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Review article

Impacts of climate change on the public health of the Mediterranean Basin population - Current situation, projections, preparedness and adaptation

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ABSTRACT

The Mediterranean Basin is undergoing a warming trend with longer and warmer summers, an increase in the frequency and the severity of heat waves, changes in precipitation patterns and a reduction in rainfall amounts. In this unique populated region, which is characterized by significant gaps in the socio-economic levels particularly between the North (Europe) and South (Africa), parallel with population growth and migration, increased water demand and forest fires risk - the vulnerability of the Mediterranean population to human health risks increases significantly.

Indeed, climatic changes impact the health of the Mediterranean population directly through extreme heat, drought or storms, or indirectly by changes in water availability, food provision and quality, air pollution and other stressors. The main health effects are related to extreme weather events (including extreme temperatures and floods), changes in the distribution of climate-sensitive diseases and changes in environmental and social conditions. The poorer countries, particularly in North Africa and the Levant, are at highest risk. Climate change affects the vulnerable sectors of the region, including an increasingly older population, with a larger percentage of those with chronic diseases, as well as poor people, which are therefore more susceptible to the effects of extreme temperatures. For those populations, a better surveillance and control systems are especially needed. In view of the climatic projections and the vulnerability of Mediterranean countries, climate change mitigation and adaptation become ever more imperative. It is important that prevention Health Action Plans will be implemented, particularly in those countries that currently have no prevention plans. Most adaptation measures are "win-win situation" from a health perspective, including reducing air pollution or providing shading solutions. Additionally, Mediterranean countries need to enhance cross-border collaboration, as adaptation to many of the health risks requires collaboration across borders and also across the different parts of the basin.

1. Introduction: vulnerability and risk - main causes

Climate change is a complex phenomenon that is threatening all aspects of human society including increasing risks to human life and health (COP24, 2018). Most climate-related health impacts are mediated by complex ecological, environmental and social processes, while the impacts vary in magnitude, scale and duration as a function of the local environmental conditions and the vulnerability of the human population (Shuman, 2010; Smith et al., 2014; Crowley, 2016). Climate change impacts the human health directly through extreme heat, cold, drought or storms, or indirectly by changes in air quality, water availability, food provision and quality, and other stressors. The main health effects are related to extreme weather events (including extreme temperatures, droughts and floods), changes in the distribution of climate-sensitive diseases (such as vector-, water- and food-borne diseases), and changes in environmental and social conditions (EU, The Climate Policy). According to the WHO, between 2030 and 2050, climate change is expected to cause approximately 250,000 additional deaths per year, from malnutrition, malaria, diarrhea and heat stress alone. The direct damage costs to health is estimated to be between USD 2–4 billion per year by 2030 (WHO, 2019).

The current paper reviews the impacts of climatic changes on the

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health of the Mediterranean Basin population by presenting the current situation in the region and the main projections for the next decades. Additionally, the review deals with health preparedness and adaptation measures in the health systems. The literature search process was conducted by systematic and semi-systematic search using PubMed and Google Scholar with relevant keywords such as 'climate change', 'heat wave', 'Mediterranean' OR 'names of Mediterranean countries', 'West Nile virus' 'Chikungunya', 'Aedes', 'migration', 'mental health', 'early warning', 'mitigation', 'adaptation'; among others.

Part of the search were done according to a modified PRISMA methodology, such as that laid out in (Martinez et al. (2015). The timeframe was 2001–2019 and restricted to English, including both grey literature (filtered according to the AACODS criteria) (Tyndall, 2010) and conventional peer-reviewed scientific literature.

The climate of the Mediterranean basin is determined by the interaction between mid-latitude and sub-tropical circulation regimes and a complex morphology of mountain chains and land–sea contrasts. This makes the Mediterranean a vulnerable region and one of the main climate change hotspots which is most responsive areas to global warming (Giorgi and Lionello, 2008; Negev et al., 2015). Indeed, the annual mean temperatures of the Mediterranean basin-wide are now 1.4 °C above late-nineteenth-century levels which is higher than the global mean warming (Cramer et al., 2018). The Mediterranean Basin is undergoing a warming trend with longer and warmer summers, an increase in the frequency and the severity of heat waves, changes in precipitation patterns and a reduction in rainfall amounts (Cramer et al., 2018). With significant gaps in the socio-economic levels among the Mediterranean countries, particularly between the North (Europe) and South (Africa), parallel with population growth and migration (WorldBank, 2017), increased water demand under conditions of decrease in water availability and quality (Bucak et al., 2017), ecosystems degradation (Coll et al., 2010) and increased risk for forest fires (Turco et al., 2014) - the vulnerability of the Mediterranean population to human health risks increases significantly. Since health impacts largely arise due to exposure and vulnerability, they are enhanced by climate change. These additional climate-related stressors create increased risks and make the communities of the Mediterranean Basin more vulnerable (Cramer et al., 2018).

Population vulnerability to climate change is strongly influenced by socioeconomic and demographic factors (Smith et al., 2014). Although the main factors of vulnerability may vary geographically, depending on the social, economic and political setting, there are some commonalities across populations in terms of risk factors (UNEP, 2018). The following parameters impact the population's risk:

1.1. Ageing and those suffering from chronic diseases

The older persons are particularly at risk to the health effects of climate change, such as heatwaves, due to dysfunctional thermoregulatory mechanisms, chronic dehydration and the use of medications. People with pre-existing diseases, especially cardiovascular or pulmonary illnesses (Mayrhuber et al., 2018) and with chronic diseases like diabetes are more vulnerable (Yardley et al., 2013), as are those who are obese and those with cognitive impairment (Bouchama et al., 2007; Linares et al., 2016).

1.2. Gender

Gender vulnerabilities may stem from differences of a collective nature (such as body size, physical condition), or physiological factors such as women's tendency to sweat less than men (Gagnon et al., 2013), a natural thermoregulation mechanism which might explain the greater impact of heat on women than on men. 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). Gender may be related also to social factors such as differences in social isolation, a factor that tends to be greater among men than among women, and may prove a risk factor in a heat-wave situation (Canouï-Poitrine et al., 2006). Also women living in a single household (de'Donato et al., 2018) are cited to be more vulnerable.

1.3. Geographic location

Most of the studies show that there is important geographical variability in the effects of climate change on morbidity and mortality that are in relation with geographic location and sensibility of populations to heat and extreme events (Allen and Sheridan, 2018). The regional or local climate varies due to geographic location and other reasons based on the intersection of different variables: meteorological or climate-related variables (temperature, humidity, and wind), geographic variables (latitude), use of the subsoil (urban vs. rural, or periurban) (de' Donato et al., 2015).

1.4. Socioeconomic status

Population vulnerability to high temperatures are affected by socioeconomic factors (Semenza et al., 2008). Studies show that the health effects of heat waves are particularly pronounced among people who are socially isolated, substance abusers and the homeless (Nicolay et al., 2016). Populations living in poverty might be less likely to have secure, air-conditioned homes (Paz and Semenza, 2013) and therefore become more vulnerable to the impacts of extreme heat. 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 from heat and other extreme events (McMichael et al., 2012).

1.5. Level of acclimation

Climate change will affect an increasingly ageing population, with a larger percentage of those with chronic diseases, which is therefore more susceptible to the effects of extreme temperatures such as more frequent and more prolonged heatwaves. In fact, people over the age of 65 years are identified as being particularly vulnerable for heat impacts as this target population is known to suffer disproportionately from energy poverty and to live 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 of 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 socioeconomic circumstances and infrastructure of homes, as well as the increase in the number of air cooling facilities (Díaz et al., 2018a,b), among others.

1.6. Occupational health

Extreme heat and cold waves have been linked to an increased risk of occupational injuries. Studies reporting important losses in work capacity and productivity linked to climate warming. The impact of heat waves seems to be increasing in those aged 18–44 years, the risk factors associated with this age group, such as occupational, coupled with a lower awareness of prevention plans (Díaz et al., 2015). Several mechanisms are thought to underlie 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). Similarly, 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, which can also trigger occupational injuries (Makinen et al., 2009). The sectors with a high percentage of outdoor workers, mainly agriculture and construction, have the highest risk of injury.

The recent report of The Lancet Countdown on Health and Climate Change (Watts et al., 2019) refers to the economic cost of the impact of climate change on the ability to function under increased heat stress and shows an upward trend of potential work hours lost (WHL) since 2000. In 2018, 45 billion work hours more than in 2000, were lost. Of note, for 300 Watts (W) work in the shade (typical for manufacturing), over 10% potential daily work hours were lost in densely populated regions such as the Nile Delta of Egypt in the southern Mediterranean.

1.7. Influence of urban landscape

Urban Heat Islands (UHI) are considered to be one of the greatest problems of the 21st century confronted by humanity and results from increasing urbanization and industrialization (Memon et al., 2008). The temperature differences between cities and rural areas due to the UHI effect can reach values of up to 10 °C in large cities. The effect of heat in urban areas increases with population density, extensive economic activities and city expansion (Milojevic et al., 2016; Burkart et al., 2016). Factors that amplify the vulnerability or exposure to the urban heat island effect are 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 later irradiation during the night), and lack of good thermal isolation (Lopez-Bueno et al., 2019; Vandentorren et al., 2006).

2. Direct impacts on the Mediterranean population: recent and current situation

2.1. Heat related impacts

2.1.1. Historical pattern of temperature effects on mortality and time-trends

Global temperatures and the frequency and intensity of heatwaves will rise in the 21st century as a result of climate change. Extended periods of high day and nighttime temperatures create cumulative physiological stress on the human body which exacerbates the top causes of death globally. Heatwaves can acutely impact large populations for short periods of time often trigger public health emergencies, result in excess mortality, and cascading socioeconomic impacts (e.g. lost work capacity and labor productivity) (WHO, 2011).

Heat waves were the deadliest extreme weather events in the European Region in the period 1991–2015, and they caused tens of thousands of premature deaths. The greatest impact of heat in terms of deaths attributable to extremely hot temperatures was observed in the Mediterranean cities: Athens, Barcelona and Rome (Guo et al., 2016). Actually, despite the population aging observed in Europe and the increase in temperatures as a consequence of global warming, in general, there has been a decrease in the impact of heat on daily mortality (Vicedo-Cabrera et al., 2018). This lower impact of heat on mortality could be related to various factors, like the existence of Heat Health Action Plans (HHAPs) (present in 66% of European countries), and geographic variability (since the effect of heat is lesser in warmer locations probably due to "greater awareness", the existence of air conditioning, improvements in health services, and improvements in building design e.g. insulation of roofs, facades and exposed walls in housing infrastructure, the use of double glazing for apertures, and shadowing apertures from direct sunlight (Vicedo-Cabrera et al., 2018; Díaz et al., 2018a,b).

In Europe, there is a pattern of greater decrease in mortality due to heat in places with warmer temperatures, as the northern Mediterranean countries (Díaz et al., 2018a,b). This can be explained by greater efforts at raising awareness among the population of the health effects of heat (Ragettli et al., 2017) and preventive measures, such as early warning and response systems, that alert the public to take preventive measures (e.g. to stay indoors and drink more) during extreme weather events (such as heatwaves). There has also been an important decrease in heat-related mortality among children and elderly people, although the decrease among the elderly has been less demonstrated (Schifano et al., 2012; Díaz et al., 2015). Other studies find no consistent differences by age group (de' Donato et al., 2015). The reduction in heat-related mortality has also been analyzed by gender (Allen and Sheridan, 2018), and the majority of studies have not found differences between men and women related to the decrease in heat-related mortality.

A study of nine European cities (de' Donato et al., 2015) compared the deaths attributable to heat in two different periods, prior to (1996–2002) and after (2004–2010) the heat wave of 2003. The study showed a reduction in mortality due to heat in Mediterranean cities (Athens and Rome) that was not present in cities in Northern Europe, which the authors associate with the implementation of prevention plans, a greater level of adaptation of the local population and greater awareness of the population about exposure to heat, which could be related to the greater presence of the issue in the media. In France, the implementation of the prevention plan and alert system after the heat wave of 2003 is considered to be responsible for a reduction of 4400 deaths during the heat wave of 2006 (6452 deaths expected vs. 2065 produced), benefitting especially those over age 75 years (Fouillet et al., 2008). More recently, a sharp decrease in mortality attributable to heat over the past 10 years has been reported in Spain (Díaz et al., 2018a,b).

A study carried out in 16 Italian cities concluded that there had been a reduction in daily mortality due to extreme temperatures during the summer among the population over age 65, which the authors attribute to variations in the temperature distribution during the summer, changes in the patterns of susceptibility of the population and the introduction of prevention programs, which could have played a key role in mitigating the impact of high temperatures. The study alerts the fact that there is still an effect of mild temperatures, which can be detected at the beginning and end of the summer (May and September), and therefore the recommendation is to extend the activation period of the prevention plans to include these months (Schifano et al., 2012). In the city of Florence (Italy), there was a general reduction in mortality in the face of high temperatures. Risk went from 23% for the period 1999–2002 (without a prevention plan) to 21% for the period 2004–05 (with a prevention plan) and to 12% for the period 2006–07 (with a prevention plan) and only affected those age 75 and older. The effect of heat on mortality was greater and was of a longer duration in the first period, which the authors associate with prevention measures and the implementation of a plan with specific interventions to protect health among people who were elderly and frailer. For Rome, the prevention plans were especially successful among older people due to the campaigns that targeted them specifically (Morabito et al., 2012). In addition to this evidence, there are also studies that have not found an association between the decrease in mortality due to heat and the implementation of prevention plans. In Athens, one of the hottest cities in Europe and a place where the impact of high temperatures is greatest, there has also been a decrease in mortality due to heat among elderly people, despite not having a prevention plan (de' Donato et al., 2015). In the city of Madrid, despite the fact that the heat wave of 2005 was of less intensity than that of 2003, in 2003 for each increase of 1 °C in temperature the risk of mortality increased by 23%, while in 2005 it increased to 47%. The study could not conclude that prevention plans and high temperature warning systems served to decrease heat-related mortality (Culqui et al., 2014). Other studies show that the decrease in heat-related mortality in Spain cannot be consistently attributed to prevention plans and that it varies spatially (Linares et al., 2015a,b). Heat may also impact social behavior. A study in Madrid found an association between heat waves and increase in intimate partner violence, including increase in police reports and help line calls three days fter the heat wave (Sanz-Barbero et al., 2018).

2.1.2. Heat impact on other health variables

Studies that analyse the impact of heat waves on hospital admissions are less numerous than those that focus on mortality, and generally report less impact on admissions than on mortality (Kovats et al., 2004a, Kovats et al., 2004b; Mastrangelo et al., 2006; Linares and Díaz, 2008; Li et al., 2015). This might well be explained by the fact that processes linked to heat-related mortality tend to be acute processes which develop within a very short space of time (Mastrangelo et al., 2006) and so result in the persons affected not being admitted to hospital. Ranking high among such causes would be circulatory diseases (Alberdi et al., 1998; Argaud et al., 2007), since respiratory diseases usually present at a later point in time in the case of heat, as a consequence of the exacerbation of other already existing diseases (Viegi et al., 2006), something that is in line with the results found in this study in terms, not only of the diseases themselves, but also of the lags at which the association with heat appears. For these reasons, studies such as the one conducted in Apulia on the impact of the 2011 heat wave on cardiovascular diseases, using calls to the emergency and telemedicine services as an indicator (Brunetti et al., 2014; Sun et al., 2014; Ng et al., 2014; Kataoka et al., 2015; Calkins et al., 2016), provide a new perspective for the study of the effect on morbidity in relation to cardiovascular diseases. Otherwise, in Zhang et al. (2007), the authors conducted a systematic review of the studies of disability-adjusted life years (DALYs) lost because of climate change. The measurement of DALYs attributable to climate change presents additional difficulties over measurement of DALYs attributable to other causes. Further studies linking DALYs and climate change should be conducted in various populations and in different ecological regions, including developing countries.

2.2. Heat impact time-trends by specific causes and gender perspectives

Some studies show a similar decrease in mortality due to respiratory and cardiovascular causes (Bobb et al., 2014; Ng et al., 2016) but others find a decrease only for cardiovascular mortality (Muthers et al., 2010; Miron et al., 2015). These decreases in the impact of heat have also been found for morbidity due to cardiovascular causes (Fechter-Leggett et al., 2016), while other studies detect an increase in hospitalizations (Carter et al., 2005) and in the calls to ambulance services (Nitschke et al., 2011) for cardiac causes, heat stroke and other heat-related illnesses.

The reduction in heat-related mortality has also been analyzed by gender (Sheridan and Allen, 2018), and the majority of studies have not found differences between men and women related to the decrease in heat-related mortality. There has also been an important decrease in heat-related mortality among children and elderly people, although the decrease among the elderly has been less demonstrated (Coates et al., 2014). Other studies find no consistent differences by age group (de'Donato et al., 2015).

2.3. Cold related impacts

2.3.1. Historical pattern of temperature effects on mortality and time-trends

While the increase in winter mortality associated with low temperatures has been studied for a number of decades and has more recently been associated with extremely low temperatures or cold waves (The Eurowinter Group, 1997), it is nevertheless a phenomenon that has attracted far less attention than has the analysis of heat waves, though its impact on mortality is at least comparable, with some studies undertaken in the UK and Australia even indicating that cold-related deaths are of an order of magnitude greater than those related to heat (Vardoulakis et al., 2014). In 2017 Gasparrini et al. analyzed the impact of extreme temperatures under different climate change scenarios over a long time horizon, 2090–2099 (Gasparrini et al., 2017) and concluded that southern European regions were going to experience an increase in heat-related mortality and a clear decline in cold-wave-related mortality. This means in turn that the greater the increase in greenhouse-effect gas emissions, the greater the intensity of any increase in summer mortality. These conclusions are reached on the twin assumptions that there will be no population acclimatization processes to such extreme temperatures and no changes in the population mortality rate. In contrast, other studies indicate that populations are indeed adapting to heat (Oudin Åström et al., 2018). Despite the rise in mean temperatures across the planet (IPCC, 2013) under a climate change scenario, cold waves are not going to disappear. Added to this the fact that the impact of cold-related daily mortality is greater than that of heat-related daily mortality (Carmona et al., 2016), from a public health standpoint it is essential that the impact on mortality is analyzed by considering the impacts of heat and cold waves jointly.

2.3.2. Heat and cold impacts at short-term led by temperature variability

Recently another indicator has been considered in relation to the temperature variability (TV) with important impact on public health. TV indicator calculated from the standard deviation of the minimum and maximum temperatures during the exposure days. A study from 372 locations in 12 countries/regions (Australia, Brazil, Canada, China, Japan, Moldova, South Korea, Spain, Taiwan, Thailand, the United Kingdom, and the United States) (Guo et al., 2016), shows that there was a significant association between TV and mortality in all countries, even after controlling for the effects of daily mean temperature. In stratified analyses, TV was still significantly associated with mortality in cold, hot, and moderate seasons. Mortality risks related to TV were higher in hot areas than in cold areas when using short TV exposures (0–1 days), whereas TV-related mortality risks were higher in moderate areas than in cold and hot areas when using longer TV exposures (0–7 days).

Another study in Australia (Cheng et al., 2019) for the five most populous Australian cities (Sydney, Melbourne, Brisbane, Adelaide, and Perth), from 2000 to 2009, shows that the greatest percentage increase inmortalitywas for cold followed by heat and TV. The most of attributable deaths were due to cold and noticeably, contribution from TV was greater than that from heat. The results indicate that more attention should be paid to unstable weather conditions in order to protect health. These findings may have implications for developing public health policies to manage health risks of climate change.

2.4. Vector-borne diseases

2.4.1. Impacts of climate change on vector-borne diseases

One of the main impacts of environmental and climatic changes on the human health is the influence on vector-borne diseases (VBDs) transmission since a warmer climate and changing rainfall patterns may create hospitable environments for mosquitoes, ticks, and other climate-sensitive vectors (Crowley, 2016).

Long-term anthropogenic climate change interacts with natural variability (such as perennial variability in precipitation amounts), 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. These influences may reinforce one another (Campbell-Lendrum et al., 2015). The impacts of climatic changes are potentially complex and further complicated by nonlinear feedbacks inherent in the dynamics of many infections (Metcalf et al., 2017) including impacts of other environmental drivers such as biodiversity loss or intense changes in land use (Marcantonio et al., 2015). Although climate is one of several factors that influence the distribution of VBDs, it is well known as a major environmental driver influencing

Table 1
Linkages between VBD transmission and climate variability in the Mediterranean Basin (selected examples).

Vector-borne disease	Distribution of cases in Mediterranean/ Adriatic countries (based on ECDC reports)	Linkage with climatic parameter	References
West Nile Virus	France, Italy, Greece, Croatia, Cyprus, Turkey, Israel	Temperature increase (heat waves) during the hot season before diagnosis	Paz et al., 2013; Tran et al., 2014; Marcantonio et al., 2015; Moirano et al., 2018
		High precipitation amount before diagnosis in late winter/early spring	Marcantonio et al., 2015; Moirano et al., 2018
Chikungunya	Spain, France, Italy, Greece	There is a current potential distribution of mosquito vectors in the Mediterranean countries	Kamal et al. (2018)
Leishmaniasis	Algeria, Libya, Tunisia, Israel, Turkey	Ambient temperatures during early night successfully explained the high proportion of the variance in the spatio-temporal of the vectors activity patterns	Waitz et al. (2018).

their complex epidemiology (Reisen et al., 2014; Paz, 2015). Following the recent climatic and environmental changes in the Mediterranean basin (Cramer et al., 2018), it is expected that VBDs 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 advanced socio-economic level. Many activities, particularly social gatherings, occur in outdoor locations such as shaded balconies, courtyards, outdoor restaurants and in the countryside - all ideal for contact with the vector. While warmer summers extend the potential range of the disease, the 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 Leishmaniosis (Table 1).

2.4.2. Vector-borne diseases in the Mediteranean basin

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. It is known that ambient temperature increase causes an upsurge in the growth rates of mosquito populations, a decrease in the interval between blood meals and a shortening in the incubation time in mosquitoes (Paz, 2015; Moirano et al., 2018). Indeed, clear associations have been found during the past years between warm conditions and WNV outbreaks in various locations including 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), annual outbreaks occur every summer (2011–2019) and provide evidence of ongoing transmission in Europe and Euro-Med countries (Semenza and Suk, 2017). During the last decade, WNV outbreaks in humans erupted in many Mediterranean and Adriatic countries including France, Italy, Croatia, Slovenia, Greece, Turkey, Israel and the Mediterranean islands (European Centre for Disease Prevention and Control ECDC, 2019a). It is worth noting that in 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 the response of disease incidence is influenced by the amount of precipitation (increased rainfall, floods or droughts), depending on the local conditions and the differences in the ecology and sensitivity of mosquito species (Paz, 2015, 2019). In the Mediterranean area, increased rainfall and humidity together with high temperatures have probably favoured the multiplication of Culex species, leading to the occurrence of numerous cases of WNV infection in humans in Central Macedonia in summer 2010 (Papa et al., 2010). Paz et al. (2013) did not detect significant linkages between rainfall amounts and WNV cases in the Mediterranean region. However, they noted that three infected sites, Trapany (Sicily, Italy), Campobasso (Molise, Italy) and Thessaloniki (Greece), were rainier than usual in July. In northern Italy, heavy precipitation has been associated with the incidence of WNV infection after a lag of 2–3 weeks (Moirano et al., 2018). A study for Europe and the Mediterranean stressed the importance of water bodies in the risk of WNV transmission by showing that areas including wetlands with positive anomalies of the Modified Normalized Difference Water Index (MNDWI) in June are more at risk (Tran et al., 2014). 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).

Aedes *aegypti* and Ae. *albopictus* are the primary vectors that transmit several arboviral diseases, including dengue, yellow fever, chikungunya, and Zika. These viruses are widely distributed across tropics and subtropics regions of the world. Based on present-day climatic conditions, there is a current potential distribution of Ae. *aegypti* and more widely of Ae. *albopictus* in the Mediterranean countries (Kamal et al., 2018), which is similar with the current known distribution of Ae. *albopictus* in the region (European Centre for Disease Prevention and Control ECDC, 2019b).

Chikungunya is a viral disease transmitted by Aedes mosquitoes to humans. The most common clinical form associates fever, arthralgia and rash. In 2007, an outbreak of autochthonous chikungunya virus infections took place for the first time in Euro-Med country (Italy). In 2010, 2014, autochthonous cases were reported in France. The risk of chikungunya spreading in 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 has been confirmed in southeastern France (WHO, 2017a) and in Italy, six in Rome and eight in the coastal area of Anzio in Lazio Region (WHO, 2017b).

During August 2019, three cases of locally acquired Zika virus (ZIKV) disease were detected in southern France (Hyères city, Var department), laboratory confirmed in October 2019. The cases had no travel history to Zika-endemic countries, which reinforces the hypothesis of autochthonous vector-borne transmission of ZIKV in this neighbourhood of Hyères city. This event was the first report of vector-borne transmission of ZIKV by *Aedes albopictus* in Europe (ECDC, 2019c).

Leishmaniasis is a vector-borne disease with two main clinical forms: Cutaneous Leishmaniasis (CL), and a 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 Cutaneous Leishmaniasis (CL) species, which manifest as skin sores, are common: Leishmania major and Leishmania tropica. Leishmania tropica, transmitted by the Phlebotomus sergenti sand-fly, 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). In a research on the temperature effects on the sand fly *Phlebotomus sergenti* and *Phlebotomus arabicu*, the vectors of *L. tropica* in the eastern Galilee (Israe), ambient temperatures for early night successfully explained the high proportion of the variance in the spatio-temporal sand fly activity patterns (Waitz et al., 2018).

2.5. Food- and waterborne diseases

Climate change increases the risks of food- and waterborne diseases (Ebi et al., 2018). For example, it is known that survival and multiplication of salmonellosis in the environment and in food is influenced by high temperatures (Miraglia et al., 2009; Milazzo et al., 2016). The relationship between environmental temperature and reported Salmonella infections have been investigated in the past for ten European countries including Spain. It was detected that temperature influences transmission of infection 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., 2004a, 2004b).

Campylobacter species have emerged as leading bacterial causes of gastroenteritis and foodborne infections in developed countries (EFSA (European Food Safety Authority) and ECDC (European Centre for Disease Prevention and Control), 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). Indeed, 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 authors noted, however, that 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. However, in summer 2018, large outbreak of human leptospirosis was linked to contaminated water bodies in northern Israel after years of severe drought conditions resulted in seasonally low water levels in the region (Dadon et al., 2018).

2.6. Mental health

Climate change has a negative impact on mental health through multiple pathways. Loss of homes, destruction of settlements and damage to communities due to floods, droughts and sea level rise, cause anxiety, depression and post-traumatic stress disorders which can persist for years (Watts et al., 2015). However, the mental health impacts of climate change remain an under researched field internationally (Watts et al., 2018) and regionally in Mediterranean countries. The few studies that were conducted in the Mediterranean found negative impact of high temperature on mental health. For example, in Thessaloniki, Greece, research showed that high temperature is associated with male suicide. In the context of the economic crisis in Greece, a multilinear regression showed that high temperature explains 51% of the variance in male suicides while unemployment was found insignificant (Fountoulakis et al., 2016). Another study in Northern Italy found a strong positive association between number of daily emergency psychiatric visit and mean daily air temperature (Cervellin et al., 2014). More research is needed regarding the impact of difference extreme climatic events on diverse mental health outcomes (Berry et al., 2018a, 2018b).

3. Indirect impacts: recent and current situation

3.1. Air quality

Few studies address the issue of synergy between meteorological conditions and pollution and the effects on health. Climate change can affect air quality, and as a result impact the human health, through several pathways such as changes in the ventilation and dilution of air pollutants, removal processes, stratosphere–troposphere exchange of ozone and increase in the frequency of wildfires (Fiore et al., 2015; Von Schneidemesser et al., 2015). Emissions of ozone precursors can increase at higher temperatures, promoting higher ozone concentrations (Kinney, 2018). Indeed, positive association has been observed between high temperatures, ozone and PM10 concentrations with mortality, especially on days of heat waves (Katsouyanni et al., 2009). An increase in mortality of 1.66% was observed for each 1 °C increase in temperature on days with low ozone levels and an increase of up to 2.1% in days of high ozone (Analitis et al., 2008). NOx emissions can also increase with temperature, due to increased fossil fuel combustion for electricity generation during heat waves (Kinney, 2018). A positive relationship has also been observed between cardiovascular mortality and the concentrations of nitrogen dioxide (NO2), the main precursor of tropospheric ozone (Nuvolone et al., 2013).

The main emission source of pollutants is vehicle traffic, which is concentrated in large cities. Levels of air pollutants, e.g. PM2.5, have been observed to have increased as a result of the increase in the fleet of fossil-based motor vehicle cars as is the case in Mediterranean countries such as Malta (National Statistics Office, Malta, 2019)

According to global estimates, it is expected that the number of days with ozone concentrations that exceed the thresholds for protection of human health will increase. In Europe, a study of interactive effects between hot temperature and the levels of ozone and PM10 was found (Analitis et al., 2018) to have a detrimental synergistic effect on human health. There have also been studies that have observed no synergy and part of the inconsistency in the reported results may be attributed to specific characteristics of the cities or areas where the studies were done. However, there is accumulating evidence that the warm/hot increasing temperature effects are enhanced by high pollution levels (especially PM10 and ozone) and vice versa and those effects of pollutants are enhanced by the presence of high temperatures.

A recent paper (Lelieveld et al., 2019) focusing on cardiovascular disease burden from ambient air pollution in Europe, estimate that the health impacts attributable are substantially higher than previously assumed, though subject to considerable uncertainty.

These pollutants linked to climate change could also be a major contributor to the unparalleled rise in the number of people sneezing, sniffling and wheezing during allergy season. Nitrogen dioxide and ground-level ozone, appear to provoke chemical changes in certain airborne allergens that could increase their potency. That, in combination with changes in global climate, could help explain why airborne allergies are becoming more common (American Chemical Society 2015).

Moreover, there is a clear link between policies that reduce Greenhouse Gas (GHG) emissions and a reduction of local air pollutants that results in clear health benefits (Smith et al., 2014). That is because of the commonality in the sources, such as power plants, industrial processes and motor vehicles, of both types of pollution. As a result, there is a positive synergy between air quality improvement policies and mitigation ones. In the European Union, for example, Scasny et al., (2015) estimated that a mitigation scenario compatible with +2 °C (RCP 2.6) would reduce total pollution costs, mostly from PM2.5, by 84%, with about 90% of those savings come from human health benefits. Similarly (Schucht et al., 2015), concludes that large health benefits can be expected if the EU were to boost its air quality improvement policies with ambitious climate mitigation ones.

3.2. Mineral dust and forest fires

The main health impacts associated with particulate matter (PM) occur in densely populated urban areas where the principal component in nature is anthropic (Karanasiou et al., 2012) i.e., if one takes an urban area in southern Europe by way of example, 80% of such particulate and aerosol emissions will be seen to be linked to anthropogenic activities, while the remaining 20% continue to have a component of natural origin, stemming 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. The contribution to PM levels by sources of natural origin in southern Europe is fundamentally due to Saharan dust intrusions and PM advections from wildfires. Far fewer studies have analyzed the health impact of PM produced by biomass combustion from wildfires (Finlay et al., 2012). At an international level, these studies have generally focused on hospital admissions due to ensuing respiratory problems (Mirabelli et al., 2009) or exacerbations of previous respiratory diseases (Martin et al., 2013). Warmer and drier conditions in southern Europe in the next decades will increase the risk of large fires with a rise of the burned area (Turco et al., 2018). Recently, exposure to forest fire smoke has also been linked to cardiac diseases (Weichenthal et al., 2017).

Not only does long-distance transport bring about a change in the respective atmospheric concentrations of the different sized particles and in the chemical composition of the particles present in the air (Perez et al., 2012), but there is even evidence to show that desert dust itself transports biological matter harmful to health (Griffin, 2007). The possibility that Saharan dust may contain toxic biological allergens of irritants is supported by several studies (Garrison et al., 2006; Polymenakou et al., 2008). It is also possible that non-biologic compound in dust may generate adverse health effects or that local conditions change the toxicological properties of the dust. May be these two circumstances of change, i.e., in particulate matter (PM) concentrations and chemical composition, make for clearly differentiated morbidity-mortality patterns, which are observable on days with desert dust intrusions as compared to days without 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, meningococcal meningitis, valley fever, diseases associated with toxic algal blooms, and mortality and injuries related to transport accidents (Goudie, 2014).

A study over the years 2001–2015 in the eastern Mediterranean (Israel) found an increase in PM10 concentrations due to dust storms, especially over the last five years. Dust events in the area since 2009 became more extreme with much higher daily and hourly levels. The higher values were recorded in the arid city of Beer Sheva. The authors note that changes in PM10 concentrations over the years are likely attributed to changes in synoptic-scale conditions driven by climate (Krasnov et al., 2016).

A study on 13 southern European cities (Stafoggia et al., 2015), including Madrid and Barcelona, analyzed the relationship between PM10 and hospital admissions and mortality on days with and without Saharan dust advections. The results obtained show that excess PM10-related morbidity-mortality is similar for days with and without these advections. These inconclusive results regarding the effect of Sahara dust intrusion on mortality in Europe, are similar to the findings of Samoli et al. (2011), conducted in Athens (Greece). In this study the PM effects were significantly higher during non-desert dust days because fine PM from traffic sources prevail on non-desert dust days, have more toxic effects than the ones originating from long-range transport, such as Sahara dust. Another research conducted in Italy (Zauli Sajani et al., 2011) concludes that the days with Saharan dust intrusions increase mortality in person aged 75 years or more by respiratory causes but not by circulatory causes. This fact occurs for the whole year and the warm season. At last, in Nicosia (Neophytou et al., 2013) a relation was found with the increment of mortality due to circulatory causes in days with desert dust, but not relation with respiratory causes was found. About the relation studied with Sahara dust intrusions on hospital admissions, one study located in Rome in which analyzed specific causes (Alessandrini et al., 2013), revealed that a clear enhanced effect of PM2.5–10 on respiratory diseases and of PM10 on cerebrovascular diseases emerged during Saharan dust outbreaks. Another study in Nicosia (Middleton et al., 2008), that is not so specific as the Rome study's, established that there was an increased risk of hospitalization on dust storm days, particularly for circulatory causes.

As for air pollution from forest fires -from the standpoint of this PM's impact on mortality, existing studies are few in number, local in scope, and somewhat inconclusive. While a Denver-based study reported no association between wildfire air pollution and increases in daily mortality (Vedal and Dutton, 2006), others such as that undertaken in Athens, showed that so-called medium-sized fires do indeed have an influence on increases in daily mortality (Analitis et al., 2012). In the city of Madrid, the impact of PM advections from biomass combustion on daily all-cause, circulatory-cause and respiratory-cause mortality was analyzed (Linares et al., 2015a,b). The existence of a shift in the PM-related mortality pattern on days with as opposed to those without advection, characterized by an increase in the relative risk (RR) of PM10-related mortality was reported, essentially in the over-75 age group. Similar results were obtained in 10 southern European cities (Faustini et al., 2015), which found that “smoke is associated with increased cardiovascular mortality in urban residents, and PM10 on smoky days has a larger effect on cardiovascular and respiratory mortality than on other days”.

3.3. Migration

Climate change affects vulnerable countries, such as Least Developed Countries (which are mostly African countries), disproportionately. This has direct implications on population displacement across the Mediterranean Sea; more specifically, from North Africa to Europe. The literature suggests that climate change is one factor that is already contributing to the recent increase in migration to the Mediterranean from Sub-Saharan Africa and the Middle East (Costello et al., 2009; Niang et al., 2014). Climate related environmental stressors that impact the health of migrants include heat waves, water shortage, floods and sea level rise (McMichael et al., 2012). There is some evidence that climate change may intensify violent political conflicts in the Mediterranean countries, across 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). Vulnerability to heat-related morbidity and mortality, poor mental health, malnutrition, infectious diseases, and the lack of access to healthcare that many migrants experience intensify their vulnerabilities to climate change related morbidity and mortality (McMichael et al., 2010; Wu et al., 2016; Zimmerman et al., 2011). The WHO issued an Action Plan for Refugee and Migrant Health in the WHO European Region, with strategy priorities including establishing a framework for collaborative action across origin, transit and destination countries, advocating for the right to health, strengthening health systems preparedness and resilience, offering culturaly sensitive health care, and improving health information and communication in appropriate language (WHO, 2016). Certain Mediterranean countries are already providing healthcare to migrants, for example Turkey that provides free healthcare to Syrian refugees under the Temporary Protection regime (World Bank Group, 2015). However, Mediterranean health systems are not prepared for a future increase in climate migration (Negev et al., 2019).

4. Projections for the Mediterranean Basin under global warming of 1.5 °C, 2 °C and more

4.1. Vulnerabilities and risks under different scenarios of warming

Recent Special Report of IPCC (2018) focuses on the impacts of global warming of 1.5 °C above pre-industrial levels. The report shows that a warming of 2 °C poses greater risks to human health than one of 1.5 °C, often with the risks varying regionally (Hoegh-Guldberg et al., 2018). Higher risk is predicted at greater increases in surface air temperature. The risks may be particularly elevated for heat-related morbidity and mortality, heat stress, ground-level ozone, and undernutrition. 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).

4.2. Heat related impacts

The majority of projections about heat-related mortality are made without taking into account the socioeconomic conditions of the population. In order to show the contribution of changes in socioeconomic and climate conditions to mortality due to heat in the European population, a study that combined socioeconomic scenarios with GEIS emissions (RCP) was developed (Mayrhuber et al., 2018). The results showed that the percentage of the European population at risk for thermal stress will be in constant increase over the upcoming years and could increase from the current 4%–20.3%, 32.0% or even 48.4% in 2050 depending on different combinations of scenarios. This study assures that the impact of heat on mortality will be more influenced by socioeconomic factors due the influence on vulnerability than by the exposure to high temperatures. It also finds that the effects of heat-related mortality in Europe will vary considerably, and that the Mediterranean region will be the most affected.

One of the few studies carried out for all of Europe that considers different emission scenarios through RCP 4.5 and 8.5 (Kendrovski et al., 2017) determined that the countries of Mediterranean Europe and Eastern Europe will be those that are most affected by heat waves under difference future scenarios. In this work, 1971–2000 is used as the reference period. For RCP 4.5 for the period 2036–2064, annual attributable mortality will be multiplied by 1.8, and for RCP 8.5 this will be 2.6 times that of the reference period. For the period 2017–2099, the increases will be 2.9 and 7.2 times the reference period for scenarios RCP4.5 and 8.5, respectively.

A multi-country study carried out in different cities in the world (Gasparrini et al., 2017) in the period 1990–2099, without assuming population changes, estimates for the countries in Southern Europe the increases would be 1.9 °C (1.3–2.2) and 4.5 (3.0–5.1), respectively for RCP4.5 and RCP 8.5 with respect to the average values of 15.9 °C in the period 2010–2019. The greatest changes would be produced in the countries of Southern Europe, with increases of 10.5% (IC95%: 5.6–17.3). In terms of heat wave mortality, another study carried out in 412 locations in 20 countries (Guo et al., 2018) analyzed excess mortality from heat waves in some EU countries. The greatest temperature increases occur in countries in the South of Europe. In Italy, the increase is 1.7 °C for the 2031–2080 period for RCP 4.5 and 3.2 °C for RCP8.5. In the case of Spain, the increases in the 95th percentile of the series of average daily temperatures are 1.4 °C for RCP4.5 and 3.0 °C for RCP8.5. According to this study, although the countries of Southern Europe would be those with greater increases in temperatures, they would not be those that experience greater excess mortality associated with heat waves.

4.3. Cold related impacts

The expected rise in temperature referenced above does not signify the end of what are known as “cold waves” or days on which the minimum daily temperature falls below the so-called cold-related mortality threshold temperature. As a consequence of the progressive adaptation to heat, there is going to be a process of disadaptation to cold, i.e., cold-wave definition temperatures are going to increase with time, and a temperature which is not currently indicative of a cold wave, will be so in future. This increase can be modeled over future time horizons, assuming that it is the percentile corresponding to the current cold-wave definition temperature which is going to remain constant over time (Martinez et al., 2018). In terms of their effect on mortality, cold waves are not about to disappear; unlike what happens in the case of heat, their impact is not declining (Vicedo-Cabrera et al., 2018). In a study conducted in Spain, the attributable daily cold-related mortality correspond to 3.5 deaths/day, the same value calculating to heat waves correspond to 3.0 deaths/day (Carmona et al., 2016), and it would instead remain practically constant over time and give rise to an estimated overall figure of around 250 deaths per year, equivalent to close on a quarter of Spain's current annual cold-related mortality and entailing a cost of approximately €1000 million per year (Díaz et al., 2019).

4.4. Vector- food- and water-borne diseases

Since populations exposed to variability in weather patterns and increasingly warm temperatures, there is a very high confidence for increased risks of food- and water-borne diseases such as diarrhoeal diseases, including *Salmonella* spp. (Smith et al., 2014). With rising average temperatures and an increase in the frequency and length of heat-waves, it is expected to observe a rising number of cases of food-borne illness in a business-as-usual scenario, unless education, epidemiological surveillance and enforcement (related to food safety) is intensified. This will be compounded in the event that there are electricity power-cuts, due to peak electricity demand (e.g. during heat-waves), and refrigerators stop working (Seventh National Communication of Malta, 2017).

In parallel, there is high confidence that higher temperatures will affect the transmission of some vector-borne diseases, with increases and decreases projections depending on the disease region and degree of temperature change (Hoegh-Guldberg et al., 2018).

Conte et al. (2015) used predictive tools to indicate the areas and periods at major risk of WNV transmission in Europe and the Mediterranean. It was found that during the period from May to June, the more suitable areas are in Tunisia (eastern coast and central part), Libya, Egypt, and Northern Cyprus, while suitable conditions start to be recognized also in the European continent in July. The following months (August, September, and October) show increased significance in Italy, France, Spain, the Balkan countries, Morocco, northern Tunisia, and all along the Mediterranean coast of Africa and Middle East. In November, Europe returns to unsuitable conditions, with the exception of limited coastal areas facing the Mediterranean Sea (Italy, France, Spain, and Greece). The persistence of suitable conditions in December is confined to coastal areas in Morocco, Tunisia, Libya, Egypt, and Israel.

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. Predictions for 2025 show an elevated risk in

Table 2
Main results showing effectiveness of Heat wave Prevention plans in Mediterranean regions.

Country	Results	Reference
Nine European Cities	Reduction in mortality due to heat in Mediterranean cities (Athens and Rome) that was not present in cities in Northern Europe	de' Donato et al., 2015
France	The prevention plan and alert system after the heat wave of 2003 is considered to be responsible for a reduction of 4400 deaths	Fouillet et al. (2008)
Spain (52 Cities)	Risk went from 15% for the period 1983–1993 and 1994–2003 (without a prevention plan) to 2% for the period 2004–2013 (with a prevention plan)	Díaz et al. (2018a)
Italy (Florence)	Risk went from 23% for the period 1999–2002 (without a prevention plan) to 21% for the period 2004–05 (with a prevention plan)	Morabito et al. (2012)
Greece (Athens)	Decrease in mortality due to heat among elderly people, despite not having a prevention plan	de' Donato et al., 2015
Spain (Madrid)	Not conclude that prevention plans and high temperature warning systems served to decrease heat-related mortality	Culqui et al. (2014).

northeastern Greece, eastern Croatia and northwestern Turkey while projections for 2050 show a further expansion of high-risk areas (Semenza et al., 2016; Semenza and Suk, 2017).

Predicted future potential distribution of Ae. *aegypti* and Ae. *Albopictus* (the primary vectors that transmit dengue, chikungunya and Zika), under four future representative concentration pathways of climate conditions in 2050 (RCPs 2.6, 4.5, 6.0, 8.5) show clear dispersal in many Mediterranean countries of Ae. *aegypti* and more widely of Ae. *albopictus* (Kamal et al., 2018). Indeed, European areas with current and future climatic suitability of Chikungunya transmission were identified. An increase in risk is projected for Western Europe (e.g. France and Benelux-States) in the first half of the 21st century and from mid-century onwards for central parts of Europe (e.g. Germany). Interestingly, the southernmost parts of Europe do not generally provide suitable conditions in these projections. Nevertheless, many Mediterranean regions will persist to be climatically suitable for transmission. Overall, the highest risk of transmission by the end of the 21st century was projected for France, Northern Italy and the Pannonian Basin (East-Central Europe) (Fischer et al., 2013).

4.5. Air quality

Climate change could alter the dispersion of primary pollutants, particularly particulate matter, and intensify the formation of secondary pollutants, such as near-surface ozone. The relationships between climate change, air pollution and air pollution-related health impacts highly depend on the climate change scenario used and on projections of future air pollution emission, with relatively high uncertainty. More studies primarily focused on mortality; projections on the effects on morbidity are needed (Orru et al., 2017).

Regional projections indicate an increase of 10%–14% in ozone-related morbidity and mortality from 2021 to 2050 in several countries, including Spain and Portugal. For the 2050 horizon, 8–11% increase in non-accidental mortality and for 2080 horizon 15–16% increase, compared to 2000 horizon (O3 and PM2.5 combined) in Europe (Orru et al., 2017).

5. Resilience, preparedness and adaptation

5.1. Heat-health warning systems

Plans and alert systems have served to raise awareness among the population about health risks of climate change, but have not been sufficient to provoke changes in the behavior of the population leading people to take measures to protect themselves (Wolf et al., 2010). The theories of health promotion and behavior suggest that people most likely to adopt these measures are also those who feel most threatened. The low perception of risk among the most vulnerable groups and the cost of engaging in these protection measures against heat – such as the cost and the negative impact of air conditioning - are some of the barriers that prevent the population from taking action. In the European region, the increase in temperatures will affect both warm and cold 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 in places that already have them. The effectiveness of prevention plans will depend on their capacity to adapt to these changes, the ability to incorporate climate change into the global research framework on adaptation and implementation, and the knowledge generated in this field (Hess and Ebi, 2016). There is a lack of research on public awareness regarding climate change and health in the Mediterranean. A research conducted in Malta, found that people who perceive climate change as a risk to public health are more supportive of mitigation policy and more willingness to take individual measures to mitigate climate change (DeBono et al., 2012).

A better surveillance and control systems are needed for people who are especially vulnerable to the effects on health from climate change. Educational programs are needed to inform that population, especially those who are most vulnerable and their caregivers, about the risks of exposure to high temperatures and how to handle them. The movement of populations towards cities, and the expansion of cities without accounting for climate criteria will mean a greater level of exposure as well as percentage of the population exposed. Some studies show that this will generate pressure on electrical infrastructure, the social care system and the health system, such that they may become inefficient, or, in the case that they cannot adopt the needed measures, they may collapse (Environmental Audit Committee, 2018). Prevention plans and early warning systems regarding heat, for example, are adaptation measures that address the problems caused on health by high temperatures. The main results showing effectiveness of heat wave prevention plans in Mediterranean regions appear in Table 2.

5.2. Health preparedness and adaptation measures in health systems

Health preparedness and adaptation to climate change includes adaptation of health systems to axcess morbidity due to extreme weather 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 North/South division. Health systems in the Mediterranean face climate change in the context of increasingly elderly population, which is particularly vulnerable to heat waves, an increase in vector-borne diseases, and 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 overall in a relatively early stage. For instance, less than 50% of the countries bordering the Mediterranean Sea have completed a “climate change and health vulnerability and adaptation assessment” (CCHVA). Countries that have completed one include Albania, Algeria, France, Greece, Israel, Italy, Morocco, Spain and Tunisia (Berry et al., 2018a, 2018b). Yet these exercises, or similar ones, are crucial to obtain relevant information about current associations between health outcomes and weather or climate, population vulnerability and projections of future risks under various climate scenarios. This information, in turn, is essential for health systems to deliver on their functions under a changing climate. Moreover, the distribution of actual health adaptation policies and plans in place shows clear disparities. For instance, regarding heat wave public health prevention with most of the northern Mediterranean countries having a heat-health action plan and no country (save Israel) in the eastern or southern Mediterranean having a formal plan (GHHIN, 2018a, b).

Health systems in the Mediterranean should take the following preparedness and health adaptation measures:

For health-protecting climate change adaptation activities outside of the competencies of health systems, the health sector should be involved by:

- Assessing the potential health impacts (benefits or damages) from proposed policies, and
- Through evidence-based advocacy of those policies with net and equitable health benefits.

Regarding public health activities to minimize climate-aggravated health impacts, health systems in the Mediterranean should engage in:

- Implementing measures for adequate preparedness of emergency medicine institutions and professionals for treating morbidity related to climatic extreme 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
- Implementation of heat-health warning system and more generally heat-health action plans (HHAPs) with core elements as recommend by WHO (WHO, 2008) and adequate attention to monitoring and evaluation of both process and outcomes in terms of their effectiveness and effectiveness
- Prevention of water-borne and food-borne diseases
- Provision of access to healthcare, including mental health, to climate migrants
- Working with other sectors and agencies to promote urban green infrastructure appropriate for the region, and increase thermal comfort in streets, squares and playgrounds, in order to reduce heat and sun exposure and related morbidity (Shashua-Bar et al., 2012)
- Increase public awareness to 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.

Regarding the increase in resilience of health systems themselves to climate impacts and extreme weather events, the health sector should:

- Train health professionals, including physicians, nurses and administrative staff, regarding the health impacts of climate change, preparedness and adaptation in the health system
- Increase the resilience of healthcare facilities and hospitals, prioritizing (WHO, 2015): 1) Enabling hospitals to continue to function and provide adequate care during and following emergencies; 2) Protecting health workers, patients and families; 3) Protecting the physical integrity of healthcare facilities, equipment and critical systems; and 4) Making hospitals safe and resilient to future risks, including climate change.

5.3. Regional coordination and collaboration

The Mediterranean, particularly the eastern and southern regions, is an area troubled by internal and cross-border conflicts, with limited cross-border collaborations and 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 the entire Italy and the whole extension of Slovenia, Croatia, Greece, Malta and Cyprus, as well as the UK territory of Gibraltar and 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 emphasis 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/). Other Meditteranean cross-border collaborations are the Mediterranean Action Plan (MAP), which is a long-standing collaboration of the 22 parties to the Barcelona Convention (http://web.unep.org/unepmap/) and the Mediterranean Experts on Environmental and Climate Change (MedECC, http://www.medecc.org/), an international network of more than 400 scientists who work with intergovernmental agencies, such as the Climate Experts Group of the Union for the Mediterranean and the Barcelona Convention. Climate change is expected to impact across Mediterranean borders, 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 and environment agencies prove that this is possible (e.g. in the cases of MECIDS, and MAP), and regional collaboration at the Mediterranean level should be a priority for health agencies in the region.

6. Conclusions

- Climate change impacts the health of the Mediterranean population directly through extreme heat, drought or storms, or indirectly by changes in water availability, food provision and quality, air pollution and other stressors. The main health effects are related to extreme weather events (including extreme temperatures and floods), changes in the distribution of climate-sensitive diseases and changes in environmental and social conditions. The poorer countries, particularly in North Africa and the Levant, are at highest risk.
- Climate change could alter the dispersion of primary pollutants, particularly particulate matter, and intensify the formation of secondary pollutants, such as near-surface ozone.
- Climate change affects vulnerable sectors, including an increasingly older population, with a larger percentage of those with chronic diseases, as well as poor people, which are therefore more susceptible to the effects of extreme temperatures. For those populations, a better surveillance and control systems are especially needed.
- In view of the climatic projections and the vulnerability of Mediterranean countries, climate change mitigation and adaptation become ever more imperative.
- It is important that prevention Health Action Plans will be implemented, particularly in those countries that currently have no prevention plans.
- Most adaptation measures are “win-win situation” from a health perspective, including reducing air pollution or providing shading solutions.
- Mediterranean countries need to enhance cross-border collaboration, as adaptation to many of the health risks (e.g. vector-borne diseases, draughts, migration) requires collaboration across borders and also across the different parts of the basin.

CRediT authorship contribution statement

Cristina Linares: Writing - original draft. **Julio Díaz:** Writing - original draft. **Maya Negev:** Writing - original draft. **Gerardo Sánchez Martínez:** Writing - original draft. **Roberto Debono:** Writing - original draft. **Shlomit Paz:** Writing - original draft, Conceptualization, Project administration.

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