least, have revised their HHAPs to account for COVID-19 risks and have given additional information on heat and COVID-19 risks and diversified measures given the related restrictions in place. In addition, WHO European Region has adjusted its regularly issued summertime advice to include information on minimising the adverse health effects of hot weather, integrating it with advice on protection from COVID-19 (Sanchez Martinez et al., 2022).

The European Climate and Health Observatory includes case studies of heatwave plans from Austria, Portugal and North Macedonia (see Box 3.3).

Box 3.3 Examples of national heatwave action plans

The Austrian Heat Protection Plan, led by the Ministry of Health and Women's Affairs with the involvement of several relevant actors at the national and provincial levels, was prepared and put into action in 2017. The plan describes the connection between climate change and health and sets out the baseline meteorological information for heat warnings, which is provided by the national meteorological service (ZAMG). The information and warnings are directed to citizens via a network of institutions and actors in the health field.

Following the 2003 heatwave, the Portuguese heatwave contingency plan was established, which operates every year from May to September and covers the whole of continental Portugal. The aim of the current plan is to prevent the adverse health effects of heat stress on the population during periods of elevated temperatures. Daily alerts are a key factor of the successful implementation of this plan, as they indicate what protection measures must be carried out.

The national heat-health action plan of North Macedonia (approved in 2012) lead to implementation of a heat-health warning system, as well as a series of actions aimed at mainstreaming health protection in other relevant policies, raising citizens' and health sector workers' awareness about the consequences of climate change and mobilising resources for managing the effects of heat on health.

The development of monitoring and surveillance systems to track climate change-related impacts, including the implementation of early-warning systems, was the most common measure planned to address climate change impacts on health in national climate adaptation strategies and national health strategies, according to the analysis by the European Climate and Health Observatory (2022a). The establishment of integrated national structures for public health surveillance and response was frequently identified in national policies as the vital element of an effective health system. For example, in Italy, the heat health watch warning system was implemented in 2005 to provide warnings of heatwaves that activate preventive actions at the local level. In Germany, the second progress report on the strategy for adaptation to climate change includes several ongoing, planned and proposed research projects, including analyses of the effectiveness of health adaptation measures in the context of heat action plans (European Climate and Health Observatory, 2022a).

([4]) Countries participating in the survey: Austria, Belgium, Croatia, France, Germany, Hungary, Italy, Lithuania, Malta, the Netherlands, North Macedonia, Portugal, Slovenia, Spain, Sweden and Switzerland.

([5]) Cyprus, Denmark, Estonia, Finland, Montenegro, Norway, Poland and Serbia.

There are also examples of heatwave action plans at the subnational level (see Box 3.4) that focus on vulnerable groups. For example, in Lisbon, the social care department of the municipality implements a contingency plan for homeless people whenever alerts for various extreme weather-related events are recorded (EEA, 2020a). In addition to organised and proactive action by the public sector, one way of preventing health impacts from heat is through encouraging community solidarity and self-help. For example, the city of Paris holds a register of people vulnerable to heatwaves and encourages solidarity networks to ensure that neighbours look after each other during heatwaves. Similarly, in Bologna, Italy, volunteers and non-governmental organisations assist vulnerable individuals during heatwaves through a payment-free call centre, looking after people at risk and accompanying them to cooling centres or hospitals (ETC/CCA, 2018).

An effective HHAP involves raising awareness among the public, particularly vulnerable groups, of the threats from heat stress. In 2021, the WHO European Region adjusted its regularly issued summertime advice to include tips for minimising the adverse health effects of hot weather, integrating this with advice on protection from COVID-19. The advice was summarised in a fact sheet, available in 15 languages, which was promoted in a broad communication and outreach campaign with four short video clips featuring public health advice on how people can 'keep cool in the heat'. The Swiss climate change adaptation plan describes several measures in place to improve citizens' awareness of the health threats from high temperatures, including a public website on which the Federal Office of Public Health provides an overview of and behavioural recommendations on the subject. Similarly, in Italy, in accordance with the national prevention plan 2020-2025, the Ministry of Health website publishes bulletins on heatwaves, which are also available through a mobile application (European Climate and Health Observatory, 2022a).

Box 3.4 Examples of subnational heat action plans

The city of Kassel in Germany provides the 'heat hotline parasol', a free service that, during the summer months, calls registered citizens to give them information about heat warnings from the German Weather Service and suggest ways to best deal with and adapt to higher temperatures and heat. The hotline provides support to elderly residents and their families in particular. The service is run by volunteers from the elderly committee and is coordinated by the health department of the Kassel region.

The municipality of Botkyrka in Sweden experienced a heatwave in 2010 that affected the health and well-being of the residents of nursing homes. Since then, extensive efforts have been made in Botkyrka to reduce the health impacts of heatwaves. Staff of establishments for elderly people have been educated on heatwave threats, and procedures to follow in case of heatwave warnings have been. If necessary, additional staff can be mobilised to ensure further support for safe care. Botkyrka also supports actions aimed at improving indoor thermal comfort and creating 'cool spots' in various areas of the municipality.

In Belgium, heat health action plans are triggered based on temperature forecasts in rural settings, which leads to an underestimation of heat stress in cities such as Antwerp where the urban heat island (UHI) effect causes twice as many heatwave days as in rural surroundings. A 5-day neighbourhood-level heatwave forecasting system was set up for Antwerp that takes into account the UHI effect. This efficiently targets help to vulnerable people (elderly and children) in locations where it is needed most. Furthermore, a web platform was developed by the city to issue heatwave warnings and advice on action to healthcare workers and other relevant stakeholders.

When extremely hot weather is predicted in Tatabánya, Hungary, a heatwave and UV radiation protocol is set in motion. The Hungarian Meteorological Service and the National Public Health Office report warnings of heatwaves or high UV radiation to the local authorities. After that, citizens receive an alert in printed or electronic form, advice about preparing for the forecast heatwave and details of who to contact in case of health problems. A key aspect is that information reaches citizens rapidly and through different channels (local radio, television, the city's home page, social media). Instructions for citizens, public institutions, healthcare organisations and the media are updated every 30 minutes.

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3.5.2 *Urban greening*

Vegetation in cities helps to reduce temperatures through evapotranspiration, shading and lower heat absorption and thus can help to decrease the heat-related mortality (Pascal et al., 2021). Parks, trees and green roofs emerge as effective measures for reducing ambient air temperature and improving both outdoor and indoor thermal comfort (EEA, 2020a). UBA (2022) identifies maintaining existing trees and planting new ones, supplemented by roof and facade greening, among the heat adaptation options suitable for temperate climates.

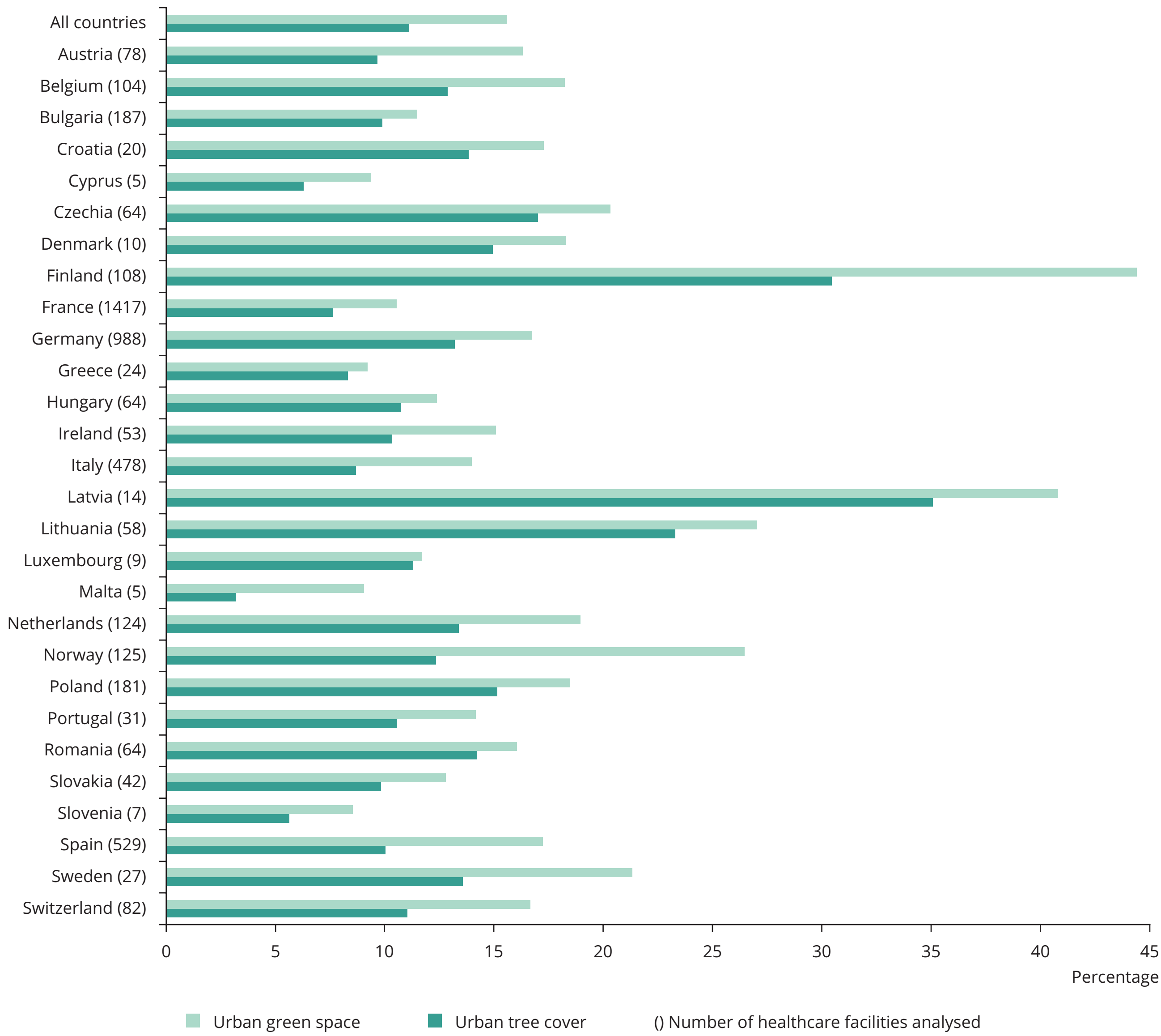
Apart from reducing temperatures, urban greening increases water retention (thereby reducing the likelihood of flooding), filters the air, dampens noise and improves mental well-being of urban residents (EEA, 2019a). The benefits of urban greening to health are so significant that, beyond contributing to sustainable, liveable and healthy cities, increasing exposure to green space could prevent a large number of premature deaths in European cities (Pereira Barboza et al., 2021). WHO recommends that urban residents have access to at least 0.5-1ha of public green space within 300m of their home (WHO Europe, 2017b).

European cities contain an average of 42% green space (EEA, 2021b), and 30% of the average city area is urban tree cover (EEA, 2021c), but the extent of greenness varies widely between and within cities. For example, cities in Finland and Norway have the highest proportion of tree cover, at over half of the area, while cities in Cyprus, Iceland and Malta have the lowest, at below 10%. In addition, the degree of greening varies across city neighbourhoods, with less and lower quality green space typically found in communities of lower socio-economic status. Therefore, ensuring equitable access to green space, and that urban greening efforts do not result in gentrification, is paramount (EEA, 2022a).

Furthermore, in European cities, the average proportion of green space around schools (within a straight-line distance of 300m as per the WHO recommendation) is well below the city average. On average, only 9% of the area in close proximity of schools is green, with urban tree cover constituting 6%. For hospitals, the amount of green space cover within 300m is 16%, and urban tree cover is 11% (Figure 3.3; European Climate and Health Observatory, 2022e), which emphasises the need to prioritise adaptation to heat of those facilities to improve the thermal comfort of their users.

European policies promote the use of nature-based solutions and urban greening. The EU's 2030 biodiversity strategy encourages bringing nature back into cities by creating biodiverse and accessible green infrastructure. The strategy also emphasises the importance of developing urban greening plans in larger cities and towns (EC, 2020c). The role of nature-based solutions in climate resilience is recognised by the EU strategy on adaptation to climate change (EC, 2021a). The proposal for a nature restoration law sets targets of no net loss and an increase in urban green spaces in cities, towns and suburbs (EC, 2022a).

Figure 3.3 **Average percentage of urban green space and urban tree cover within 300m of hospitals in European cities, per country**



Note: Data available for EU-27, excluding Estonia, plus Norway and Switzerland

Source: European Climate and Health Observatory (2022e).

Many national adaptation strategies include measures to create fresh air corridors and 'cool islands' of green spaces in cities. For example, the Dutch strategy includes a plan to strengthen natural networks in cities to simultaneously improve biodiversity and use the natural cooling effect of green areas as a 'climate buffer' for people. The 2021 climate impact and risk assessment for Germany outlines plans to define and implement guidelines for the selection of tree species and other vegetation, considering the resilience of the plants to drought and heat, as well as their allergenicity. In Czechia, the national adaptation strategy plans to engage architects, developers and construction agencies in implementing architecture and greening aimed at reducing the UHI effect and therefore heat stress (European Climate and Health Observatory, 2022a).

Adaptative actions aimed at maintaining the health and well-being of vulnerable groups through urban greening are also embedded in other types of national policies. For example, the 2019 German Federal Government's 'Urban Nature' master plan proposes more high-quality green spaces in disadvantaged areas to encourage residents to use these. Similarly, the Swedish National Board of Housing, Building and Planning offers funding to projects focused on greening disadvantaged neighbourhoods, with the aim of improving equity of access to urban green spaces (ETC/CCA, 2021).

At the local level, there are examples of greening to reduce the negative impacts of high temperatures on health and well-being. For example, in residential areas of Trnava and Košice, Slovakia, that contain housing prone to overheating and high proportions of older people and children, tree planting and the construction and restoration of water features were implemented, alongside actions aimed at behaviour change during heatwaves. In Paris, the OASIS — 'Openness, Adaptation, Sensitisation, Innovation and Social Ties' programme greens school playgrounds and makes them accessible to local communities, reducing the risks to vulnerable people from heatwaves. The greening of school playgrounds is also done in Flemish Brabant, Belgium.

In Antwerp, Belgium, the construction of buildings is regulated by a building code that contains specific regulations to help reduce heat stress in the city over time. This includes compulsory green roofs on all new or renovated roofs larger than 20m² and with a slope of less than 15%; permeable grassed surfaces on all outdoor private plots; and limiting paving in gardens to one third of the area. In Stuttgart, Germany, a number of planning and zoning regulations preserve green space (urban forests, parks, street trees) in densely built-up areas to reduce temperatures and improve air flow. Other adaptation measures implemented in Stuttgart include green roofs, greening of tram tracks, shading of building facades using street trees, upgrading of smaller public spaces to 'cool spots', or provision of drinking fountains and other water elements.

While urban greening seems a sustainable and effective solution to heat stress in cities, at the European scale the conversion of abandoned, vacant or underused land into green spaces ([6]) is minuscule (EEA, 2019b). This is associated with land pressures in many European cities, for example the need for housing overriding plans for the development of more green space or a lack of long-term political vision for urban greening (Buffam et al., 2022). Solutions integrating vegetation into existing built-up areas are therefore viable. Since 2010, homeowners in Vienna have been able to apply for a subsidy for green facades (both living walls and climbing plants growing from the soil at ground level) and green roofs. The city has greened the facades of the Department for Waste Management in central Vienna and the roof of the Vienna Environmental Protection Department (Eurofound, 2016). Another example of regulating the amount of green space in cities at the level of individual plots is a 'green area factor' system, which requires that a proportion of the development area is constructed as green space. Such a system is used in Berlin, and also in Oslo and Bærum in Norway and Malmö in Sweden (Kruuse, 2011).

In addition, from the climate adaptation perspective, urban green spaces need to be designed and maintained in a manner that ensures their sustainability in water-scarce conditions (e.g. by using drought-resilient species, capturing rainwater or using waste water for irrigation) and does not further increase the risk of vector-borne diseases (EEA, 2020a).

3.5.3 Built environment interventions

As Europeans spend on average around 90% of their time indoors (WHO Europe, 2013), improvements to the built environment can substantially help to reduce heat stress. With regard to structural solutions, various modelling studies have shown that shutters and solar blinds preventing heat gain are efficient ways to lower indoor temperatures (EEA, 2020a). Other methods of preventing the heat increase in buildings include reflective roofs and facades. For example, in Antwerp, buildings undergoing renovation in the city centre are required to be repainted in light colours, which increases reflectivity and reduces warming, thereby lowering indoor temperatures but also minimising heat radiation from the building outside. The use of light-coloured materials for roofs and facades as well as streets and pavements is also recommended in Germany as an adaptation measure (UBA, 2022). Increasing the height of buildings (or using appropriate street orientation) can create more shade and wind channels, improving thermal comfort on the streets (EEA, 2020a). Improving ventilation is another key method of lowering indoor temperatures. In Dresden, Germany, a consultation with one district's residents on ways to improve thermal comfort in homes and the neighbourhood as part of the HeatResilientCity project led to the decision to plant more trees, install window shutters, and boost the existing ventilation in apartment blocks (EEA, 2020a).

The demand for active (mechanical) cooling is on the rise. In the residential sector of the euro area (19 EU Member States), the amount of final energy used for space cooling tripled between 2010 and 2019. Although across Europe cooling constitutes 0.4% of domestic energy use, in Malta, Cyprus and Greece, the share of energy used for domestic cooling has reached 11.4%, 10.5% and 4.9%, respectively (Eurostat, 2021). Future energy demand for cooling is likely to increase most in southern European countries; it is estimated that Italy, Spain, Greece and Portugal could represent 70.8% of the EU total potential average yearly cooling demand for residential buildings (Jakubcionis and Carlsson, 2017).

Yet, although they improve thermal comfort indoors, air conditioning or heat pumps result in waste heat that disperses into the areas surrounding buildings (WHO Europe, 2021a), contributing to the UHI effect (Puig, 2021) and, in the case of fossil-fuelled electricity systems, to greenhouse gas emissions. Therefore, there is a need to explore sustainable and equitable ways of cooling residential buildings, such as district cooling using sea or river water (EEA, 2020a; EEA, forthcoming). This is of particular importance for people on low incomes, who often live in energy-inefficient homes (see Section 3.3.2) and may suffer from energy poverty, reducing their ability to use electricity-powered cooling methods. Improving the energy efficiency of homes and home appliances, ensuring affordable electricity supply and improving building quality all contribute to the protection of vulnerable groups from high temperatures (EEA, forthcoming).

([6]) So-called 'green recycling'; see EEA (2019b).

Implementing interventions to reduce the temperatures in public buildings (such as schools or hospitals) that serve vulnerable groups is paramount, especially given the disproportionate exposure of these buildings to the UHI effect (see Section 3.3.2) and the small amount of green space usually available in their proximity (see Section 3.5.2). For example, Bulgaria's national adaptation strategy is specifically aimed at adapting healthcare facilities. The German national adaptation strategy highlights the need to improve building insulation and introduce passive cooling systems in hospitals and other care facilities (see also Box 3.5). Similarly, the Maltese national adaptation strategy aims to safeguard nursing homes and healthcare facilities against higher temperatures and more frequent heatwaves (European Climate and Health Observatory, 2022a). District cooling solutions for hospitals exist in, for example, Brescia, Italy, and Copenhagen, Denmark (Galindo Fernández et al., 2016). Kicked off in 2022, the Life Resystal project works with seven pilot hospitals to improve their resilience to climate hazards, including heatwaves.

Box 3.5 Climate adaptation in social institutions in Germany

In 2020, the German Federal Ministry for Environment, Nature Conservation, Nuclear Safety and Consumer Protection launched the new funding programme 'Climate adaptation in social institutions'. With EUR150 million, the ministry supports social facilities such as hospitals, nursing homes, homes for the elderly and hospices, as well as kindergartens, schools, neighbourhood centres and facilities for refugees and homeless people. Employees and people under their care are to be better protected against acute climatic stress and comprehensively prepared for future climatic changes. For example, targeted support is provided for structural changes such as green roofs and facades, the construction of shady pavilions and sun sails or the purchase of drinking water dispensers. Social institutions are to receive expert advice and the opportunity to develop customised climate adaptation concepts for themselves. Training and further education programmes as well as information campaigns will raise awareness of the consequences of climate change among employees as well as the people being cared for and their relatives. The climate adaptation funding programme will run until the end of 2023 (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, 2020). One of the largest projects includes support of over EUR5 million to the psychiatric centre in Königslutter am Elm for new thermally insulated windows and shading to better protect the patients and employees against heatwaves (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, 2022).

3.5.4 Heat-aware working conditions

According to EU Directive 89/391/EEC (EU, 1989), workers' health and safety should be protected from any risks, including emerging ones. However, at the EU level, there is currently no binding legislation protecting workers from extreme temperatures.

Few Member States have developed specific plans for the protection of the working population from heat events, including maximum temperature thresholds. Cyprus was the first EU Member State to include special provisions in its legislation covering heat stress among workers (Department of Labour Inspection, 2022). While strategies in the workplace are being implemented progressively, the maximum permissible working temperature varies significantly across Member States, from as low as 18°C to as high as 35°C. Some of these limits are statutory and some are collectively bargained, while others are a combination (ETUC, 2019). For example, in Germany, a workplace temperature is normally defined as 26°C, and beyond 35°C the employer must implement 'cool down' measures. In France, labour laws require safe working conditions for employees, including protection from extreme heat. Additionally, construction sector workers must be provided with at least 3 litres of water per day. In Spain, there are strict guidelines for the temperature to be set between 17°C and 27°C for sedentary work, and between 14°C and 25°C for light physical work. In Belgium, the maximum temperatures are set at 29°C for light physical work, 26°C for moderate-heavy physical work, 22°C for heavy physical work and 18°C for very heavy physical work, while in Hungary the thresholds are 31°C for light work, 29°C for moderate work and 27°C for heavy work. In Latvia, the temperature threshold for indoor work is set at 28°C. In Montenegro, the maximum temperature for outdoor work is 36°C, while in Slovenia the air temperature threshold in work areas is set at 28°C (ETUC, 2022). With such thresholds increasingly common, various ways of reducing temperatures can be applied. For example, in Oslo, Norway, green roofs have been constructed on waste treatment facilities to improve the thermal comfort of workers on hot days (Box 3.6).

Box 3.6 Green roofs and natural ventilation in waste treatment facilities in Oslo, Norway

In Oslo, three waste treatment facilities (Haraldrud, Ryen and Smestad) have green roofs on their buildings. Haraldrud waste treatment facility, constructed in 2007, has the largest green roof in the Nordic region (28,000 square metres). Not only does the roof have a positive effect on heat regulation in the building, but the sedum plants also absorb rainwater and trap dust (Official Norwegian Reports NOU, 2010). In addition, the slats on the facade push outside air into the facility, ensuring natural ventilation (GASA, no date).

The Smestad waste treatment facility has a sedum roof and an open hall construction. The openings in the facade provide air flow and daylight in the hall, at the same time ensuring protection from the sun, as the screening facing south-west is most dense (City of Oslo Architecture Award, 2016).

The roof of the Ryen waste treatment facility also includes solar panels (see Image 3.1), which are more effective thanks to cooling by the sedum roof underneath. The green roof cools the air underneath as well as reducing noise (Oslo Kommune, 2022).

Image 3.1 Green roof and solar panels on Ryen waste treatment facility in Oslo

According to Casanueva et al. (2019), Germany, the Netherlands and Switzerland specifically target workers and trade unions in their heat-health warning systems. Local guidelines are also in place. For example, according to the heatwave action plan in Tatabanya, Hungary, employers should supply employees working outside with drinking water and proper clothing and should take care to implement an appropriate working regime (1 hour of working outdoors in a heatwave should be followed by 30 minutes of rest). In Puglia, Italy, regulations limiting hours working in intense heat have been introduced for agricultural workers (Box 3.7).

A large share of the European workforce lacks information on effective measures to mitigate occupational heat stress.

Practical solutions to occupational heat stress, alongside changes in working hours, include technical measures such as air conditioning, increased ventilation and window shades (Day et al., 2019). Artificial cooling (especially in the short term) and robotic solutions as adaptation measures to combat heat stress among workers have the potential to reduce economic and productivity losses by 30-40% (Szewczyk et al., 2021). Raising awareness of the threats posed by high temperatures is crucial: a large share of the European workforce lacks information on effective measures to mitigate occupational heat stress. For example, 60% of Slovenian and 50% of Greek workers stated in a survey that they lacked information on heat impacts on health (Morris et al., 2021). With teleworking becoming more common, regulations are also likely to be needed to protect workers' physiological and psychological health when working at home (Eurofound, 2020).

Box 3.7 Protecting workers from heat stress in Puglia, Italy

Increases in the average temperature and the frequency and intensity of heatwaves affect the health of workers. Therefore, regulations are required to protect workers from high heat stress. Against this backdrop, and following the heat-related death of a farm worker, authorities in the Puglia region of Italy passed a regulation in June 2021 prohibiting farm work between 12:30 and 16:00 on 'high-risk' days between June and September. The definition of risky conditions is based on the results of Worklimate ([a]), a national initiative aimed at assessing the impact of environmental thermal stress on workers' health and productivity.

The main objectives of the ordinance implemented in the Puglia region are to (1) protect agricultural workers in the region from prolonged exposure to extreme heat, (2) inform relevant stakeholders (employees, employers and public health authorities) of the risks of extreme heat, and (3) inform citizens about the issue of extreme heat and physical activity. This integrated weather-climatic and epidemiological heat health warning system, specifically developed for the outdoor occupational sectors, aims to improve knowledge about the effect of thermal stress conditions on workers, specifically on the estimation of the social costs of associated injuries at work.

The ordinance has succeeded in raising awareness about heat-related injuries in the workforce. Given that temperatures in the Puglia region exceed 40°C during the summer, the regulation has been well received by workers and labour unions. This is despite the rigidity of the warning system, as outdoor work is prohibited only during the hours of 12:30 and 16:00, and heat stress could pose 'high risks' at other times of the day. The ordinance was reissued in June 2022, with the prohibition extended until 31 August 2022. Other regional ordinances were implemented in 2021 in Campania, Molise, Basilicata, Calabria and selected municipalities of Sardinia. However, the uptake of such policies across Italy remains a challenge.

Image 3.2 Fields in Puglia in summer

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Note: ([a]) https://www.worklimate.it/il-progetto

Source: Climate-ADAPT (2022d).

4
Climate-sensitive infectious diseases as an emerging threat to human health in Europe

Key messages

- The prevalence or outbreaks of many vector-, food- or water-borne diseases is affected by climatic conditions or exacerbated by extreme weather events such as heavy rain and flooding.
- Climate trends and projections show that climate suitability will increase for the *Aedes albopictus* mosquito, a vector carrying dengue, chikungunya and Zika virus disease across Europe, which, combined with increased international connectivity, increases the probability of local transmission of these diseases.
- The annual length of season suitable for malaria transmission by *Anopheles* mosquitoes has increased across Europe since 1950, with central and eastern Europe experiencing the largest number of suitable months. This increases the likelihood of local malaria transmission.
- Europe has experienced a steady increase in the risk of West Nile virus transmission since the turn of the century. Warmer winters and springs drive outbreaks in southern, central and eastern Europe and are projected to expand West Nile virus to previously unaffected regions.
- Climate change has contributed to the increased suitability of marine waters for the dangerous *Vibrio* bacteria in Europe, increasingly affecting regions on the coast of the Baltic Sea.
- Tick-borne diseases are common across Europe but predominantly occur in central Europe, where milder winters and warmer summers are increasing the number of cases. Climate change facilitates the further spread of ticks and related diseases to northern and western Europe.
- People working in agriculture or forestry are particularly exposed to mosquito- and tick-borne diseases. Through contact with contaminated flood water, emergency workers are most exposed to water-borne diseases. Those suffering most from severe disease courses are elderly people, young children, pregnant women, and those with compromised immune systems.
- Effective monitoring of vectors and surveillance of diseases support the development of early warnings and prevent outbreaks of diseases. Further awareness raising is needed among both the public and health professionals about the threats of climate-sensitive infectious diseases and prevention methods. Vaccination programmes (for tick-borne encephalitis) and vector control measures emerge as actions that limit the number of locally transmitted infectious disease cases.

4.1 Infectious diseases sensitive to climatic and weather factors

The probability of infectious disease outbreaks is affected by factors such as land use, vector control, human behaviour, global trade and travel, and public health capacities. In addition, climatic conditions (temperature, humidity and precipitation levels) affect the geographical distribution and seasonal occurrence of infectious diseases, and extreme weather events can affect the timing and intensity of disease outbreaks. Globally, most of the pathogenic diseases influenced by climate hazards are aggravated by them: 19% are made either worse or better by climate hazards, depending on the situation, and only 3% are exclusively diminished by climate hazards (Mora et al., 2022).

Figure 4.1 provides an overview of the key infectious diseases in Europe grouped by pathogen type (virus, bacteria, parasite). Many of them are vector-borne diseases. Disease-carrying vectors of particular relevance for Europe are the following:

- *Aedes albopictus,* or tiger, mosquitoes (a vector for chikungunya and dengue; see Section 4.3.1)
- *Aedes aegypti* mosquitoes (a vector for chikungunya, dengue, yellow fever and Zika virus disease)
- *Anopheles* mosquitoes (a vector for malaria; see Section 4.3.2)
- Culex mosquitoes (a vector for West Nile virus (WNV); see Section 4.3.3)
- *Phlebotomus* sandflies (a vector for leishmaniasis)
- *Ixodes ricinus* ticks (a vector for Lyme borreliosis and tick-borne encephalitis (TBE)).

Higher temperatures have already allowed many of these vectors to expand their distribution further north and to higher altitudes. Locally transmitted outbreaks of dengue, chikungunya, West Nile fever and even malaria have occurred in southern and south-eastern Europe in recent years. Several European countries have reported that *Ixodes ricinus* has migrated north and to higher altitudes. A high incidence of both Lyme borreliosis and tick-borne encephalitis is correlated with mild winters and warm, humid summers.

In addition, populations of *I. ricinus* are persistent and potentially increasing in green spaces in European cities, where humans and domestic animals can be subject to infected tick bites. Climate change, in combination with increasing urbanisation, the propensity for more pets in smaller spaces and the popularity of outdoor sports and leisure activities, may increase exposure to ticks in urban and peri-urban areas (Rizzoli et al., 2014).

In addition, elevated water temperatures accelerate the growth of certain water-borne pathogens, such as *Vibrio* species (see Section 4.3.4). Other water-borne and food-borne diseases of relevance to Europe include Legionnaires' disease, salmonellosis, cryptosporidiosis and campylobacteriosis. High air temperatures can adversely affect food quality during transport, storage and handling. The disruption of electrical, refrigeration and cooking systems —caused by flooding, for example, but also power blackouts during heatwaves, intense storms or wildfires — may facilitate the transmission of food-borne illnesses, particularly during warm summer months (EFSA, 2020; ECDC, 2021).

The impact of climate change on the threat from infectious diseases is well recognised in national policies.

Severe floods, more of which are projected in large parts of Europe as part of the changing climate (Dottori et al., 2020), can lead to higher immediate, medium- and long-term likelihood of food- and water-borne infections and zoonoses, as they may cause animal faeces in soil or sewage to flow over land, into buildings or into water systems, increasing the likelihood of human contact with viruses, bacteria and parasites, causing diseases (ECDC, 2021).

The impact of climate change on the threat from infectious disease is well recognised in national policies; among other climate-related hazards, this is included in the largest number of national adaptation policy and national health strategy documents (European Climate and Health Observatory, 2022a). In addition, according to a WHO (2021) report analysing the overall progress made by governments around the world in including health risks from climate change in policy and institutional arrangements, vector-borne diseases are the most frequently addressed climate-related health threats in surveillance, early-warning systems and/or response plans (14 out of 15 EEA member and cooperating countries). Similarly, according to a global survey by the International Association of National Public Health Institutes (IANPHI, 2021), national public health institutes seem to prioritise risks from vector-borne diseases, followed by heat-related morbidity and mortality.

4.2 Incidence of climate-sensitive infectious diseases over time

The European Centre for Disease Control and Prevention collects data reported by EU Member States on cases of all of the infectious diseases listed in Figure 4.1 except vibriosis. The reporting of Lyme neuroborreliosis started only in 2018. The changes in the number of cases reported over the years can be seen in Figure 4.2. In some instances, the increase in reported cases is associated with the development of more robust detection methods and diagnosis.

Figure 4.1 Overview of the key climate-, weather- and flooding-sensitive infectious diseases in Europe

	Disease (references, see Annex 1)	Climatic factors, aggravated to diminished ratio ([a])		Modes of transmission	Confirmed cases per 100,000 population in 2019 ([b])	Symptoms and severity	Prevention and treatment ([c])
Viral diseases	Chikungunya (4, 5, 6)	Higher temperatures; Heavy precipitation; Extended warm season	50:3	Mosquito; Organ, blood donor	0.07	High fever, myalgia, skin rash, fatigue, muscle pains and joint stiffness. Severe cases may progress to ophthalmological, neurological or heart complications. Shock or severe haemorrhage is very rarely observed.	**Prevention:** Individual protection against mosquito bites; vector control. **Treatment:** No specific and effective antiviral therapy.
	Dengue (7, 8, 9, 41)	Higher temperatures; Heavy precipitation; Extended warm season; Drought	163:3	Mosquito; Organ, blood donor	0.68	High fever, headache, vomiting, myalgia, joint pain, pain behind eyes, swollen glands and sometimes rash. Most patients show only mild symptoms and recover without complications, but severe dengue can be fatal.	**Prevention:** Individual protection against mosquito bites; vector control; limited vaccine use. **Treatment:** No specific and effective antiviral therapy, symptom treatment only.
	Tick-borne encephalitis (25, 26, 27, 28, 29)	Higher temperatures; Heavy precipitation; Extended warm season	42:0	Tick; Food	0.73	Fever, fatigue, headache, muscular ache and nausea. Leads to meningitis and/or encephalitis Mortality rates of 0.5-2% (European subtype) (26).	**Prevention:** Vaccines; avoidance of tick-infested areas individual protection against ticks; pasteurisation of milk. **Treatment:** No specific and effective antiviral therapy.
	West Nile fever (13, 14)	Higher temperatures; Heavy precipitation; Extended warm season; Drought	119:4	Mosquito; Organ, blood donor	0.06	Headache, vomiting, fatigue, weakness, nausea, aching body parts and rash. Only 20% of infected people develop symptoms. Sever illness may progress to meningitis, encephalitis or poliomyelitis, which may cause partial paralysis. Case fatality of 12% (13).	**Prevention:** Individual protection against mosquito bites; vector control; virus surveillance in other vertebrate hosts and vectors; testing for viral agents in the blood of organ donors. **Treatment:** No specific and effective antiviral therapy.
Bacterial diseases	Campylo-bacteriosis (1, 2, 3)	Higher temperatures; Heavy precipitation	27:1	Animals; Food; Bathing water	34.25	Diarrhoea (sometimes bloody), abdominal pain, fever, headache, nausea and vomiting. Most cases are sporadic and self-limiting. Severe cases may progress to hepatitis or pancreatitis.	**Prevention:** Vaccine; clean drinking water; enhanced biosecurity; improved sanitary conditions. **Treatment:** Electrolyte replacement and rehydration; antimicrobials (only in severe cases).
	Legionnaires' disease (18, 19, 20, 21)	Higher temperatures; Heavy precipitation; Extended warm season; Drought	12:1	Water	2.26	Fever, chills, headache, muscle pain, dry cough, diarrhoea and later pneumonia Case fatality rate of 5-15% (19).	**Prevention:** High flow in hot- and cold-water systems; control of rainwater harvesting systems; drinking water quality; biofilm prevention. **Treatment:** Antibiotics.
	Leptospirosis (36, 37)	Higher temperatures; Heavy precipitation; Flooding	116:1	Animals; Food; Bathing water; Water	0.21	Mild flu-like symptoms (fever with sudden onset, headache, chills) that may develop into meningitis, rashes, haemolytic anaemia, haemorrhage into skin and mucous membranes, hepatorenal failure, jaundice, mental confusion and depression, myocarditis and pulmonary involvement with or without haemorrhage and hemoptysis, rarely liver failure. Case fatality rate of 6-17% (37).	**Prevention:** Flood risk reduction; rodent control; protective clothing; avoidance of swimming and wading in contaminated waters; avoidance of contact with infected animals. **Treatment:** Antibiotics.
	Lyme disease	Higher temperatures; Extended warm season	47:2	Tick	Limited reporting since 2018	Fever, headache, fatigue, rash (erythema migrans).	**Prevention:** Avoidance of tick-infested areas; individual protection against tick bites. **Treatment:** Antibiotics.
	Salmonellosis (22, 23, 24)	Higher temperatures	41:1	Animals; Food; Water	17.35	Diarrhoea, fever, stomach cramps, nausea and sometimes vomiting. Symptoms are usually mild, but the associated dehydration can in rare cases be severe. Case-fatality rate of 0.25% (23).	**Prevention:** Control measures for food-producing animals; good hygiene practices around animals and food. **Treatment:** Antibiotics for severe cases or people at risk.
	Shigellosis (38, 39)	Higher temperatures; Heavy precipitation; Flooding	16:0	Food; Water; Human contact	1.10	Diarrhoea (sometimes bloody), fever, nausea, toxaemia, tenesmus and stomach cramps. Most infections are rather mild and asymptotic so that most people recover without needing antibiotics. The severity of the disease depends very much on the serotype. While *S. dysenteriae* often results in a severe illness and is associated with a high case fatality, almost none of the *S. sonnei* infections results in death.	**Prevention:** Good hygiene practices to prevent faecal-oral transmission. **Treatment:** Antibiotics.
	'STEC/VTEC (toxin-producing Escherichia coli) (15, 16, 17)	Heatwaves; Flooding	39:1	Food; Water; Animals	1.52	Symptoms range from gastrointestinal symptoms with mild diarrhoea to severe bloody diarrhoea, which is often associated with abdominal cramps, nausea, vomiting and fever or haemorrhagic colitis. Severe cases may result in permanent damages of the nervous system, pancreas or heart. Case-fatality rate of 0.2% (15).	**Prevention:** Good hygiene in household and premises dealing with animals. Adequate cooking of food. Milk pasteurisation, avoiding cross-contamination. **Treatment:** No specific therapy; mixed recommendations on antibiotics.
	Vibriosis (40)	Higher temperatures; Heatwaves	69:0	Food; Bathing water	Not reported	Wound infections, ear infections, gastroenteritis, and primary septicaemia.	**Prevention:** Avoidance of raw or undercooked seafood; avoidance of swimming in salt- or brackish water with wounds. **Treatment:** Antibiotics for wounds; no specific treatment for gastroenteritis.
Parasitic diseases	Crypto-sporidiosis (30, 31, 32)	Higher temperatures; Heavy precipitation; Flooding; Drought	67:4	Food; Water; Animals; Bathing water	1.07	Diarrhoea, abdominal pain, less commonly fever, nausea and vomiting. Most people with normal immune system recover, but patients with an impaired immune system may undergo prolonged and severe clinical course contributing to death.	**Prevention:** Vaccination programmes; protective technologies; improved sanitary conditions. **Treatment:** Anti-diarrhoeal medicine.
	Giardiasis (33, 34, 35)	Higher temperatures; Heavy precipitation; Flooding	25:1	Food; Water; Animals; Human contact; Bathing water	1.89	Low-grade diarrhoea with severe flatulence, stomach cramps or pain, upset stomach or nausea, dehydration. Most people recover, but some experience long-term complications.	**Prevention:** Good hand hygiene; avoidance of contaminated food and water; good hygiene. **Treatment:** Prescription drugs.
	Malaria (10, 11, 12)	Higher temperatures; Heavy precipitation; Extended warm season	235:24	Mosquito; Organ, blood donor	1.44	Headache, back pain, muscle ache, fatigue, sweats, fever, chills, vomiting and enlarged spleen. Most patients have a relatively mild disease outcome, but severe malaria can be fatal due to one of the following clinical manifestations: acute encephalopathy, severe anaemia, icterus, renal failure, hypoglycaemia, respiratory distress, lactic acidosis, coagulation defects. Severe malaria is a possible cause of coma and other central nervous system symptoms.	**Prevention:** Individual protection against mosquito bites; vector control; prophylactic drugs; limited vaccine use. **Treatment:** Therapeutics (artemisinin-based combination therapy believed to be most efficient).

Climatic conditions affecting transmission

Higher temperatures · Heatwaves · Heavy precipitation · Flooding · Extended warm season · Drought

Modes of transmission

Mosquito · Tick · Water · Food · Animals · Human contact · Organ, blood donor · Bathing water

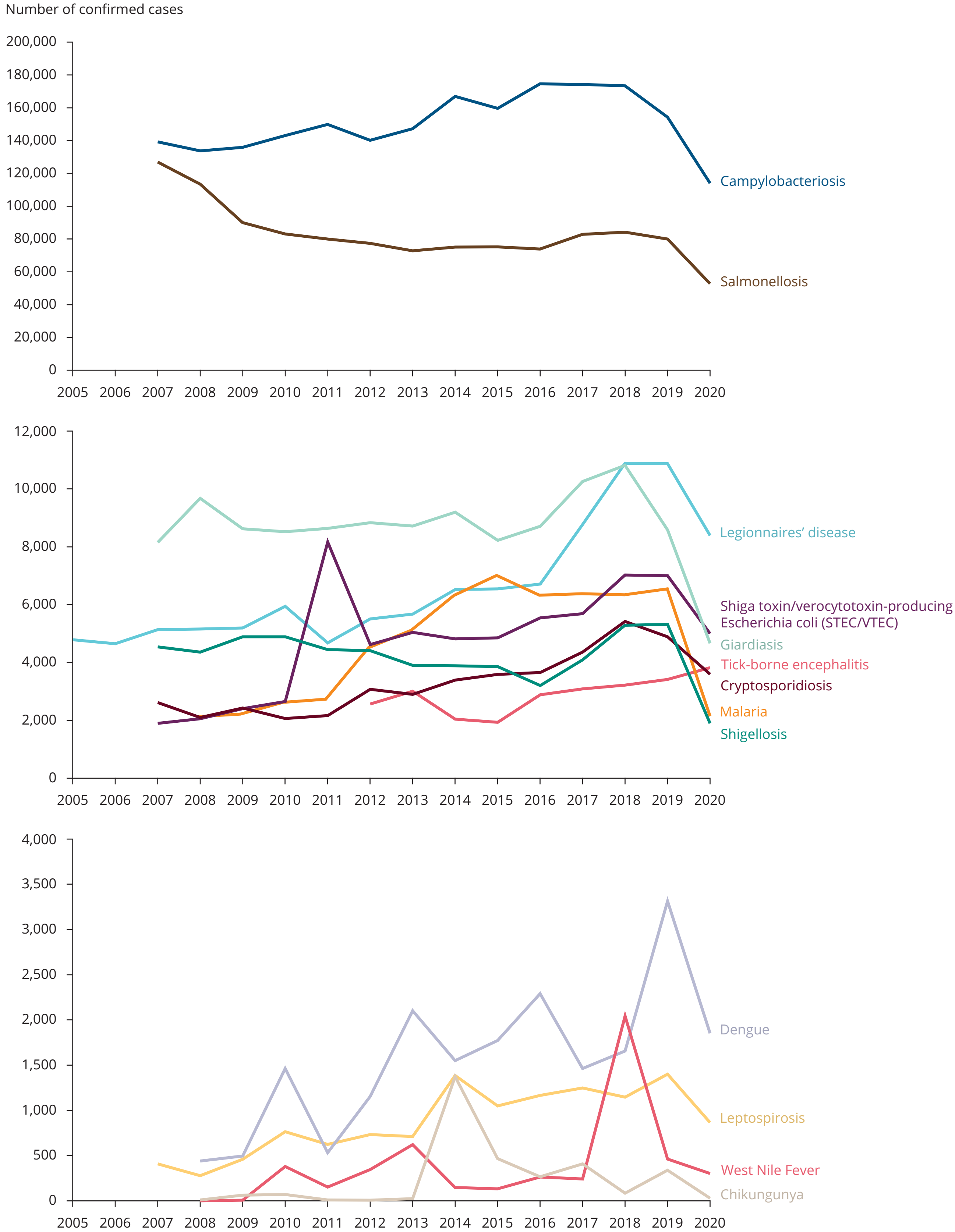
Note: ([a]) Aggravated-to-diminished ratio presents the number of scientific sources with evidence that a given disease has been aggravated by climatic factors and the number of sources containing evidence that climatic factors have diminished the disease (Mora et al., 2022).

([b]) EEA-32 excluding Switzerland and Türkiye (ECDC, 2022a).

([c]) Prevention of all diseases should include raising awareness of the public and development of early-warning systems.

Source: EEA compilation based on the references in the figure (see Annex 1), ECDC (2022a) and Mora et al. (2022).

Figure 4.2 **Number of confirmed cases of selected climate-sensitive infectious diseases in EEA32 countries (excluding Switzerland and Türkiye)**



Note: Travel-related cases are included. The 2020 reduction in the number of cases may be associated with the COVID-19 pandemic.

Source: ECDC (2022a).

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In addition, the reported cases of some diseases are largely associated with international travel; for example, 86% of chikungunya cases and over 93% of the dengue cases reported in 2019 were travel associated (ECDC, 2022b). The number of reported cases of these diseases decreased in 2020 due to the COVID-19 restrictions in place. However, links between the number of reported cases and unusually warm weather, in particular early in the year, have been observed, for example in the case of WNV in 2018 (see also Section 4.3.3).

4.3 Changing climate suitability for transmission of selected infectious diseases

4.3.1 Dengue

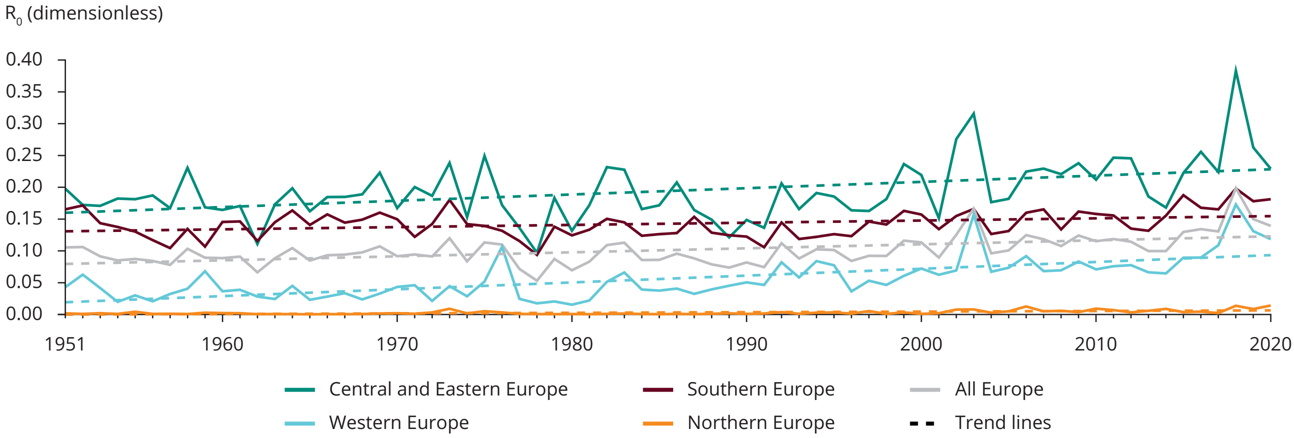
Dengue is transmitted by the mosquitoes *Aedes aegypti* and *Aedes albopictus* (tiger mosquito), which are widespread in tropical and subtropical areas. Aedes albopictus is present in Europe and is expanding its territory. Alongside accelerated human global mobility, climate change has been suggested as a driver of the emergence of dengue and other arboviral diseases in Europe (Semenza et al., 2014; Lillepold et al., 2019; Colón-González et al., 2021), illustrated by recent autochthonous outbreaks in countries such as France and Spain.

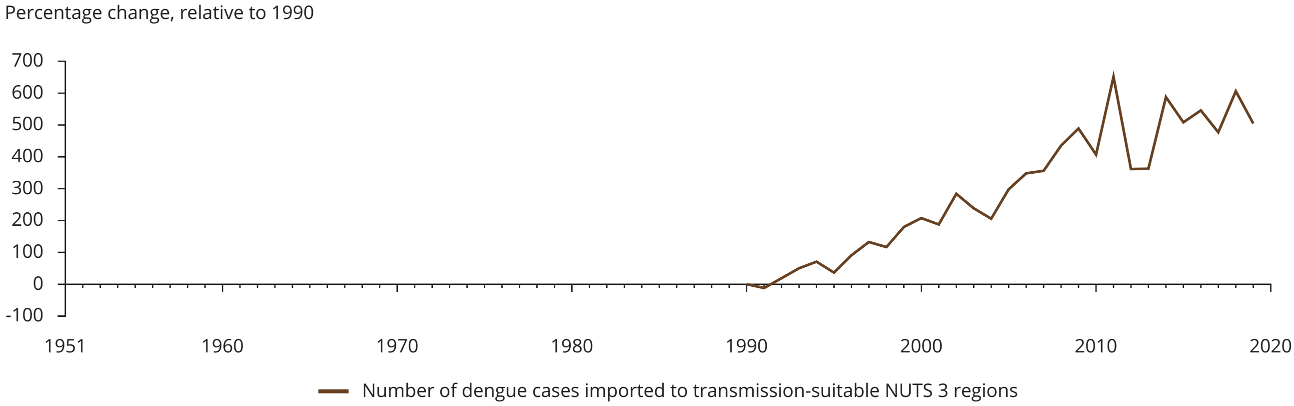
The climatic suitability for the transmission of dengue is influenced by shifts in temperature and precipitation caused by climate change. Higher temperatures increase the mosquito bite rate and viral replication (IPCC WGII, 2022a). Mosquito larval development and adult emergence rates are also boosted by higher temperatures, and high humidity lengthens the lifespan of mosquitoes, and therefore it increases the potential for virus transmission. However, lower rainfall may prompt people to store water in containers, which mosquitoes then use for egg laying, also boosting mosquito numbers (WHO Europe, no date).

One way of measuring the health threats associated with dengue under the changing climate is to estimate the changes in the basic reproduction rate (R_0) ([7]) associated with climatic conditions. When R_0 is higher than one, outbreaks have the potential to grow. The higher R_0 is, the faster the outbreak will grow. In the period 1986-2020, the R_0 of dengue in Europe increased by 17.3% compared with 1951-1985 (Figure 4.3). The R_0 value for the whole of Europe in 2020 was estimated as 0.07 (European Climate and Health Observatory, 2022c). The highest R_0 value is modelled for central and eastern Europe, followed by southern Europe.

([7]) R_0 estimates the expected number of secondary infections from one infectious case in a completely susceptible population.

Figure 4.3 **Basic reproduction rate (R_0) for dengue transmitted by *Aedes albopictus* (1951 and 2020) and the estimated change (% relative to 1990) in the yearly number of dengue cases imported to transmission-suitable NUTS 3 regions in EEA-38 and the UK from dengue-endemic regions (1990-2019)**





Note: Central and Eastern Europe: Albania, Bulgaria, Czechia, Estonia, Croatia, Hungary, Lithuania, Latvia, North Macedonia, Poland, Romania, Slovenia, Slovakia; Northern Europe: Denmark, Finland, Iceland, Norway, Sweden.

Southern Europe: Cyprus, Greece, Spain, Italy, Malta, Portugal, Türkiye; Western Europe: Austria, Belgium, Switzerland, Germany, France, Ireland, Luxembourg, Netherlands.

Source: van Daalen et al. (2022).

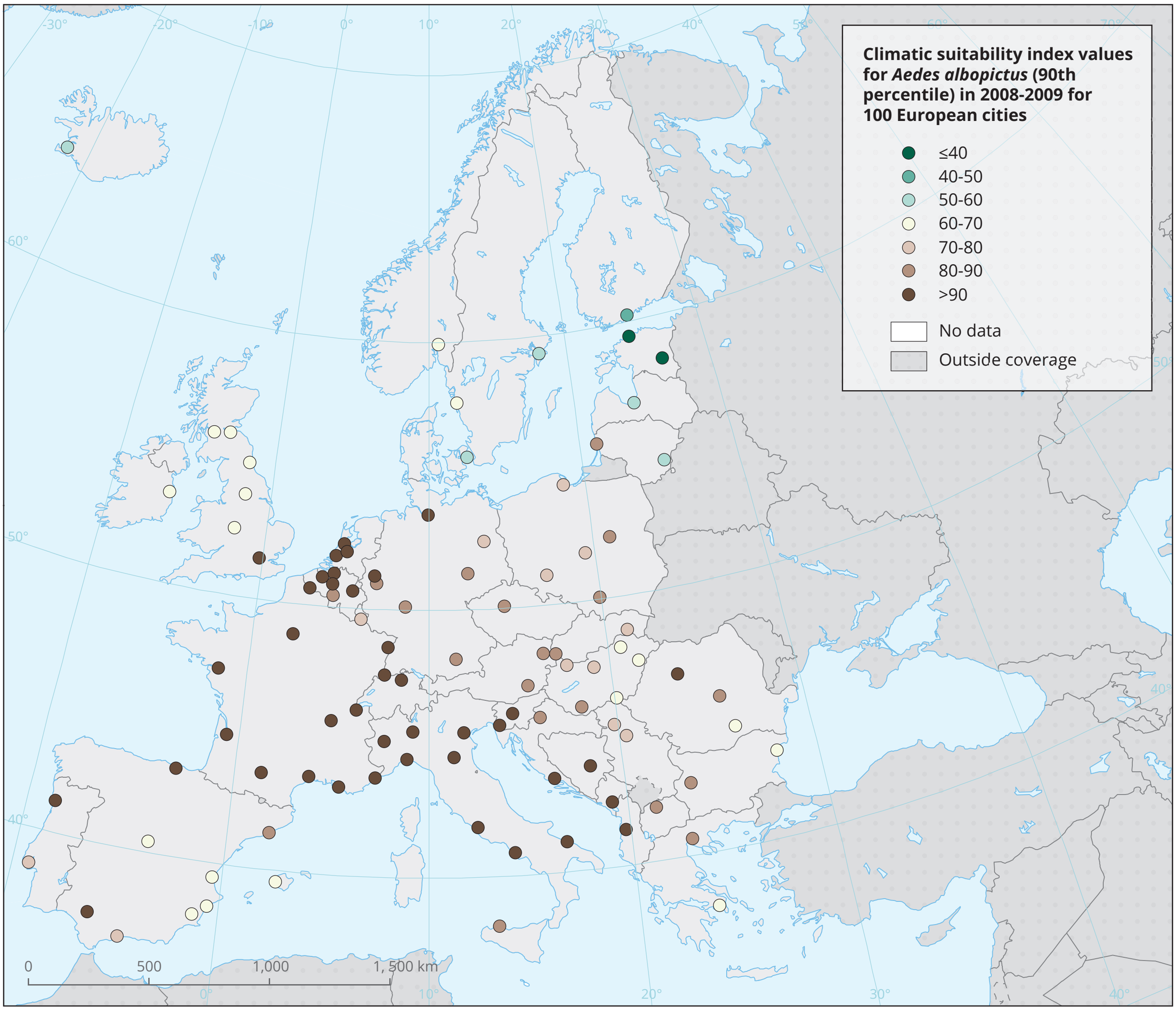
Furthermore, Europe has experienced a lengthening of the dengue transmission season. Central and eastern Europe observed the greatest increase in the length of the transmission season in 1986-2020 compared with 1951-1985, with an increase of about 0.2 suitable months (van Daalen et al., 2022). In addition, between 1990 and 2019 an increase of over 600% in imported cases from dengue-endemic world regions to European locations with conditions suitable for dengue transmission ([8]) was observed (van Daalen et al., 2022; Figure 4.3). The combination of more imported cases and increased climatic suitability for disease transmission via mosquito vectors results in a higher likelihood of outbreaks.

The probability of dengue infection may be higher in cities, which, as international travel and trade hubs, may contribute to the accidental introduction of exotic mosquito species (Ibáñez-Justicia, et al., 2020). Aedes albopictus can be common in the peri-domestic environment, particularly in urban areas with abundant vegetation (ECDC, 2020). Moreover, the urban heat island (UHI) effect may increase climatic suitability for mosquitoes. The most suitable cities emerge as those near the Adriatic coast, in France and Italy, but some Belgian and Dutch cities are also suitable (Map 4.1).

The probability of dengue infection may be higher in cities.

([8]) Conditions suitable for dengue transmission are defined by R_0 above 1 for at least 1 month.

Map 4.1 Climatic suitability index values for *Aedes albopictus* (90th percentile) in 2008-2009 for 100 European cities



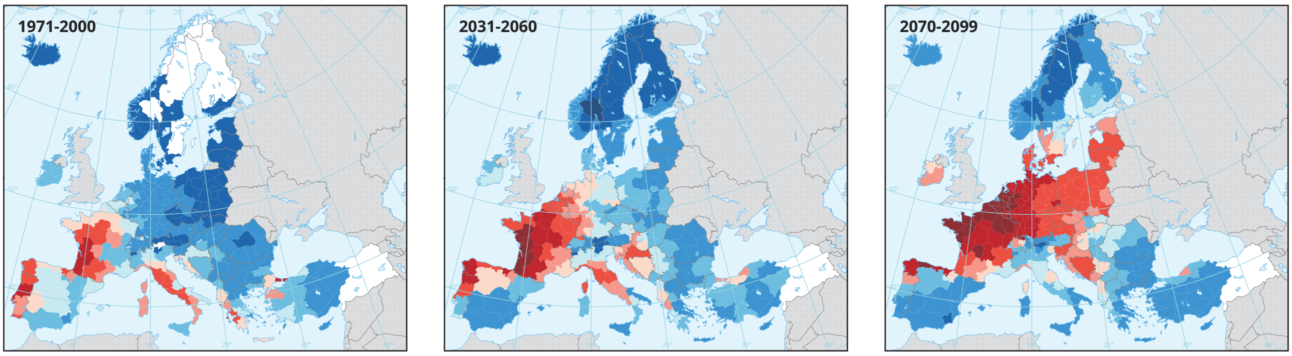
Reference data: ©ESRI

Notes: The climatic suitability is expressed as an index ranging from 0 to 100. The P90 indicator of the climatic suitability is the 90th percentile value of the range modelled across the city. The modelling is based on 100m-resolution hourly temperature data (based on simulations with the urban climate model UrbClim). From this data set, this climate suitability data set has been generated based on annual precipitation and the average temperature in January and during the summer months for the years 2008 and 2009. The selection of cities comes from the source data.

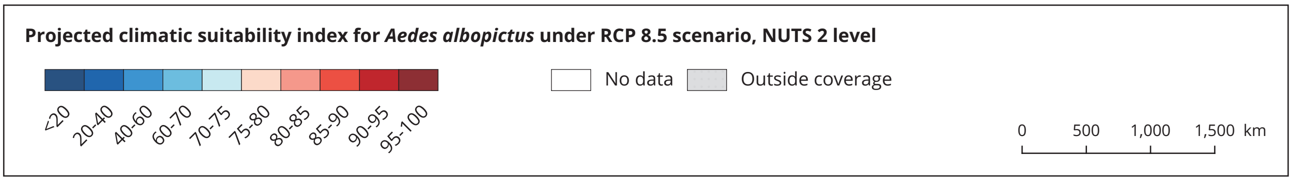
Source: Adapted from VITO (2019); based on data from the Copernicus European Health contract for the Copernicus Climate Change Service. See the EEA geospatial catalogue for more details (EEA, 2020b).

The climate suitability for *Aedes albopictus* is projected to increase in large parts of Europe, with western Europe emerging as a hot spot by the end of the century. However, in some countries with favourable baseline conditions (Italy, Portugal, Spain), the changing climate will reduce the suitability for *Aedes albopictus* (Map 4.2). In line with the changing climate suitability, the length of the activity season of *Aedes albopictus* will increase in the majority of European countries (Map 4.3). Given the increasing dengue reproduction rate, the rising number of imported cases of dengue and the projected increased climate suitability, dengue outbreaks could become a health risk in Europe in the future if no appropriate preparedness and disease management actions are taken.

Map 4.2 Projected climatic suitability index for *Aedes albopictus* under RCP 8.5 scenario, NUTS 2 level



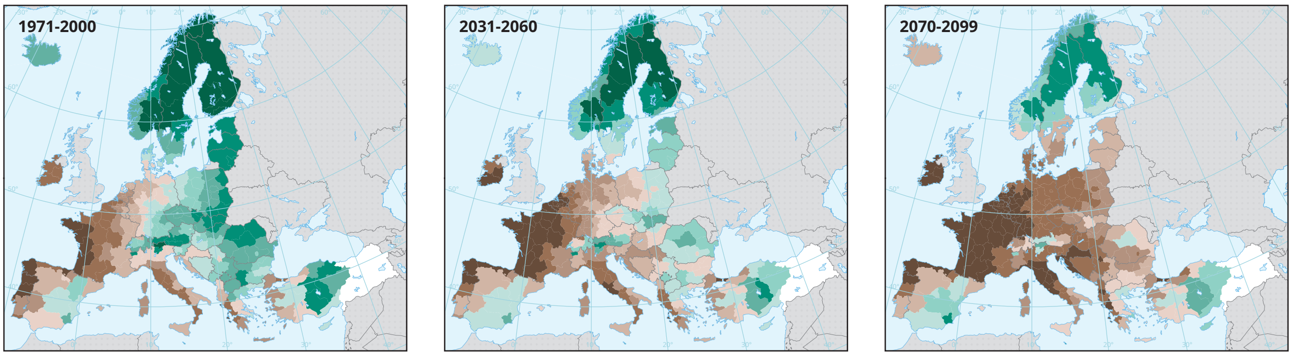
Reference data: ©ESRI



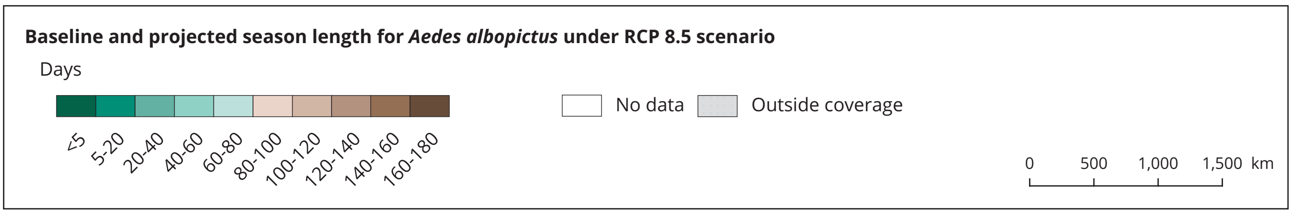
Notes: A suitability index of 0 indicates that an area has no favourable environmental conditions for Aedes albopictus, whereas an area with an index of 100 is totally suitable. The climatic suitability index is determined by annual rainfall, summer temperatures and January temperatures. For annual rainfall, the suitability is zero when rainfall is lower than 450mm; maximum suitability is reached when the annual rainfall is higher than 800mm. For summer temperatures, the suitability is zero when temperatures are lower than 15°C and higher than 30°C, and maximum between 20°C and 25°C. For January temperatures, the suitability is zero when temperatures are lower than -1°C and maximum when temperatures are higher than 3°C.

Source: Climate-ADAPT (2022b).

Map 4.3 Projected season length for *Aedes albopictus* under RCP 8.5 scenario



Reference data: ©ESRI



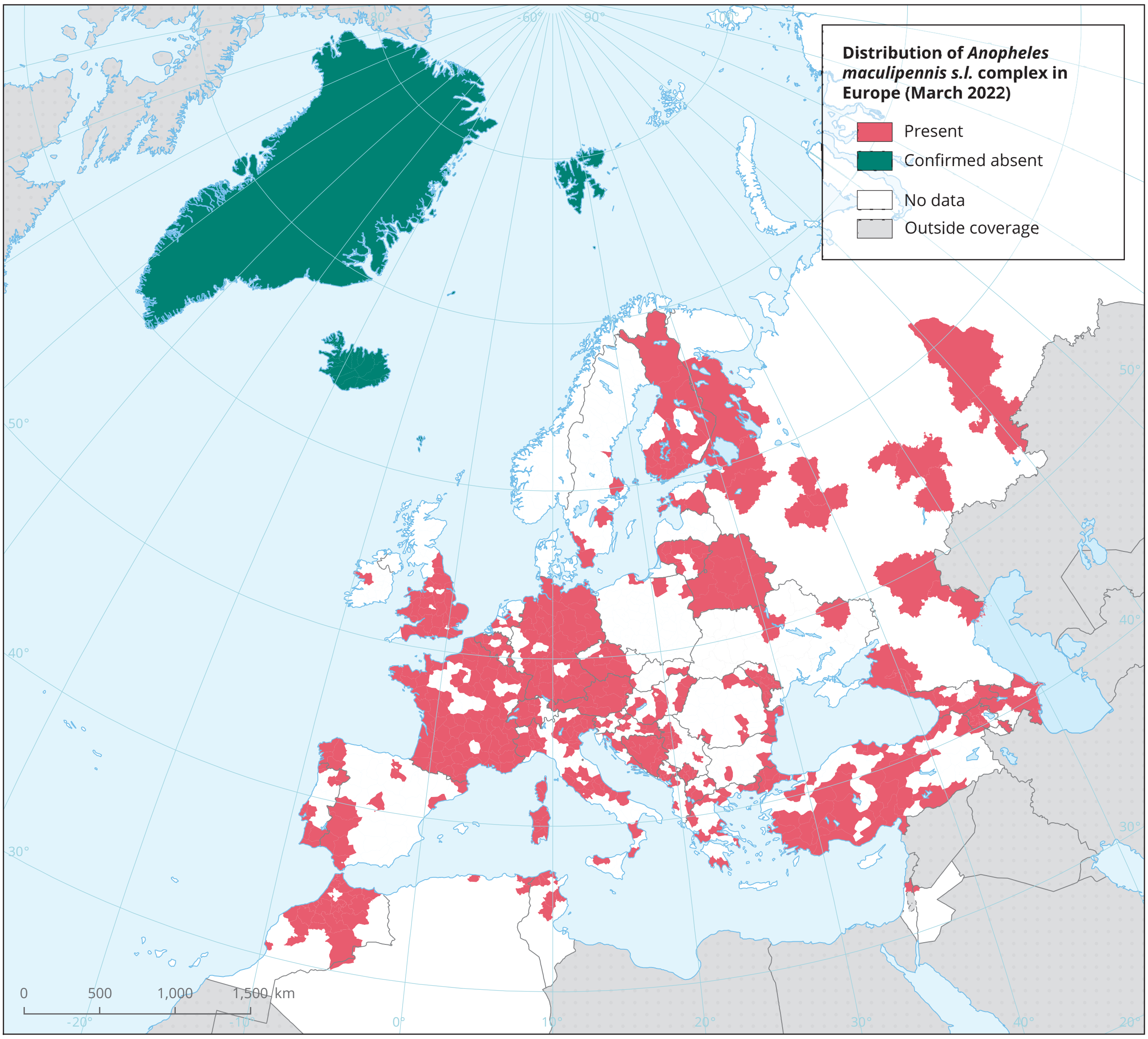
Notes: The duration of *Aedes albopictus* presence is also known as the mosquito season. It begins when the insect's eggs hatch after winter and continues until the eggs no longer hatch (go into diapause) in autumn.

Source: Climate-ADAPT (2022c).

4.3.2 Malaria

Malaria was endemic in Europe until the 1970s, when its elimination was achieved through a combination of public health interventions and improved socio-economic conditions (Zhao et al., 2016; Boualam, et al. 2021). The increasing number of malaria cases currently being registered in Europe (see Figure 4.2) is largely attributable to international travel and immigration from malaria-endemic countries. In addition, the widespread presence in Europe of the malaria vector (*Anopheles* mosquitoes) (ECDC, 2022c; see Map 4.4) and the increasing climatic suitability for this vector may lead to the re-emergence of malaria in Europe. While most of the confirmed cases of malaria in Europe reflect patterns of travel to and from malaria-endemic countries (Alenou and Etang, 2021; see also Section 4.2), locally transmitted cases have already been reported in France, Germany, Greece, Italy, the Netherlands and Spain (Fischer et al., 2020).

Map 4.4 Distribution of *Anopheles maculipennis* s.l. complex in Europe (March 2022)



Reference data: ©ESRI

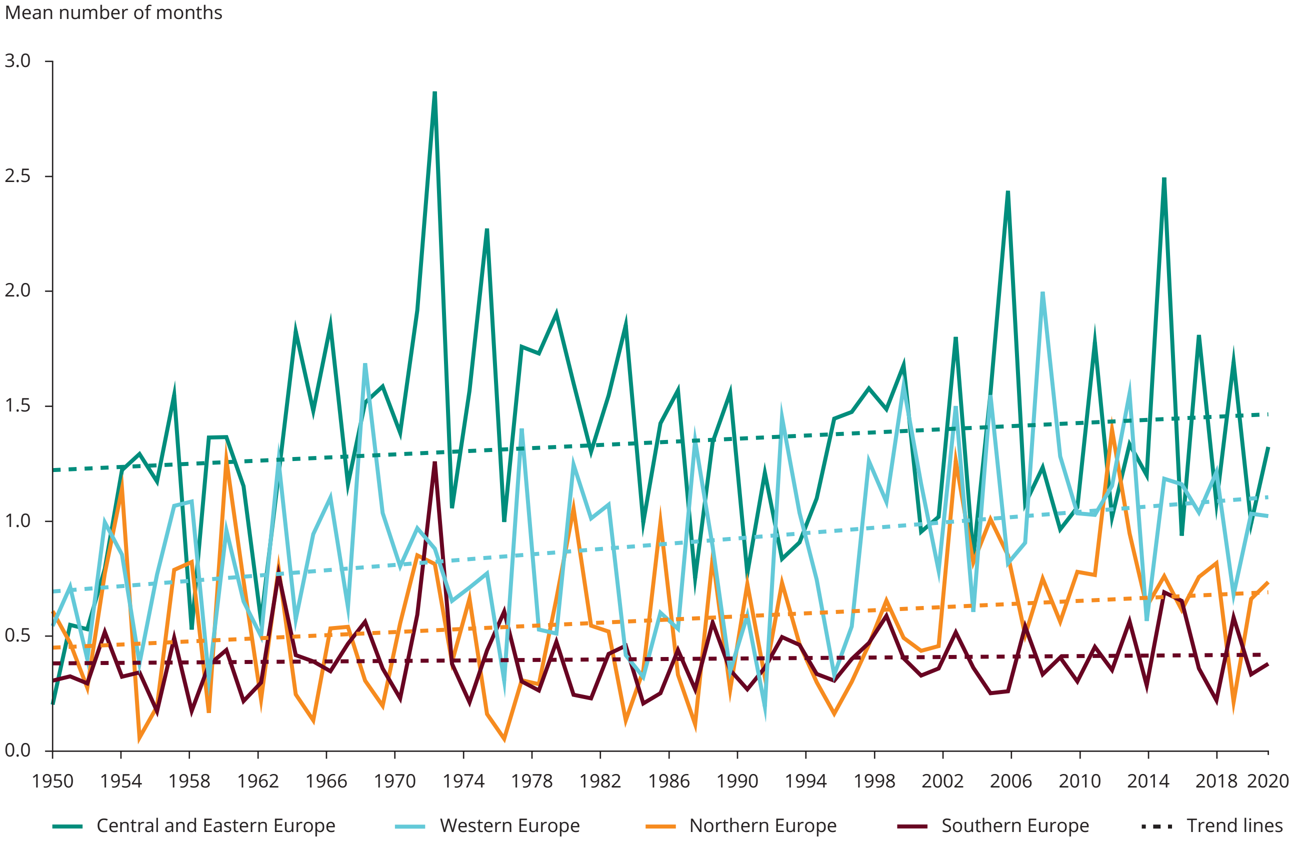
Notes: Present: The species has been observed to be present in at least one municipality within the administrative unit; Confirmed absent: the species has never been reported within the administrative unit and there have been field surveys or studies on mosquitoes within the last 5 years of the distribution status date; No Data: No sampling has been performed and no data on the species is available (ECDC, 2022d). The data is provided at NUTS 3 level.

Source: ECDC (2022c).

Malaria is caused by *Plasmodium* parasites that are spread to humans through the bites of infected female *Anopheles* mosquitoes. The spatial limits of the distribution of female Anopheles species and seasonal activity are sensitive to climatic factors (Caminade et al., 2014). Increased rainfall creates more habitat for mosquitoes (stagnant water), and warmer temperatures increase the rates of mosquito bite and parasite development (IPCC WGII, 2022a). The transmission of *Plasmodium vivax* requires accumulated precipitation of above 80mm per month, a monthly mean temperature of between 14.5°C and 33°C, monthly relative humidity above 60%, and the presence of land cover classes suitable for mosquito breeding, such as rice fields or permanently irrigated croplands (Grover-Kopec et al., 2006; Benali et al., 2014; van Daalen et al., 2022).

On average, in areas suitable for *Anopheles* mosquitoes across Europe, the number of months suitable for malaria transmission increased from 0.4 in 1951-1960 to 0.51 in 2011-2020. Central and eastern Europe are the most suitable regions, with 1.3 months, followed by western Europe with around 1 month (see Figure 4.4). However, a substantial increase was also detected in northern Europe (van Daalen et al., 2022). These results suggest that, although currently sporadic, local transmission could increase following importation events where Anopheles mosquitoes are present or can become established (Fischer et al., 2020).

Figure 4.4 Mean number of months suitable for *Plasmodium vivax* transmission between 1950 and 2020 in EEA member and cooperating countries plus the United Kingdom, grouped by European region



Note: The number of suitable months was calculated as the number of months per year with precipitation above 80mm, average temperature between 14.5°C and 33°C, and relative humidity above 60%, in land types highly suitable for Anopheles mosquitoes (e.g. rice fields, permanently irrigated croplands). Linear regression was used for trend estimation. Central and Eastern Europe: Albania, Bulgaria, Czechia, Estonia, Croatia, Hungary, Lithuania, Latvia, Macedonia, Poland, Romania, Slovenia, Slovakia; Northern Europe: Denmark, Finland, Iceland, Norway, Sweden; Southern Europe: Cyprus, Spain, Greece Italy, Malta, Portugal, Türkiye; Western Europe: Austria, Belgium, Switzerland, Germany, France, Ireland, Liechtenstein, Luxembourg, Netherlands, United Kingdom.

Source: van Daalen et al. (2022).

A further projected northward spread of Anopheles mosquitoes and an extension of seasonality in Europe will enable malaria transmission for up to 6 months of the year in 2051-2080, particularly in southern and south-eastern Europe (Kulkarni et al., 2022). Disease surveillance and vector control measures should be intensified in areas with increasing climatic suitability to avoid the importation and onward spread of malaria in Europe (see Section 4.4).

4.3.3 West Nile Virus infection

West Nile Virus (WNV) infection is a mosquito-borne zoonosis that is endemo-epidemic ([9]) in southern, eastern and western Europe. WNV is brought to Europe through migratory birds travelling from sub-Saharan Africa, North Africa or the Middle East. It is usually transmitted among birds via the bite of infected mosquitoes, but it can also infect humans and other mammals, particularly horses (ECDC, 2022e). In Europe, the mosquito species *Culex pipiens* and *Culex modestus* are the main vectors of WNV (ECDC, 2019).

WNV cases were sporadic in Europe until the mid-1990s, when, introduced by migratory birds, it started to spread quickly, leading to outbreaks in some countries (Paz and Semenza, 2013; Zeller and Schuffenecker, 2004). Since 2010, there have been more recurrent, intense and geographically expansive WNV outbreaks, with the largest in terms of geographical extent and human infections occurring in 2018 (ECDC, 2018; Farooq et al., 2022). In 2019, 11 EU Member States reported 443 WNV infections; 96% of these had been locally acquired, most of which were reported by Greece and Italy, representing 65% and 13% of EU cases, respectively (ECDC, 2019).

Higher temperatures accelerate the ability of *Culex* mosquitoes to spread WNV to humans (Leggewie et al., 2016; Mordecai et al., 2019). Warm weather in the spring and summer months speeds mosquito development and extends their breeding season, which can, in turn, increase their numbers (Farooq et al., 2022). Apart from increasing the growth rate of vector populations, higher temperatures decrease the interval between blood meals, shorten the virus incubation time in mosquitoes, accelerate the virus evolution rate and increase viral transmission efficiency to birds (Paz, 2015). Warmer winters allow mosquitoes to survive the cold months and spread the virus earlier in the year (Farooq et al., 2022). Furthermore, as a result of an early increase in the mean spring temperatures, some bird species that are hosts for the virus have migrated to their breeding grounds earlier (Paz, 2015).

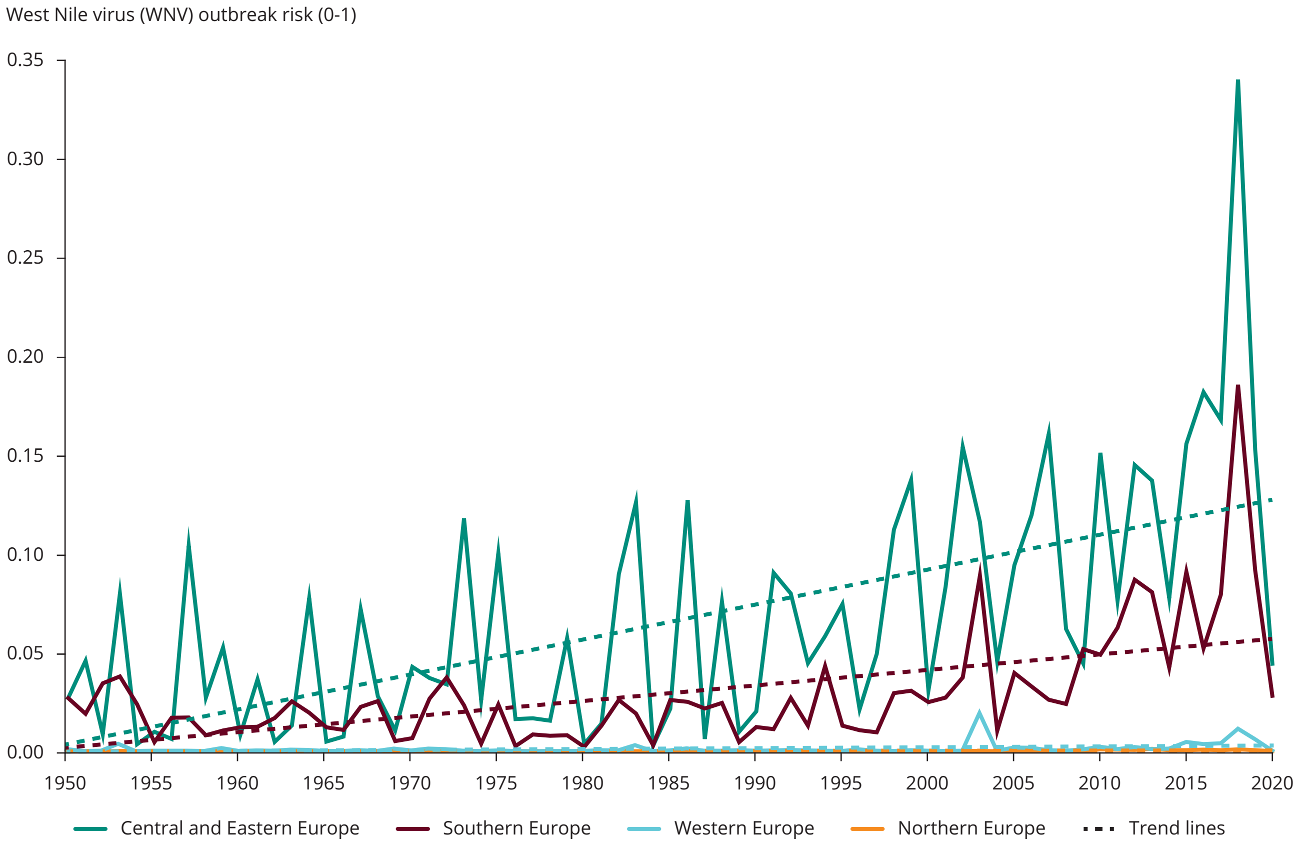
Drought may increase the intensity of disease outbreaks, as scarce water resources lead mosquitoes and birds to congregate around water bodies, increasing the likelihood of potential transmission events and amplifying the prevalence of the WNV, which can then spill over into human populations (Paz, 2015; Farooq et al., 2022). Therefore, changes in climatic conditions, particularly increases in ambient temperature and fluctuations in rainfall amounts, contribute to the maintenance of WNV in various locations in southern Europe (Paz and Semenza, 2013).

Overall, the probability of WNV outbreaks increased between 1951 and 2020 across Europe ([10]). The highest absolute risk of WNV outbreaks was in central and eastern Europe, followed by southern Europe (see Figure 4.5). While the WNV transmission risk has remained low in northern and western Europe, comparing 1951-1985 with 1986-2020, these regions have experienced respective relative increases in risk of 445% and 242%. This suggests that increasing temperature suitability is likely to result in longer WNV transmission seasons and further expansion of the virus to previously unaffected European regions.

The probability of WNV outbreaks increased between 1951 and 2020 across Europe.

([9]) Endemo-epidemic refers to a temporary large increase in the number of cases of an endemic disease.
([10]) The decline in 2020 could be associated with COVID-19 pandemic restrictions in place, but also the depletion of susceptible people following the WNV outbreaks in 2018 and natural immunity developed by those previously infected, or suboptimal environmental and climate conditions for a big outbreak year (Jan Semenza, Heidelberg Institute for Global Health, personal communication, 6 September 2022).

Figure 4.5 **Change in the estimated WNV outbreak risk between 1951 and 2020 in the EEA member and cooperating countries and the UK, grouped by European region**



Note: Central and Eastern Europe: Albania, Bulgaria, Czechia, Estonia, Croatia, Hungary, Lithuania, Latvia, Macedonia, Poland, Romania, Slovenia, Slovakia; Northern Europe: Denmark, Finland, Iceland, Norway, Sweden; Southern Europe: Cyprus, Spain, Greece, Italy, Malta, Portugal, Türkiye; Western Europe: Austria, Belgium, Switzerland, Germany, France, Ireland, Liechtenstein Luxembourg, Netherlands, United Kingdom.

Source: van Daalen et al. (2022).

4.3.4 *Vibriosis*

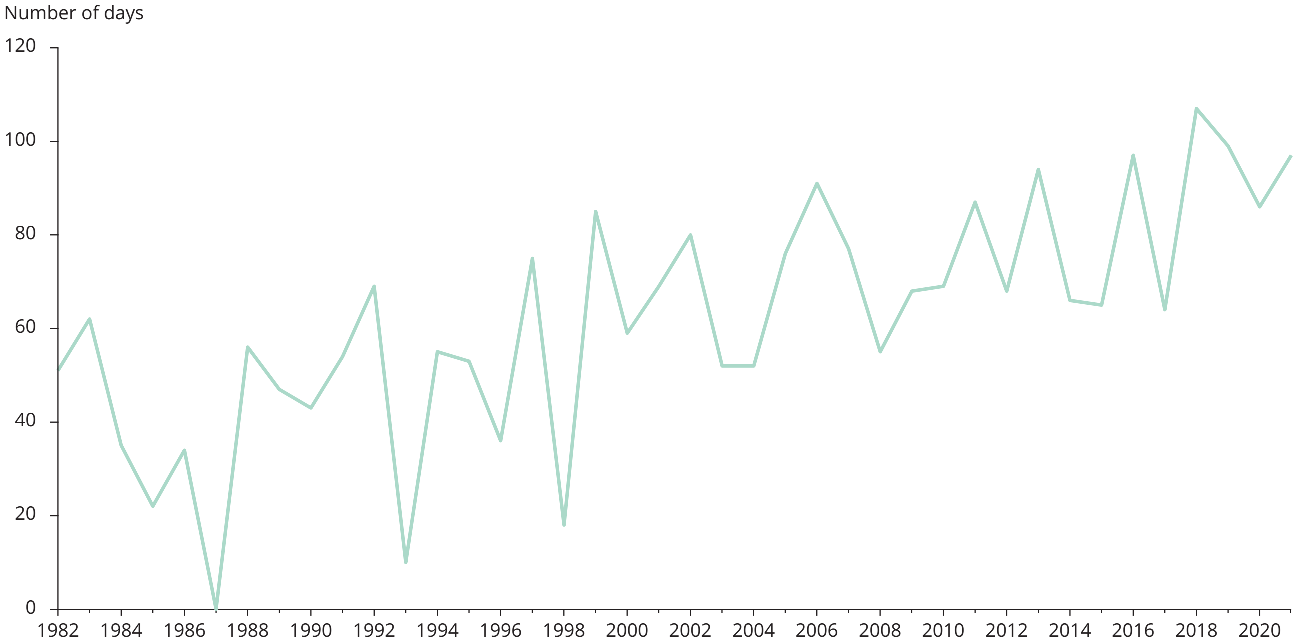
Exposure to the *Vibrio* bacteria in seawater can lead to severe gastrointestinal, skin and ear infections, and in some cases to necrotising fasciitis, septicaemia and death. *Vibrio* bacteria grow extremely well in warm water (up to 37°C) and moderate salinity (below 30 parts per thousand). According to a study of *Vibrio* presence in German coastal waters, water temperature is the main driving factor of *Vibrio* abundance, whereas salinity modulates *Vibrio* community composition (Fleischmann et al., 2022).

Vibrio has one of the fastest replication times of any studied bacteria, making it extremely responsive to environmental change. Climate change has led to increased sea surface temperatures in all European seas, with the Baltic Sea and the North Sea having seen the largest absolute increase. In 2021 the annual sea surface temperature around Europe was between the sixth and eighth highest on record (ESOTC, 2021). The warming of marine and saline inland waters is likely to support larger numbers of *Vibrio* populations and consequently increase the likelihood of *Vibrio* infections. An increase in reported infections in northern Europe corresponds in both time and space to heatwaves (Le Roux et al., 2015). Although vibriosis is not a notable disease in the EU, Europe has observed steady increases in cases in the 21st century (Semenza et al., 2017).

The Baltic Sea is particularly suitable for *Vibrio* due to its brackish water ([11]). The number of days in a year suitable for *Vibrio* infections in the Baltic region has been growing since 1980 (see4.6). The entire coastline of Estonia, Latvia, Lithuania ([12]) and Poland showed suitable conditions for *Vibrio* in 2020. In contrast, the *Vibrio* suitability in Southern Europe is low, with only 4% of the coast suitable for non-cholera *Vibrio* in Spain and 2% suitable in Italy, because of higher surface salinity in the Mediterranean (van Daalen et al., 2022; see Figure 4.7). As the conditions suitable for the transmission of Vibrio pathogens are spreading to the considerable percentage of coastlines in previously unaffected countries, early-warning systems and preventive measures are essential to protect the population from the severe infections that could result.

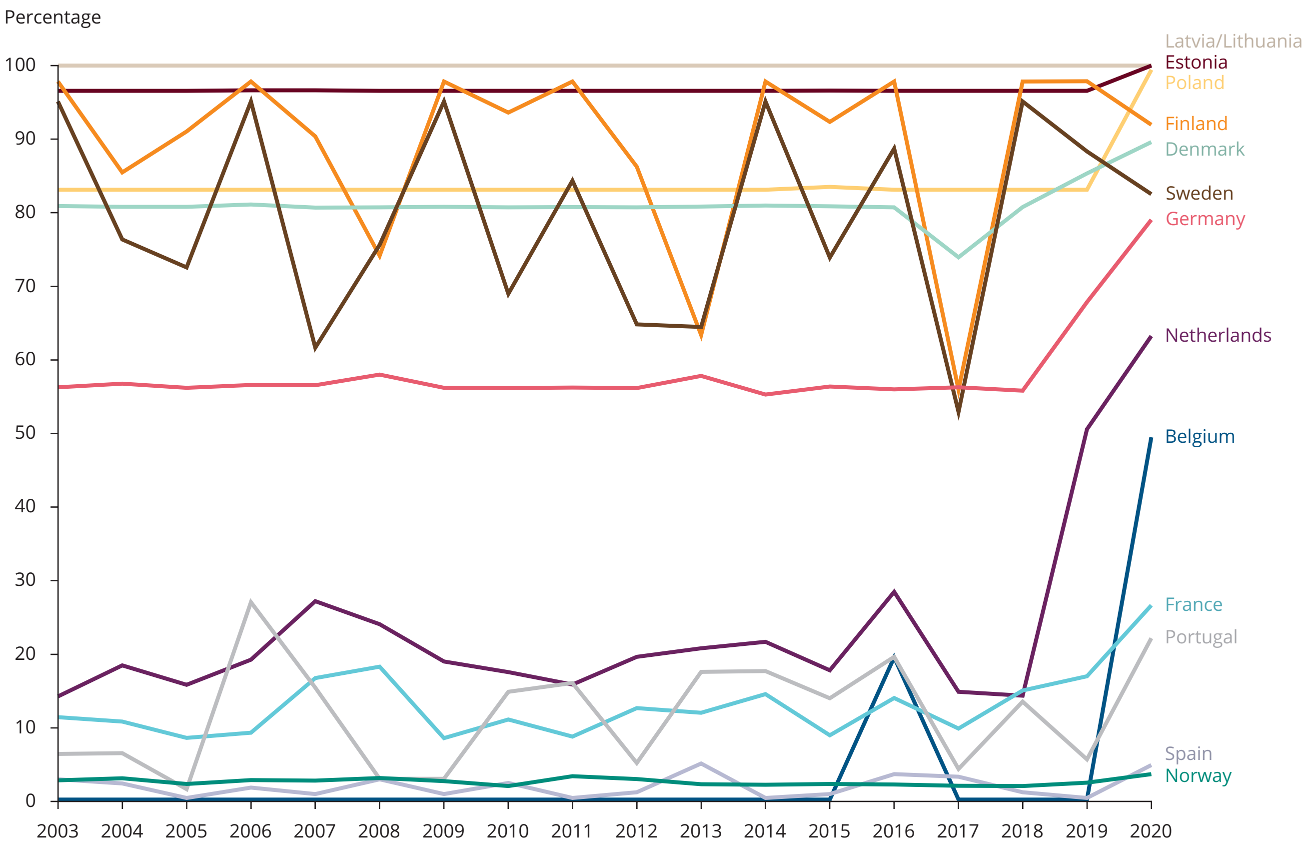
([11]) 'Brackish' describes water that is saltier than fresh water, but not as salty as seawater (EEA glossary).
([12]) The coastlines of Estonia, Latvia and Lithuania have had an above 96% suitability for *Vibrio* since 2003, see Figure 4.7.

Figure 4.6 Annual number of days suitable for *Vibrio* infections in the Baltic region



Source: van Daalen et al. (2022).

Figure 4.7 Estimated annual percentage of coastline with suitable conditions for non-cholerae *Vibrio* (2003-2020) for selected countries



Source: van Daalen et al. (2022).

4.4 People at risk from infectious diseases

Pregnant women, fetuses and young children are considered among the most vulnerable humans, which means that they are also most at risk of infectious diseases. Some mosquito-borne diseases, such as malaria, dengue and Zika virus disease, are known to harm fetal health and development, putting both pregnant women and fetuses at risk (Rylander et al., 2013). Younger children may be at risk of more severe dengue (Khan et al., 2021). Children can also be more exposed to some diseases, for example cryptosporidiosis, through play. In 2013, an outbreak of *Cryptosporidium hominis* infection was detected in Germany among children who had been playing on a floodplain after it had dried out (Gertler et al., 2015).

Advanced age and pre-existing health conditions, especially those associated with weaker immune systems, can also make the course of disease more severe in certain people. People over the age of 50 years and some immunocompromised people are at the highest risk of becoming severely ill when infected with WNV (WHO, 2017). Those over the age of 60 years have a higher risk of mortality and other consequences of tick-borne encephalitis than younger people (WHO Europe and ECDC, no date).

Certain environments and activities are conducive to contracting climate-sensitive infectious diseases. For example, agriculture and forestry workers are exposed to animal- and insect-borne diseases. The numbers of these workers exposed to tick-borne diseases is increasing, as the climate suitable for tick-borne diseases (such as Lyme disease and tick-borne encephalitis) moves to north and west Europe (De Keukeleire et al., 2018; EU-OSHA, 2021). In relation to flooding, first responders (for example fire and rescue service workers) and those involved in clean-up operations have a higher likelihood of contracting acute gastroenteritis (ECDC, 2021). Contamination of bathing waters after heavy rainfall increases the rate of infection with *Campylobacter, Giardia lamblia* and *E. coli* among swimmers because of the risk of swallowing water (Harder-Lauridsen, 2013). There is a need to identify those vulnerable or highly exposed populations and to adjust prevention and response measures to their needs.

4.5 Responding to the growing threat of infectious diseases

4.5.1 Monitoring, surveillance, and early-warning systems

Surveillance systems provide information for monitoring communicable disease trends, helping to identify risk factors and areas for intervention. They provide information for priority setting, planning, implementation and resource allocation for preventive programmes and for evaluating preventive programmes and control measures. At the European level, around 50 infectious diseases are monitored through the EU's epidemiological surveillance network, whereby Member States report to the European Centre for Disease Prevention and Control (ECDC), including climate-sensitive diseases (see Figure 4.1). The list was updated in 2018 to include recently emerging or re-emerging diseases such as chikungunya, dengue, Lyme neuroborreliosis and Zika virus disease (EC, 2022b).

The European Early Warning and Response System (EWRS) is a rapid system for providing alerts at EU level on serious cross-border threats to health. This confidential web-based system enables the European Commission and the designated competent authorities responsible at national level to be in permanent communication. EU Member States can alert, share information and coordinate national responses to serious cross-border threats in a timely and secure manner (EC, 2022b).

At country level, the systematic monitoring and reporting systems for surveillance of invasive species and infectious or vector-borne diseases are frequently identified in national adaptation strategies and national health strategies of the European countries as vital elements of an effective health system. For example, the Belgian national adaptation strategy mentions the Modirisk initiative, aimed at monitoring and eradicating exotic mosquitoes that may transmit infectious diseases. The Norwegian national adaptation strategy highlights a plan to implement a reporting system dedicated to the monitoring of diseases associated with climate change. The system will be operated by the Norwegian Institute of Public Health, with health professionals expected to report every instance of more than 50 cases of communicable diseases. The EU's legislative frameworks emerge as a driver of disease monitoring in EU Member States; for example, Austria notes that strategies were developed on the basis of the European Surveillance Systems TESSy (now integrated into EpiPulse alongside other surveillance systems) (European Climate and Health Observatory, 2022a).

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In Czechia, increasing numbers of tick-borne diseases identified through its national surveillance system have led to the establishment of tick activity forecasting aimed at informing the general public of the threat levels across the country (Box 4.1). In Greece, surveillance of human WNV infection has been carried out annually since 2010 (May-November) by the Hellenic National Public Health Organization (NPHO). The goal is to promptly identify human cases of WNV infection and monitor their temporal and geographical distribution to guide targeted prevention measures. In the long term, the aim of surveillance is to quantify the disease burden and identify seasonal, geographical and demographic patterns, and populations at risk. In addition, the enhanced surveillance of animal WNV infection (in horses and wild birds) has been implemented.

In Germany, citizen science supplements traditional monitoring methods. The German *Mückenatlas* ('mosquito atlas') asks citizens to submit mosquito samples, which are then identified and used for research by experts. The *Mückenatlas* therefore contributes to knowledge on native and invasive mosquito species and related diseases in Germany and seeks to establish an information base for policymakers and researchers to assess future threats. A similar initiative is the ZEPAK (Zecken und ihre Pathogene im Klimawandel), the Tick-Atlas for Germany run by the Robert Koch Institute and funded by the German Federal Ministry of Health, whereby citizens can send the ticks they find for identification and mapping. The results are presented on the ZEPAK website together with information about the tick species, the diseases carried by ticks and the association of the emerging tick species and tick-borne diseases with climate change.

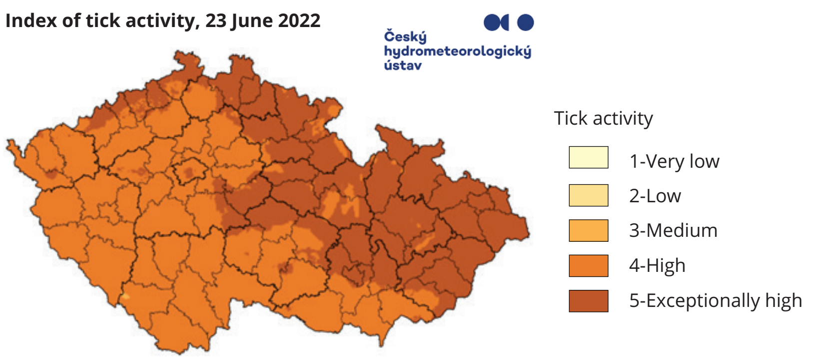
In relation to climate-sensitive vector-borne diseases, the ECDC is currently developing the 'ArboRisk' online tool, which displays near-real-time interactive maps showing the level of risk of an Aedes-borne disease outbreak. The tool combines weekly data and forecasts of rainfall and temperature from with a dynamic transmission model to predict the likelihood of an outbreak of dengue, chikungunya or Zika virus disease occurring in Europe, depending on the location and timing of imported viraemic cases. EYWA (EarlY WArning System for Mosquito borne diseases) — a research-based cross-border early-warning system to forecast and monitor mosquito-borne diseases — combines interdisciplinary scientific fields (entomology, epidemiology, ecology, Earth observation, big data analytics, citizen science and others) for outbreak forecasting and decision support modelling for vector control applications and other mitigation actions.

Box 4.1 Monitoring of ticks and tick-borne encephalitis in Czechia

In Czechia, which has one of the highest incidences of tick-borne encephalitis (TBE) in Europe, laboratory-confirmed cases have been reported since 1970. Each case of TBE is reported by the diagnosing physician to public health authorities, which carry out epidemiological investigations. Through an interview with the patient, the medical epidemiologist or infection physician obtains the medical history, including the probable time and place of infection and the possible route of transmission. The data are recorded in a standardised questionnaire, which includes the location (geographical information system grid) and route of transmission. These data are electronically transferred on a weekly basis to a safeguarded data depository of the Ministry of Health, from which they are transmitted to the National Institute of Public Health. The system has been computerised since 1993 (Kriz et al., 2012).

Due to the increasing incidence of TBE in Czechia, in 2007 the National Institute of Public Health in collaboration with the Czech Hydrometeorological Institute developed an early-warning system for tick activity and disease risk. The forecasts, available online 3 days in advance, show the predicted tick activity (proportion of ticks in a given locality that are ready to attack the host). The activity is translated into levels of risk, and preventative measures are suggested (Map 4.5). The website also provides information on the environmental, weather and climate factors affecting the activity of ticks (CHMI, 2022).

Map 4.5 Projected tick activity in Czechia and examples of risk-level descriptions and preventive measures



Level 4: High risk

Use repellent. Do not sit or lie in thickets; do not enter bushes and herbaceous vegetation, especially at the edge of forests, at the edge of watercourses, and deciduous shrubs. Evening and morning examination of the body, and possibly removal of ticks.

Level 5: Exceptionally high risk

Use repellent. Do not enter freely into deciduous and mixed forests; stick to paved roads. Evening and morning examination of the body, and possibly removal of ticks.

4.5.2 Awareness raising among the public and health professionals

The citizen science initiatives described above are powerful tools for public engagement and empowerment in policymaking and for raising awareness of environmental and climate change issues (EC, 2020d). However, only a fraction of the population engages in such activities; therefore, raising awareness of the health threats associated with infectious diseases among the general public is crucial. Awareness-raising campaigns and public outreach was the second most frequent measure for addressing climate-related threats to health in national adaptation strategies and the third most frequent in national health strategies according to the European Climate and Health Observatory (2022a). For example, the second progress report on the German strategy for adaptation to climate change plans multiple activities around public awareness, communication and information, including activities aimed at adapting curricula for schools and early-childhood education institutions; the provision of information materials to vulnerable groups; and the establishment of warning systems for ticks and tick-borne infections. France's fourth national health and environment

Raising awareness of the health threats associated with infectious diseases among the general public is crucial.

plan cites actions aimed at educating citizens about adopting behaviours that reduce the health impacts from ticks (European Climate and Health Observatory, 2022a). In Italy, awareness and behaviour change measures are included in plans for addressing WNV and Usutu virus (Ministero della Salute, 2019).

Awareness needs to be raised of threats and preventive measures, such as avoiding areas with a high abundance of vectors, using tick or mosquito repellent (see e.g. Box 4.1), and employing good hand hygiene and appropriate food preparation practices to avoid food- and water-borne diseases (see Figure 4.1). In a global review (Bowman et al., 2016), simple protection measures, such as using mosquito nets and screens in windows and doors, were found to be the most effective against dengue transmission. The ECDC (2021) recommends providing information on pathogen threats to humanitarian workers, first responders, construction workers and anyone else involved in the recovery and cleaning of flooded areas, including that they should wear appropriate personal protective equipment to avoid potential exposure to pathogens.

In addition, awareness of the emerging threats needs to be raised among health professionals, coupled with the building of knowledge about the symptoms of and treatments for ailments related to extreme weather or climate-sensitive infectious diseases, in particular those that are likely to appear in hitherto unaffected regions. Education and training of health professionals on climate change impacts on health is the fourth most frequently included measure addressing climate risks to health in national health strategies, according to the European Climate and Health Observatory (2022a). In Slovakia, the national adaptation strategy notes the necessity of complementing in-service medical training with information on the health consequences of climate change. This would increase knowledge among medical staff, allowing them to detect symptoms of heat-related diseases earlier. Czechia's national health strategy notes the need to improve the capacity of health professionals to diagnose and treat diseases that are becoming more widespread under the changing climate. The Turkish national adaptation strategy includes plans to increase awareness among public health providers of climate-related health impacts in areas vulnerable to infectious diseases (European Climate and Health Observatory, 2022a).

4.5.3 Vaccination programmes

While the number of cases of dengue and malaria remains small and mainly travel-associated, the relatively large number of TBE cases in Europe lends itself to vaccination programmes. In areas where the disease is highly endemic, the World Health Organization (WHO) recommends that vaccination be offered to all age groups, including children (WHO, 2022a). However, Austria is the only country in western and central Europe that recommends universal vaccination against TBE (Steffen, 2019); here the vaccination rate against TBE in the general population is 82% (the highest worldwide) (Kunze and Kunze, 2015). Before the introduction of a massive TBE vaccination campaign in 1981, Austria had the highest recorded TBE morbidity rate in Europe, with up to 700 patients hospitalised per year as a result of the disease (Kunz, 2003). A high awareness of TBE among the Austrian population was achieved by an annual social marketing programme, emphasising awareness raising as a precondition for action (see Section 4.3.2). The national vaccination coverage increased from 6% in 1980 to 82% in 2013, and it exceeds 90% in some high-risk areas. This has led to a steady decline in the number of TBE cases from several hundred to 50-100 per year (Kunze and Kunze, 2015). In Slovenia, vaccination against TBE is mandatory and reimbursed for those at risk of occupational exposure, and otherwise recommended. In Slovakia and Estonia, vaccination is officially recommended only for those professionally exposed. In other countries, it is recommended only for people with a high likelihood of exposure (e.g. in Poland, children and adolescents in youth camps); in others, vaccination is just to be considered (Steffen, 2019).

In relation to other diseases, the Czech national adaptation strategy includes plans to participate in research aimed at developing new vaccines, for example against Lyme disease (European Climate and Health Observatory, 2022a).

4.5.4 Vector control

As many infectious diseases in Europe have the potential to be spread by mosquitoes (see Figure 4.1), actions aimed at vector control can reduce human exposure to pathogens. In areas affected by outbreaks, elimination of adult mosquitoes through aerial spraying with insecticides can be considered (ECDC, 2020). Non-pesticide control measures are recommended to avoid pesticide resistance. Biological control methods — such as microbes, crustaceans or fish that eat mosquito larvae — are another route to reducing the number of mosquitoes (ECDC, 2017).

An example of biological vector control is the communal action group to control mosquitoes in the Upper Rhine Plain, which has a task force dedicated to taking action against *Aedes albopictus*. If these mosquitoes are detected, a targeted monitoring and vector control programme is initiated. The vector control measures include using the biological control agent Bti (*Bacillus thuringiensis* subspecies *israelensis* strain AM65-52), releasing sterile male adults and using lethal trap systems specifically for female adults. Over the years, biological mosquito control with Bti has resulted in a significant reduction in the abundance of *Aedes albopictus*, which has substantially reduced the problem and in some cases led to a complete elimination of subpopulations.

5 Conclusions and outlook

This report shows that the threats to human health associated with high temperatures and climate-sensitive infectious diseases are already substantial and likely to increase in the future with climate change. While in parts of Europe temperatures have been high (e.g. the Mediterranean region) or tick-borne diseases have been endemic (e.g. central Europe), climate change is contributing to the amplification of risk in those locations and expansion of disease to other, previously unaffected, areas of Europe.

Increasing the resilience of health systems to climate change is key.

The EU policy framework increasingly considers the impacts of climate change on health (see Section 2.1), but the limited competences of the EU in areas relevant to the development and implementation of many solutions (e.g. health, spatial planning, education) mean that most of this needs to happen within countries. At the national level, where the mandate lies to bring about change, the recognition of climate-related threats to health seems to be more advanced in climate adaptation strategies than in national health policies (European Climate and Health Observatory, 2022a). This misalignment may mean that climate change threats to human health remain a low priority for the health sector in Europe.

Therefore, several important actions are needed to reduce climate impacts on human health. First, there is an urgent need for education and training of public health and healthcare professionals on the threats from climate change. The joint statement by the EU Health Policy Platform's thematic network on climate action through public health education and training, led by the Association of Schools of Public Health in the European Region (ASPHER) and endorsed by 96 key stakeholders in Europe and beyond, calls for (among other things) building climate resilience, climate-health literacy and political literacy among public health and healthcare professionals and intensifying the investment in interdisciplinary education and training for these professionals in existing curricula and including this in EU legislation for professionals' education requirements to facilitate intersectoral action (Aspher, 2022). The 2022 Communique of the G7 Health Ministers, which includes a focus on climate-resilient and sustainable, climate-neutral systems, calls for climate change-related aspects to be integrated into the education and training of healthcare and public health professionals (G7 Germany, 2022). Some such training initiatives already exist. For example, the WHO Bonn School on Environment and Health for public health professionals addresses technical gaps and raises awareness on environment and health challenges in countries, including climate change. The European Climate and Health Observatory presents examples of training and education for health professionals. Nurses Climate Challenge Europe is an initiative delivered by Health Care Without Harm Europe in partnership with the Alliance of Nurses for Health Environments that aims to support nurses who want to educate their colleagues and communities about the health impacts of climate change. The Planetary Health Academy is a free online lecture series in Germany focusing on transformative action in addition to scientific foundations and transdisciplinary perspectives on planetary health. Yet broader inclusion of climate change in professional training and education is needed. An initiative to raise awareness is being taken by medical practitioners and organisations in some countries, for example the Medical Alliance against Climate Change in Spain and Doctors for the Climate in Poland.

Second, increasing the resilience of health systems to climate change is key. This report shows that healthcare facilities in European cities can be more severely affected by heat because of their location in densely built urban environments. In addition, the European Climate and Health Observatory (2022b) shows that flooding poses a threat to one tenth of healthcare services across Europe. According to a WHO (2021) survey, climate change impacts on healthcare facilities are considered by only 5 out of the 15 EEA member and collaborating countries that responded. This calls for greater consideration of the effect that heat and other climate hazards can have on hospitals and their staff and patients, and the possible responses to this. This consideration should also extend to home, community, and residential healthcare and long-term care providers, most of which work outside the physical structures associated with health systems but have an important role in caring for vulnerable members of society. The COVID-19 pandemic has exemplified how a crisis that creates difficulty in obtaining adequate care from outside the household can leave many care recipients with unmet needs (Eurofound, 2022). Ensuring continued access to care providers is an important element of increasing health systems' resilience to climate change.

In addition, health systems' capacity to respond to increased demand for healthcare during heatwaves, or for diagnostics during disease outbreaks, may not be sufficient. While 60 countries across the globe committed to climate-resilient health systems under the WHO COP26 Health Programme, in June 2022 this included only six EEA member and cooperating countries (Belgium, Germany, Ireland, Netherlands, Norway and Spain) (WHO, 2022b). The 2022 Communique of the G7 Health Ministers may be a beacon of change, with emphasis placed on climate-resilient and sustainable, climate-neutral health systems (G7 Germany, 2022). Further political commitment may be secured at the forthcoming WHO Europe 2023 Ministerial Conference on Environment and Health, with climate change planned as one of the foci.

Third, to effectively address threats, the varying vulnerability and exposure of different demographic and socio-economic groups needs to be considered. Older people, children, and people in poor health consistently emerge as those more affected by heat and infectious diseases. Those working outside or emergency service workers are more exposed to heat and vector- and water-borne diseases. The Communique of the G7 Health Ministers recognises the disproportionate effects on marginalised and vulnerable groups and the importance of reducing health inequalities (G7 Germany, 2022). Health equity is also a leitmotif for WHO and is strongly emphasised in the joint statement led by Aspher (2022). However, although EU and national climate policies draw attention to vulnerable groups and emphasise the need for equitable adaptation solutions, the practical implementation of such solutions remains rare. Stronger engagement of those working on climate change threats with the health, social care, education and employment sectors is essential for the appropriate identification and protection of vulnerable groups (EEA, 2022b).

In general, the examples of responses to climate-related health threats in Sections 3.5 and 4.5 show that the adaptation and prevention measures go beyond the remit of the health sector and require engagement with other sectors (e.g. built environment, spatial planning, education and employment). Examples of such collaborations emerge in some European countries. For example, in Bulgaria, the Ministry of Health has established an interdisciplinary coordination working group on climate change and health. In Germany, the Federal/ Länder Ad hoc Working Group on Adaptation to the Impacts of Climate Change in the Health Sector that was set up in 2017 is now permanent to facilitate interagency dialogue on human health under climate change (European Climate and Health Observatory, 2022a). National public health institutes are seen as actors that could usefully become more engaged with the subject of climate change (EuroHealthNet, 2021; IANPHI, 2021) and play a stronger role as connectors between the relevant sectors on climate change and health. For example, collaborations in Europe between national public health institutes and urban planning and land use sectors have not been common to date (IANPHI, 2021).

Lastly, to enable the step up from developing policies to implementing action on the ground, there is a need for the monitoring, evaluation and dissemination of knowledge on the effectiveness of solutions. Knowledge of what works best and in which context is crucial to support decision-making in the public, private and third sectors, in particular if upfront investment is needed. The EU is supporting research, implementation and knowledge-sharing activities on climate change and health. For instance, six substantial projects on the health impacts of climate change and the costs and benefits of action and inaction started in autumn 2022. The findings of such research projects contribute to the knowledge base for further policy development. The EU Mission on adaptation to climate change also kicked off in 2022, with the focus on supporting subnational action on adaptation. Funding will be provided to demonstrator regions and communities across Europe to assess climate risks, develop adaptation strategies and implement actions, with a strong focus on health and equity. The European Climate and Health Observatory is expected to play a key role as a knowledge-sharing platform for those activities.

To conclude, it is important to note that this report looks at just two among the plethora of threats to human health associated with the changing climate. Other threats, including flooding, wildfires, droughts and aeroallergens — which are covered by the European Climate and Health Observatory and will be explored in more detail in forthcoming reports — can add to or multiply the health risks of high temperatures and infectious diseases. In addition, the groups vulnerable to high temperatures and infectious diseases — elderly people, those in poor health, children, pregnant women, lower socio-economic groups and those required to work outside — are vulnerable to other climate hazards. There is a need for more knowledge on the cumulative effects of various climate and environmental threats to human health, particularly that of vulnerable groups.

Abbreviations

CI	Confidence interval
ECDC	European Centre for Disease Prevention and Control
EEA	European Environment Agency
EU	European Union
HHAP	Heat health action plan
TBE	Tick-borne encephalitis
UHI	Urban heat island
WHO	World Health Organization
WNV	West Nile virus

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Annex 1
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