5 SOCIETY 2-HEALTH

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Executive summary

Climate and environmental change cause a wide range of impacts on human health in Mediterranean countries. The vulnerability of people to the impacts of climate and environmental change is strongly influenced by population density, level of economic development, food availability, income level and distribution, local environmental conditions, pre-existing health status, and the quality and availability of public health care. Poorer countries, particularly in North Africa and the Levant, are at highest risk.

Heat waves have the potential to cause very high rates of premature deaths, especially in large cities and among older people. Heat-related morbidity and mortality have been reduced in the region over recent years thanks to Heat-Health Acton Plans (HHAPs). Despite the rise in mean temperature, cold waves are not expected to disappear with increased future climate variability.

Recent climate and landscape changes in the Mediterranean Basin may create suitable environments for mosquitoes, ticks, and other climate-sensitive vectors, and may exacerbate vector-borne diseases.

Every year, around one million fatalities are attributed to outdoor and indoor air pollution in the European and Eastern Mediterranean regions. There are synergistic effects between ozone levels, particulate matter concentrations and climate variables, especially during heat wave days, with high temporal and spatial variability. An increase in mortality of 1.66-2.1% is observed for each 1°C temperature increase.

Climate change and extreme events have a negative impact on mental health for people who experience loss of homes, destruction of settlements and damage to community infrastructure.

Future changes in the vulnerability of the Mediterranean Basin to vector-borne diseases transmission vary geographically, modifying significantly the extent and transmission patterns of these diseases. For example, by 2050, West Nile virus high-risk areas are expected to expand further, and transmission seasons will extend significantly.

It is important for prevention plans to be implemented. Most adaptation measures offer "win-win solutions" from a public health perspective, including the reduction of air pollution or providing shade. Additionally, Mediterranean countries have the potential to enhance cross-border collaboration for adaptation to many health risks.

5.2.1 Introduction

5.2.1.1 Effects of climate and environmental change on human health

Climate change is a complex phenomenon that threatens all aspects of human society, including increasing risks to human life and health (WHO 2018). Most climate-related health impacts are mediated by complex ecological, environmental and social processes, while impacts vary in magnitude, scale and timing as a function of local environmental conditions and the vulnerability of the human population (Shuman 2010; Smith et al. 2014; Crowley 2016). Climate change impacts human health directly, through exposure to extreme heat and cold events, droughts or storms, or indirectly by changes in air quality, water availability, food availability and quality, and other stressors. The main health effects are related to extreme weather events (including floods and extreme temperatures), changes in the distribution of climate-sensitive diseases (such as vector-, water- and food-borne diseases), and changes in environmental and social conditions (EU Climate Policy).

5.2.1.2 Multi-factorial changes in health attributed to environmental change

The Mediterranean Basin has been undergoing a warming trend with longer and warmer summers, an increase in the frequency, duration and severity of heat waves, and a reduction in rainfall. With significant gradients in socio-economic levels among Mediterranean countries, particularly between the North and the South, together with population growth and migration (World Bank 2017) *(Section 5.3.2.3)*, increased water demand *(Section 3.1.2)*, decreased water availability *(Section 3.1.1)* and quality *(Section 3.1.3.5)* (Bucak et al. 2017), ecosys-

[39] Parts of this chapter have been published by Linares et al. (2020).

tem degradation *(Section 4.3)* (e.g., Coll et al. 2010) and increased risk of forest fires *(Section 4.3.2.1)* (e.g., Turco et al. 2014), the vulnerability of the Mediterranean population to human health risks is increasing significantly.

5.2.2 Vulnerability and health risk – main causes

Population vulnerability to the impacts of environmental and climate change is strongly influenced by population density, level of economic development, food availability, income level and distribution, local environmental conditions, pre-existing health status, and the quality and availability of public health care (Woodward et al. 2000). Although socio-economic and demographic factors may vary geographically, there are some commonalities across populations in terms of risk factors (UNEP 2018). Characteristics that differentiate populations with particular health risks from environmental change include age, gender, geographic location, socio-economic status, acclimation, occupation, health infrastructure and the (often urban) housing situation (Smith et al. 2014).

5.2.2.1 Aging

Older populations are at particular risk of adverse climate change impacts due to decreased mobility and changes in physiology, as well as limited access to resources. These conditions may limit adaptive capacity among older and more vulnerable people (EASAC 2019). More specifically, with heat-related impacts, such as heat waves, elderly population groups are at particular risk due to dysfunctional thermoregulatory mechanisms, chronic dehydration and medications. People with pre-existing medical conditions, especially cardiovascular or pulmonary illnesses (Mayrhuber et al. 2018) and those with chronic diseases like diabetes are more vulnerable (Yardley et al. 2013), as are those who are obese and have cognitive impairment (Bouchama et al. 2007; Linares et al. 2016).

5.2.2.2 Gender

In addition to differences of a collective nature (such as body size, physical condition and state of acclimatization to heat), there are social factors such as differences in social isolation, that tend to be greater among men than women, and may prove a risk factor e.g., during heat waves (Canouï-Poitrine et al. 2006). There are factors of a physiological nature, such as women's tendency to sweat less than men (Gagnon et al. 2013), a natural thermoregulation mechanism that might explain the greater impact of heat on women. Also single-parent women (De'Donato et al. 2018) are cited as more vulnerable. Moreover, for pregnant women and babies in gestation, extreme heat is a risk factor for adverse birth outcomes, such as low birth weight and premature birth (Arroyo et al. 2016).

5.2.2.3 Geographic location

Most studies show that there is important variability in the effects of climate change on morbidity and mortality related to geographic location and the sensitivity of populations to extreme values such as extreme heat or cold, urbanization level, and distance to health system infrastructures (Allen and Sheridan 2018). For example, rural populations will be at a high risk of vector-borne diseases related to climate warming.

5.2.2.4 Socio-economic status

Population vulnerability to high temperatures will be affected not only by climate change but also by socio-economic factors (Semenza et al. 2008). In socially disadvantaged groups, the effects are particularly pronounced among the poor, socially isolated, substance abusers and homeless (Nicolay et al. 2016). Migrants, refugees and internally displaced people may have pre-existing and post-displacement vulnerabilities such as malnutrition, untreated chronic medical conditions from limited access to health care, and lack of shelters that provide adequate protection, predisposing them to decompensation caused by heat or other extreme events (McMichael et al. 2012).

5.2.2.5 Level of acclimation

Climate change will affect an increasingly aging population, a larger percentage of whom have chronic diseases, and are therefore more susceptible to the effects of increasingly extreme temperatures (changes in the population susceptibility framework). Population effects are quantified through the increased number of people over 65, which is the target population for heat impacts, as well as those in energy poverty or living in older building structures. On the other hand, there are factors that should result in a decrease in the impact of heat in the future. These include, for example, the existence of an active adaptation process within the population (both autonomously by individuals and families, and by the authorities and institutions), due to multiple factors from the so called "culture of heat" (Bobb et al. 2014), to the implementation of prevention plans (Schifano et al. 2012), improvements in health services (van

Loenhout et al. 2016), and improvements in socio-economic circumstances and infrastructure of homes, as well as an increase in the number of air conditioning units (Díaz et al. 2018b), among others.

5.2.2.6 Occupational health

Extreme heat and cold waves have been linked to an increased risk of occupational injuries. Studies report significant losses in work capacity and productivity linked to climate warming. Several mechanisms are thought to be behind the link between ambient temperatures and risk of injury in the workplace (Martínez-Solanas et al. 2018). Exposure to high temperatures can lead to physiological and psychological changes associated with heat strain, which in turn can decrease workers' performance and lead to impaired concentration, increased distractibility and fatigue (Zander et al. 2015). Sectors with a high percentage of outdoor workers, such as agriculture and construction or police and security, have the highest risk of seeing heat stroke or even heat stress develop (Martínez-Solanas et al. 2018). Additionally, despite the rise in mean temperatures, cold waves are not going to disappear. Therefore, factors related to working in cold environments, such as thermal discomfort, hypothermia, or reduced mobility while wearing protective clothing are associated with decreased dexterity and performance among workers and can also trigger occupational injuries (Mäkinen et al. 2009).

5.2.2.7 National public health infrastructures, warning systems

Better surveillance and improved warning systems are needed for vulnerable population groups. Increased urbanization increases the level of population exposure and can put pressure on water management and energy infrastructure, social care and health systems, so as to make them inefficient or unable to adopt necessary measures and prevention plans (Environmental Audit Committee 2018). Prevention plans and early warning systems began in the European region after the heat wave of 2003 and their efficiency is under evaluation. In France, the implementation of the prevention plan and alert system after the heat wave of 2003 is considered to have contributed to a reduction of around 4,400 fatalities during the heat wave of 2006, especially benefitting people over 75 years of age (Fouillet et al. 2008). In recent years, Heat-Health Action Plans (HHAPs) led to a decline in mortality during heat waves (Martinez et al. 2019). Currently, early warning systems for heat and cold waves are active in Mediterranean countries, such as the Egyptian Meteorological Authority (EMA).

5.2.2.8 Influence of urban landscape

Urban Heat Islands (UHI) are considered to be one of the greatest twentieth century problems facing humanity, and they are the result of urbanization and industrialization (Rizwan et al. 2008). Temperature differences between cities and rural areas due to the UHI effect can reach up to 10°C in large cities. The effect of heat in urban areas increases with population density, extensive economic activities and city expansion (Burkart et al. 2016; Milojevic et al. 2016). Factors that amplify the UHI effect include household characteristics such as the age of buildings, residence in the highest floor of a building, the presence of a bedroom immediately beneath the roof (due to the concentration of heat that accumulates during the day), and lack of good thermal isolation (Vandentorren et al. 2006; López-Bueno et al. 2019).

5.2.3 Health impacts: recent and current situation

5.2.3.1 Heat-related impacts

Heat waves have very high mortality rates in Europe causing tens of thousands of premature deaths, especially during the 2003 heat wave. Mediterranean cities like Athens, Barcelona and Rome have all experienced strong impacts of extremely high temperatures (De'Donato et al. 2015). Despite the aging European population and continuously increasing temperatures, Mediterranean cities (and also other areas with commonly high temperatures) have recently shown a reduction in heat-related morbidity and mortality (Díaz et al. 2018a). This reduction is attributable to several factors, such as the existence of Heat-Health Action Plans (HHAPs) and the implementation of prevention plans (Morabito et al. 2012), improvements in health services, infrastructure and housing, changes in patterns of susceptibility of the population and increased awareness of the effects of severe heat (Ragettli et al. 2017), which in turn may be a result of improved communication and media coverage (De'Donato et al. 2015).

An important decrease in heat-related mortality has been observed among children and elderly people, although at a lower rate for the elderly (Schifano et al. 2012; Díaz et al. 2015). The reduction in heat-related mortality does not show consistent differences by age group (De'Donato et al.

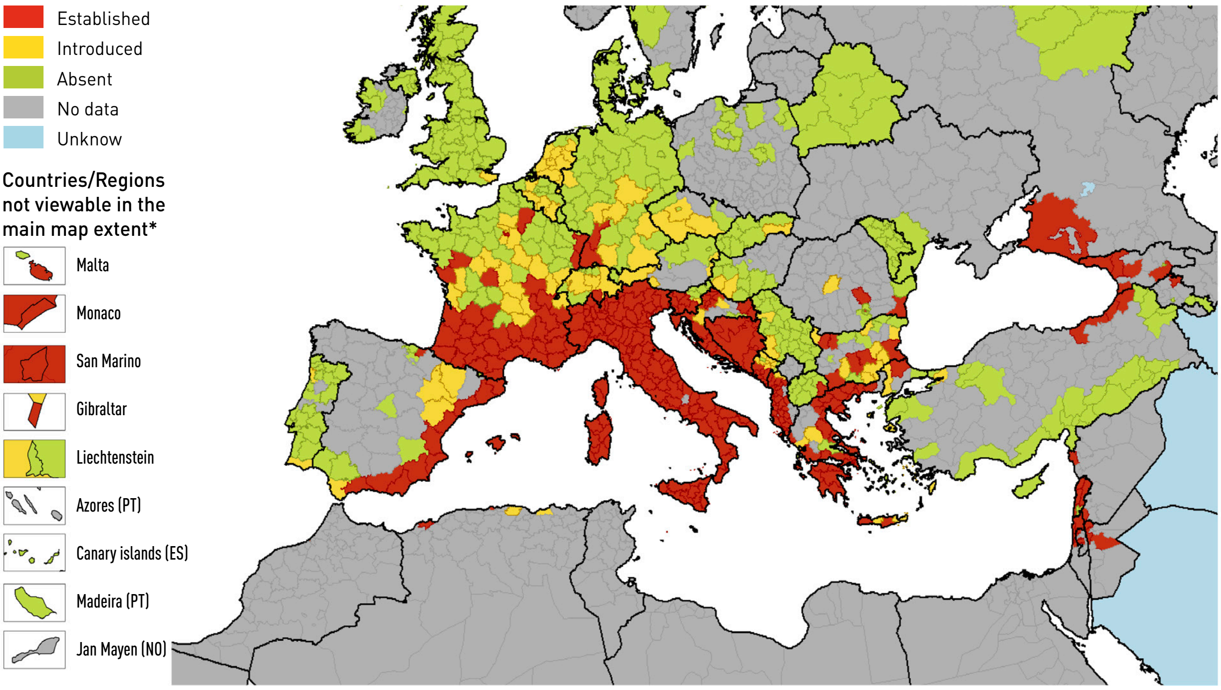
2015) or gender (Allen and Sheridan 2018) and is spatially variable (Toloo et al. 2013; Linares et al. 2015b). Plans and alert systems have helped raise awareness among the population about the risk, but they have probably not been enough to provoke changes in population behavior so as to lead people to take measures to protect themselves (Wolf et al. 2010). Health promotion and behavior studies suggest that people who are most likely to adopt these measures are also those who have a high risk perception, but the opposite is true for the most vulnerable groups.

The cost of investing in protection measures against heat is one of the barriers that prevent vulnerable populations from taking action. The negative environmental impact of air conditioning must also be considered *(Chapter 3.3).* Educational programs are required to inform the population, especially the most vulnerable and their caregivers, about the risks of exposure to high temperatures. In the European part of the Mediterranean Basin, the increase in temperatures will affect both warmer and temperate countries, and it is therefore important that prevention plans are implemented in those countries that currently have no prevention plans in place, and that they are improved where they already exist. Ultimately, the effectiveness of prevention plans depends on the capacity (of the health sector, the local community, etc.) to adapt to the changes, the plan's ability to incorporate climate change into research frameworks on adaptation and implementation, and the knowledge generated in the field (Hess and Ebi 2016).

There is insufficient research on public awareness regarding climate change and health in the Mediterranean. People who perceive climate change as a risk to public health are more supportive of mitigation policies and show more willingness to take individual measures to mitigate climate change (Debono et al. 2012).

5.2.3.2 Cold-related impacts

Winter mortality is associated with low temperatures, extremely low temperatures or cold waves (The Eurowinter Group 1997). This phenomenon has attracted less attention than the analysis of heat waves, though its impact on mortality is higher and up to an order of magnitude greater than those related to heat (Vardoulakis et al. 2014). By the end of the 21st century, southern European regions are expected to experience a clear decline in cold-relat-



ECDC and EFSA, map produced on 16 Jan 2019. Data presented in this map are collected by the VectorNet project. Maps are validated by external experts prior to publication. Please note that the depicted data do not reflect the official views of the countries. Administrative boubaries © EuroGeographics, UNFAO, TurkStat.
* Countries/Regions are displayed at different scales to facilitate their visualisation.

Figure 5.1 | Distribution of the tiger mosquito, *Aedes albopictus,* in 2019 - a known vector of chikungunya and dengue viruses (from ECDC 2019).

ed mortality opposite to the increase in heat-related mortality (Gasparrini et al. 2017). These conclusions are based on the dual assumption that there will be no population acclimatization processes to such extreme temperatures and no changes in mortality rate. Other studies indicate populations may adapt to heat (Oudin Åström et al. 2018). Despite the rise in mean temperatures *(Section 2.2.4.2)*, cold waves are not expected to disappear. Added to the fact that the impact of cold-related mortality is greater than that of heat-related mortality (Carmona et al. 2016), from a public health standpoint it is essential that the climate impact on mortality risk is analyzed by considering the impacts of both heat and cold waves together.

5.2.3.3 Vector-borne diseases

One of the main impacts of environmental and climate changes on human health is the influence of warmer climates and changing rainfall patterns on vector-borne disease (VBD) transmission which, together with anthropogenic changes in landscapes may create hospitable environments for mosquitoes, ticks, and other climate-sensitive vectors (Crowley 2016) *(Fig. 5.1)*.

Long-term anthropogenic climate change interacts with natural variability, influencing the transmission of VBDs from shorter (seasonal, annual) to longer (decadal) time scales, with variable effects and complex interactions at different times and locations (Campbell-Lendrum et al. 2015). These impacts are complex and may involve non-linear feedback inherent in the dynamics of many infections (Metcalf et al. 2017), including impacts of other environmental drivers such as biodiversity loss or changes in land use (Reisen et al. 2006; Marcantonio et al. 2015; Paz 2015) *(Chapter 2)*. It is therefore expected that VBD outbreaks will be exacerbated in the region.

Most cities in the Mediterranean Basin are compact and densely populated. Air conditioning is used in regions with sufficient resources, but windows often remain open even during the hottest months. Many activities, particularly social gatherings, occur in outdoor locations such as shaded balconies, courtyards, and outdoor restaurants - all ideal places for contact with the vector. While warmer summers extend the potential season of the disease throughout the basin, poorer countries, particularly in North Africa and the Levant, are at highest risk (Negev et al. 2015).

Currently, the main vector-borne diseases in the Mediterranean basin, transmitted by insects and potentially influenced by the changing climate are West Nile virus, Chikungunya and Leishmaniasis.

West Nile virus

West Nile virus (WNV) is a vector-borne pathogen of global importance since it is the most widely distributed virus of the encephalitic *Flavivirus* spp. Mosquito species from the genus *Culex* (family *Culicidae*) are the primary amplification vectors and also act as bridge vectors. The enzootic cycle is driven by continuous virus transmission to susceptible bird species through adult mosquito blood meal feeding, which results in virus amplification (Paz and Semenza 2013; Petersen et al. 2013).

The establishment of WNV in new regions is facilitated by warmer conditions. Ambient warming increases the growth rates of mosquito populations, decreases the interval between blood meals and shortens the incubation time in mosquitoes (Paz 2015; Moirano et al. 2018). Clear associations have been found between warm conditions and WNV outbreaks in Mediterranean countries (Paz et al. 2013; Tran et al. 2014; Marcantonio et al. 2015; Moirano et al. 2018).

Since the unprecedented WNV outbreak in 2010 in southern and eastern Europe, which was accelerated by extreme temperatures (Paz et al. 2013), outbreaks occur every summer (2011-2019) and there is evidence of ongoing transmission in Euro-Mediterranean countries (Semenza and Suk 2018). During the last decade, WNV outbreaks in humans erupted in many Mediterranean countries including France, Italy, Croatia, Slovenia, Greece, Turkey, Israel and the Mediterranean islands. During the 2018 transmission season, a higher number of cases was reported compared with previous years (ECDC 2018).

The impact of changes in rainfall patterns on disease incidence is influenced by precipitation levels (increased and extreme precipitation, e.g., Moirano et al. 2018, floods or droughts), depending on local conditions, the landscape (e.g. wetlands, Tran et al. 2014) and the differences in the ecology and sensitivity of mosquito species (Paz 2015). In the Mediterranean area, increased rainfall and humidity together with high temperatures probably favored the multiplication of *Culex* species, which led to numerous cases of WNV human infections in northern Greece in summer 2010 (Papa et al. 2010). Climate parameters were found as key predictors of WNV outbreaks including high precipitation in late winter/

early spring and summer drought (Marcantonio et al. 2015).

Chikungunya

Chikungunya is a viral disease transmitted by *Aedes* mosquitoes to humans. The most common symptoms are fever and severe joint pain. In 2007, an outbreak of chikungunya virus infections took place for the first time in Italy, indicating the possibility of mosquito-borne outbreaks by *Aedes albopictus* in the Euro-Mediterranean area. In 2010 and 2014, autochthonous cases were reported in France. The risk of chikungunya spreading in the EU and the Mediterranean is high due to importation through infected travelers, presence of competent vectors in many countries (particularly around the Mediterranean coast) and population susceptibility (ECDC). In August-September 2017, local transmission of chikungunya was confirmed in southeastern France (WHO 2017a) and in Italy, six transmissions were reported in Rome and eight in the coastal area of Anzio in the Lazio Region (WHO 2017b).

Rift Valley fever

Rift Valley fever is a mosquito-borne zoonotic climate-sensitive disease closely associated with high-rainfall conditions (e.g., after prolonged excessive rainfall in sub-Saharan Africa). However, large outbreaks have also occurred in the dry and low-rainfall climate of Egypt (Linthicum et al. 2016).

Leishmaniasis

Leishmaniasis is a vector-borne disease with three main clinical forms: Visceral (Kala-azar), Cutaneous Leishmaniasis (CL), and Visceral Leishmaniasis (VL) caused by infection of Leishmania parasites and transmitted by the bite of infected females of *Phlebotomine* spp. sandflies. Leishmania genus includes about 20 species, widely distributed in more than 85 endemic countries, with 0.7-1.2 million new cases of CL every year, of which about a third occur in the Mediterranean region (Alvar et al. 2012). In the eastern Mediterranean Basin, two CL species, which manifest as skin sores, are common: *Leishmania major* and *Leishmania tropica. Leishmania tropica,* transmitted by the *Phlebotomus sergenti* sandfly, was first discovered in Israel in the early 1990s. Since the late 1990s, rapid unexpected outbreaks occurred in new urban and rural foci in Israel, Jordan and the Palestinian Authority (Al-Jawabreh et al. 2017; Waitz et al. 2018).

5.2.3.4 Food- and water-borne diseases

Climate change increases the risks of food- and water-borne diseases (Ebi et al. 2018). For example, the survival and multiplication of salmonellosis in the environment and in food is influenced by high temperatures (Miraglia et al. 2009; Milazzo et al. 2016). It was shown for ten European countries that temperature influences infection transmission in about 35% of all cases of salmonellosis, while the greatest effect was apparent for temperature one week before the onset of illness (Kovats et al. 2004).

Campylobacter species have emerged as leading bacterial causes of gastroenteritis and foodborne infections in high-income countries (EFSA and ECDC 2015). The incidence of campylobacteriosis varies seasonally and geographically, and tends to be highest during the summer months (Bassal et al. 2016). While the temperature may directly affect the rate of replication of pathogens and their survival in the environment, increased ambient temperatures may increase bacterial contamination at various points along the food chain and also influence people's behavior which, in turn, may be translated into more risky patterns of food consumption (Lake et al. 2009). A recent retrospective study in Israel found that higher temperatures across seasons, prior to or around the time of food purchasing, played a role in human infection (Rosenberg et al. 2018).

Leptospirosis, caused by *Leptospira interrogans,* is a highly infectious emerging water-borne zoonosis of global significance. A study in Croatia showed strong influence of climate conditions on incidence of human leptospirosis at annual level. In the years 2010 and 2014 that were characterized as warm/extremely warm and wet/extremely wet, a significant temporal increase in incidence was observed. Increased risk for human infections is related to season, gender and age with peaks in incidence occurring cyclically and associated with extreme weather conditions. The influence of weather should not be considered without taking into account the wider impact of climate change on domestic, peridomestic and wild animals (Habus et al. 2017). In Israel, human leptospirosis is uncommon, but in summer 2018, a large outbreak of human leptospirosis was linked to contaminated water bodies in northern Israel after years of severe drought conditions which had resulted in particularly low water levels in the region (Dadon et al. 2018).

5.2.4 Indirect impacts: recent and current situation

5.2.4.1 Air quality

Climate and environmental change, anthropogenic activities, urbanization, industrialization, etc. affect air quality and impact human health, through several pathways, such as changes in atmospheric circulation, ventilation and dilution of air pollutants, removal processes, stratosphere–troposphere O_3 (ozone) exchange (e.g., Akritidis et al. 2016) and increase in the frequency of wildfires (Fiore et al. 2015) (see *Section 2.3.2*). Every year, around one million fatalities are attributed to outdoor and indoor air pollution in the European and eastern Mediterranean regions (WHO Regional Office for Europe and OECD 2015). In Lebanon, the prevalence of cardiovascular disease has been linked to exposure to pollution (Salameh et al. 2019). In Europe the cardiovascular diseases burden from ambient air pollution is substantially higher than previously assumed, though subject to some uncertainty (Lelieveld et al. 2019).

In Europe, 90% of citizens are exposed to levels of fine particulate matter (PM) that exceed World Health Organization (WHO) air quality guidelines. There are synergistic effects between ozone levels, PM concentrations and climate variables (Analitis et al. 2018), especially on heat wave days (Katsouyanni et al. 2009), together with a large variability on both temporal and geographical scales, likely connected to local climate characteristics, activity patterns and physical adaptation (de Sario et al. 2013). An increase in mortality of 1.66% was observed for each 1°C temperature increase on low ozone level days, and an increase of up to 2.1% on high ozone level days (Analitis et al. 2018). There is a positive relationship between cardiovascular mortality and the concentrations of nitrogen dioxide (NO_2), the main precursor of tropospheric ozone (Nuvolone et al. 2013). Out of 524,000 pollution-related premature deaths, 432,000 are estimated to be attributable to PM2.5, 17,000 to O_3 and 75,000 to NO_2. Reducing exposure to PM improves the life expectancy of Europeans by about 8 months (WHO Regional Office for Europe and OECD 2015). As the main emission source of these pollutants is vehicle traffic, largest impacts are concentrated in large cities due to microcirculation.

Atmospheric pollutants that are linked to climate change are considered major contributors to the large rise in the number of people affected during the allergy season. Airborne allergens chemically modified by the presence of NO_2 and O_3, seem to increase their potency. Airborne allergies are thus becoming more common in combination with global climate change. Together with global warming, increased pollen production and earlier spring phenology, this leads to earlier, more frequent and more widespread pollen allergies (American Chemical Society 2015).

5.2.4.2 Mineral dust and forest fires

The main health impacts associated with PM occur in densely populated urban areas where the principal component is from anthropogenic emissions (Karanasiou et al. 2012). In southern European urban areas, these account for approx. 80% of PM and aerosol emissions, while the remaining 20% are of natural origin, mainly from advections of desert dust (Viana et al. 2014), sea spray (O'Dowd and de Leeuw 2007), volcanic emissions (von Glasow et al. 2009), and aerosols from wildfires, with Saharan dust intrusions and PM advection from wildfires being the primary sources.

Impacts of PM due to wildfires on human health are mainly respiratory problems (Mirabelli et al. 2009) or exacerbations of previous respiratory diseases (Martin et al. 2013), while exposure to forest fire smoke has also been linked to cardiac diseases (Weichenthal et al. 2017). Medium-size fires are found to increase daily mortality in Athens (Analitis et al. 2012), while the accumulative impact of PM10 (PM with diameter less than 10 μm) during forest fires smoke advection exacerbates mortality for different age groups and causes (Faustini et al. 2015; Linares et al. 2015a).

Long-distance transport generates a change in the respective atmospheric concentration of the different sized particles and in the chemical composition of the particles present in the air (Pérez et al. 2012), while there is evidence that desert dust itself transports biological allergens or irritants (Garrison et al. 2006; Griffin 2007; Polymenakou et al. 2008). Non-biological compounds in dust may cause adverse health effects, or local conditions may modify the toxicological properties of the dust. The two circumstances of change, i.e., in PM concentration and chemical composition, are related to clearly differentiated morbidity-mortality patterns, which are observable on days with desert dust intrusions (Jiménez et al. 2010).

The human health effects of dust storms range from respiratory disorders (including asthma, tracheitis, pneumonia, allergic rhinitis and silicosis), to cardiovascular disorders (including stroke), conjunctivitis, skin irritations, valley fever, diseases associated with toxic algal blooms, and mortality and injuries related to transport accidents (Goudie 2014). Spatial and temporal variability of the PM effects on human health due to Sahara dust intrusions in Euro-Mediterranean countries stems from co-existing PM concentrations due to traffic sources and their higher toxicity (Samoli et al. 2011; Stafoggia et al. 2016), the varying impacts on the different age groups (Zauli-Sajani et al. 2011), the specific causes of health impacts and PM groups (Neophytou et al. 2013).

5.2.4.3 Mental health

Climate change and extreme events have a negative impact on mental health in several ways. Floods, droughts and sea level rise have long-lasting impacts on societies who have experienced loss of homes, destruction of settlements and damage to community infrastructure. These impacts on mental health include anxiety, depression and post-traumatic stress disorders (Watts et al. 2015). However, there is insufficient research on the mental health impacts of climate change, both internationally (Watts et al. 2018) and also regionally in Mediterranean countries. The few studies that have been conducted in the Mediterranean found negative impacts of high temperature on mental health. For example, in Thessaloniki, Greece, high temperatures may be associated with increased male suicide rates. In the context of the recent economic crisis in Greece, a multilinear regression showed that high temperatures explain 51% of the variance in male suicides, while unemployment was insignificant (Fountoulakis et al. 2016). Another study in Northern Italy found a strong positive association between the number of daily emergency psychiatric visits and mean daily air temperature (Cervellin et al. 2014). More research is needed regarding the impact of different extreme climate events on diverse mental health outcomes.

There is some evidence that climate change may intensify violence in the Mediterranean, across all levels. Climate change-induced water shortage and food insecurity may intensify conflicts in the eastern Mediterranean (Brown and Crawford 2009), especially in counties that lack adaptive capacity (Feitelson and Tubi 2017). At the domestic level, a study in Madrid found an association between heat waves and increase in domestic violence, including an increase in police reports and helpline calls three days after the heat wave (Sanz-Barbero et al. 2018).

5.2.4.4 Migration

Displacement related to environmental change and climate disasters is not a new phenomenon in the Mediterranean *(Chapter 5.3)* (Charef and Doraï 2016). Migration potential has increased over recent decades due to the increasing impacts of climate change, frequent and more intense extreme events, especially in areas with high population density and areas at risk, with direct and indirect impacts on the well-being, livelihood and security of populations *(Chapter 5.3)*. Displacement may lead to adverse health outcomes, especially for vulnerable population groups as well as those suffering from chronic diseases (Schütte et al. 2018). In lower-income countries hosting refugees in particular, it may undermine national health systems and diminish access to health care for domestic, as well as migrant, populations (Gostin and Roberts 2015). In Egypt, re-emerging diseases such as tuberculosis have been reported as an indirect effect of climate change linked to the crowdedness of slum areas due to irregular internal migration of farmers who have lost their land (Girardi et al. 2017).

5.2.5 Projections for global warming of 1.5°C, 2°C and more

5.2.5.1 Vulnerabilities and risks under different warming scenarios

The IPCC special report on 1.5°C global warming (IPCC 2018) shows that global warming of 2°C poses substantially greater risks to human health than 1.5°C, with actual risk levels varying regionally (Hoegh-Guldberg et al. 2018). The risks may be particularly high for heat-related morbidity and mortality, heat stress, ground-level O_3, and malnutrition. For vector-borne diseases, the risks are more variable because warmer temperatures may result in some regions becoming too hot and/or too dry for a vector (Ebi et al. 2018).

5.2.5.2 Heat-related impacts

Many projections around heat-related mortality are made without considering the socio-economic conditions of the population. In order to show the contribution of changes in socio-economic and climate conditions to mortality due to heat in the European population, a study was developed that combined socio-economic scenarios with greenhouse gas emissions (RCP) (Mayrhuber et al. 2018). The percentage of the European population at risk of thermic stress is expected to increase constantly over coming years, and could increase from the

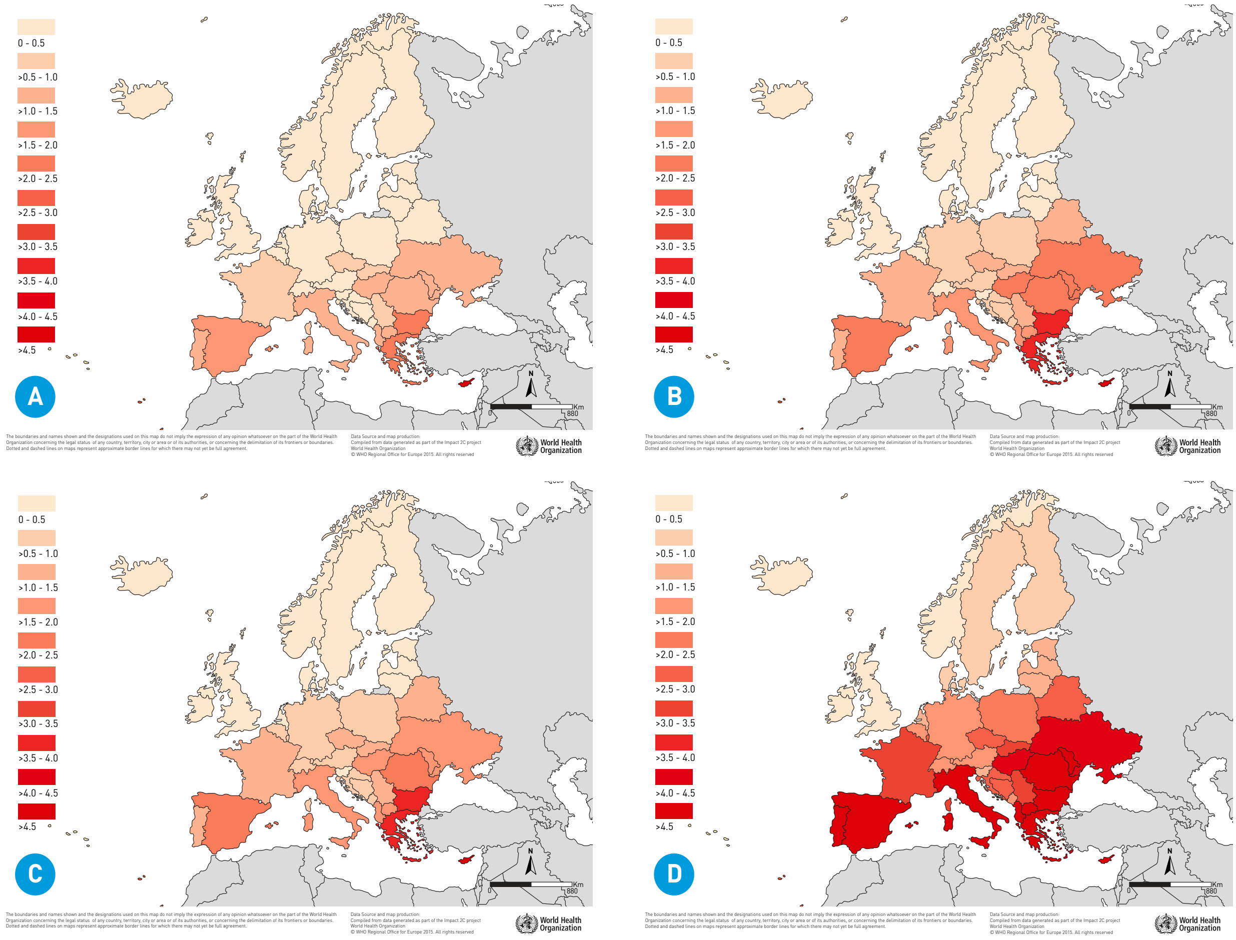


Figure 5.2 | Attributable fraction of heat-related deaths during summer by country in European sub-region, A) RCP4.5 in 2050; B) RCP8.5 in 2050, C) RCP4.5 in 2085 and d) RCP8.5 in 2085 (from Kendrovski et al. 2017).

current 0.4% to 20.3%, 32.6% or even 48.4% in 2050 depending on the scenario combination – unless substantial political changes occur rapidly and steadily shift the current socio-economic development pathway towards sustainability (Rohat et al. 2019). However, the impact of heat on mortality will be influenced more by socio-economic factors that enhance vulnerability than by exposure to high temperatures. Effects of heat-related mortality in Europe will vary considerably, with the Mediterranean region being the most affected (Mayrhuber et al. 2018).

Heat wave changes under the RCP4.5 and RCP8.5 scenarios will mainly affect the countries of Mediterranean Europe and eastern Europe (Kendrovski et al. 2017). More specifically, for the middle of the 21st century, 2035-2064, annual attributable mortality will increase by a factor 1.8 and 2.6 for RCP4.5 and RCP8.5, respectively, compared to the period 1971-2000. Heat wave attributable mortality at the end of the century will increase by around 3 and 7 times under RCP4.5 and RCP8.5 (Kendrovski et al. 2017). *Fig. 5.2* presents the mean warm season attributable fraction (the fraction of deaths attributable to mean apparent temperature above the threshold) based on the SMHI RCA4/HadGEM2 ES r1 (MOHC) climate model.

By the end of the 21st century (2090–2099), southern European countries are expected to experience a temperature increase of 1.9°C (1.3-2.2°C) and 4.5°C (3.0-5.1°C) respectively for RCP4.5 and RCP8.5, compared to the mean of 2010–2019 in a GCM-ensemble assuming no population changes (Gasparrini et al. 2017) *(Section 2.2)*. The greatest changes in heat-related excess mortality are projected for southern Europe, with a 10.5% increase (IC95%: 5.6-17.3). For mortality related to heat waves, although the largest temperature increases are expected in southern Europe (for the period 2031–2080, changes in the 95th percentile: Italy 1.7°C and 3.2°C and Spain 1.4°C and 3.0°C, under RCP4.5 and RCP8.5, respectively), the area will not experience the greatest excess mortality linked to heat waves, as a result of population adaptation and prevention plans (Guo et al. 2018).

5.2.5.3 Cold-related impacts

As global warming progresses, a decreasing trend in cold extremes is expected. However, highly variable future climates may retain cold wave hazards as a locally important threat. Cold-related mortality is also expected to increase with expected demographic changes in European cities (Smid et al. 2019), but the effect of cold waves on aging populations is not as pronounced as the heat, since its relationship with respiratory diseases affects younger age groups. At European level, cold-related mortality is projected to decrease by the 2080s as much as heat-related mortality is expected to increase for the same period (EEA 2017). Better social, economic and housing conditions in many European countries may encourage the estimated decreasing risk, despite the expected higher variability.

5.2.5.4 Vector- food- and water-borne diseases

The rise in temperature may lead to a geographic expansion of Euro-Mediterranean areas that are currently climatically suitable for WNV, and also to an extension of the transmission season, with the extent and pattern of changes varying depending on the location and degree of warming (Semenza et al. 2016). The transmission risk for WNV in Euro-Mediterranean areas varies spatially as well as temporally (Conte et al. 2015). Early summer months will provide suitable climatic conditions in Tunisia, Libya and Egypt, while in the European continent suitable conditions prevail only from July. From August to October, significantly increased transmission risk will characterize Italy, France, Spain, the Balkan countries, Morocco, northern Tunisia, and all along the Mediterranean coast of Africa and the Middle East. In November, with the exception of limited European coastal areas of the Mediterranean, the risk will be very low, while in North African and Middle Eastern coastal areas the same is valid from December. Projections for Europe indicate a continuous extension of regions with an increased risk of WNV infections, mainly on the fringes of the regions of transmission (Conte et al. 2015). Predictions for 2025 show an elevated risk in northeastern Greece, eastern Croatia and northwestern Turkey, while in 2050 high-risk areas expand further (Semenza et al. 2016; Semenza and Suk 2018).

Southernmost parts of Europe do not generally provide climatically suitable areas for Chikungunya transmission in the 21st century, except for restricted areas in France and North Italy at the end of the century (Fischer et al. 2013). A significant reduction of habitat suitability for Aedes albopictus is projected for the middle of the 21st century in southern Europe and the Mediterranean, related to significant increase of summer temperatures (Caminade et al. 2012; Proestos et al. 2015). Similar results are found for the end of the century (Tjaden et al. 2017) *(Section 2.2.4.2)*.

Since populations are exposed to variability in weather patterns and increasingly warm temperatures, there is high confidence for increased risks of food- and water-borne diseases, such as diarrheal diseases and *Salmonella* spp. (Smith et al. 2014). With rising average temperatures and an increase in the frequency and length of heat waves, a rising number of cases of food-borne illness are expected in a business-as-usual scenario unless education, epidemiological surveillance and enforcement (related to food safety) are intensified. This will be compounded in the event of power outage due to peak energy demand (e.g., during heat waves) that may lead to malfunction of food preservation practices (refrigeration) (The Malta Resources Authority 2017).

5.2.5.5 Air quality

Climate change alters the dispersion of primary pollutants, particularly particulate matter, and intensifies the formation of secondary pollutants. According to global estimates, the number of days with ozone concentrations exceeding the thresholds for protection of human health are expected to increase. In polluted areas with high levels of nitrogen oxides (NO_x), high surface temperature and humidity *(Section 2.2.4.2)* may generate an increase of surface O_3 concentrations, especially in southern Europe (Doherty et al. 2017). By the middle of the 21st century in southern Europe, climate change is expected to lead to an increased summer mean O_3 (0–3 ppb) and increased summer daily maximum O_3 (3–6 ppb) (Langner et al. 2012; Doherty et al. 2013, 2017; Colette et al. 2015). For RCP8.5, the Mediterranean Basin may experience an annual average difference in stratospheric origin ozone concentration at sea level of above 5 ppb by the end of the 21st century (Meul et al. 2018).

Regional projections indicate an increase of 10 to 14% in ozone-related morbidity and mortality from 2021 to 2050 in several countries, including France, Spain and Portugal. For 2050 a 8 to 11% increase in non-accidental mortality is expected, and for 2080 a 15 to 16% increase, compared to the year 2000 (O_3 and PM2.5 combined) in Europe (Orru et al. 2017). Changes in PMs under climate change still require further study, and important uncertainties remain with regard to the impact of temperature change on PM components, together with still uncertain precipitation patterns (Doherty et al. 2017). The relationships between climate change, air pollution and air pollution-related health impacts depend highly on the climate change scenario used, and on projections of future air pollution emissions, with relatively high uncertainty. Further studies focusing on effects on morbidity are needed (Orru et al. 2017).

5.2.6 Resilience, preparedness and adaptation

5.2.6.1 Health preparedness and adaptation measures

Health preparedness and adaptation to climate change includes adaptation of health systems to access morbidity due to extreme events, and adaptation of the built environment in order to reduce the burden of extreme climate. The quality of health systems and accessibility to healthcare is different across countries in the Mediterranean, largely along the North/South division. Health systems in the Mediterranean face climate change in the context of an increasingly elderly population, which is particularly vulnerable to heat waves, an increase in vector-borne diseases, and an increase in climate migration to Mediterranean countries. For health systems in the southern Mediterranean, another challenge is the declining resources for this sector (Sanderson et al. 2018). While investment in climate-related adaptation health systems appears to be cost-effective (Jeuken et al. 2016), health adaptation in the region is lacking, with only one out of 22 countries in the eastern Mediterranean having a Heat-Health Action Plan (UNEP 2018). Increasing preparedness of health systems in the Mediterranean Basin may be supported by the following measures:

- Implementation of heat early warning systems,
- Preparedness of emergency medicine professionals for treating morbidity related to extreme climate events, such as heat waves, cold spells and floods,
- Monitoring climate-related morbidity and mortality and designing interventions,
- Monitoring and surveillance of vector-borne diseases, including across borders with neighboring countries,
- Prevention of water-borne and food-borne diseases,
- Provision of access to healthcare, including mental health, to climate migrants,
- Training health professionals, including physicians, nurses and administrative staff regarding the health impacts of climate change, preparedness and adaptation in the health system,
- Increase public awareness of climate change-related health risks, and recommended prevention and mitigation of negative health outcomes, including behavior during heat waves, elimination of habitats for vectors, etc.,
- Expand urban green infrastructure including protecting inside areas and settlements.

5.2.6.2 Regional coordination and collaboration

The Mediterranean Basin, particularly its eastern and southern regions, is an area troubled by internal and cross-border conflicts, limited cross-border collaborations and limited links to the international frameworks for the whole Mediterranean. There are EU-funded regional frameworks such as Climate ADAPT Mediterranean area, that covers the southern part of Portugal, Mediterranean areas of Spain and France, almost all of Italy and the whole extension of Slovenia, Croatia, Greece, Malta and Cyprus, Albania, Bosnia-Herzegovina and Montenegro (https://climate-adapt.eea.europa.eu/). ClimaSouth covers Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine and Tunisia (http://www.climasouth.eu/en). While both frameworks emphasize on increasing resilience, human health is not at the center of these programs. Other frameworks focus on infectious diseases, e.g., the Middle East Consortium on Infectious Disease Surveillance (MECIDS) that coordinates between Israel, Jordan and the Palestinian Authority (http://www.mecidsnetwork.org/). Climate change is expected to affect the Mediterranean, with heat and drought impacts on morbidity and migration, and vector-borne diseases spreading across borders. It is a challenge for countries that lack diplomatic relations to collaborate, but health agencies prove that it is possible (e.g., in the case of MECIDS), and regional collaboration at the Mediterranean level should be a priority for health agencies in the region.

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