RISKS ASSOCIATED TO CLIMATE AND ENVIRONMENTAL CHANGES IN THE MEDITERRANEAN REGION

A preliminary assessment by the MedECC Network
Science-policy interface - 2019

MedECC
Mediterranean Experts on Climate and environmental Change
Union for the Mediterranean
Union pour la Méditerranée
الإتحاد من أجل المتوسط
Sweden
Sverige
UN environment
United Nations Environment Programme
MAP
Mediterranean Action Plan
Barcelona Convention
Plan Bleu

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Executive Summary

Recent accelerated climate change has exacerbated existing environmental problems in the Mediterranean Basin that are caused by the combination of changes in land use, increasing pollution and declining biodiversity. In most impact domains (such as water, ecosystems, food, health and security), current changes and future scenarios consistently point to significant and increasing risks during the coming decades. Policies for the sustainable development of Mediterranean countries need to mitigate these risks and consider adaptation options, but currently lack adequate information — particularly for the most vulnerable southern Mediterranean societies, where fewer systematic observations schemes and impact models are based. A dedicated effort to synthesize existing scientific knowledge across disciplines is underway and aims to provide a better understanding of the combined risks posed. This effort has been undertaken by the network of Mediterranean Experts on Climate and Environmental Change (MedECC) supported by the Union for the Mediterranean and Plan Bleu (UNEP/MAP Regional Activity Center). This document presents preliminary conclusions of the assessment.

Climate change in the Mediterranean region – the main facts

The Mediterranean Sea is surrounded by three continents: Africa, Asia and Europe. The cultural richness and diversity of the region are exceptional. The basin is also an area of constant change. It is shaped by human activities, such as use of the land and the sea, including urbanization and tourism, concentrated near the coast and close to sea level. The Mediterranean Sea is also an area of industrial development and one of the world's busiest shipping routes.

There are important discrepancies between Mediterranean countries. Despite a significant progress made in countries on the southern shore, in general northern Mediterranean countries perform better on several indicators of well-being, economic development, government effectiveness and social networks than southern Mediterranean and Middle East countries (with some exceptions both ways)[1]. These inequalities are exacerbated by rapid population growth in the north Africa and Middle East, which increased from 105 millions in 1960 to 444 millions in 2017[2]. The region faces unequal distribution of resources, social instability, conflict and migration. In addition to these social factors, the Mediterranean Basin is naturally exposed to a number of hazards, including earthquakes, volcano eruptions, floods, fires or droughts.

In this complex situation, several new challenges from climate change arise, including warming, more severe droughts, changing extreme events, sea-level rise and ocean acidification. These challenges interact with other environmental changes like pollution and urban growth.

Air temperature

In the Mediterranean region, average annual temperatures are now approximately 1.5°C higher than during the preindustrial period (1880-1899) and well above current global warming trends (+1.1°C) (Fig. 1). In the Mediterranean region, the trend is of 0.03°C per year, also above global trends.

WITHOUT ADDITIONAL MITIGATION
REGIONAL **TEMPERATURE**
INCREASE WILL BE **2.2°C**
IN **2040**
POSSIBLY **EXCEEDING**
3.8°C IN SOME REGIONS
IN **2100**

Summers will likely warm more than winters. High temperature events and heat waves (periods of excessively hot weather) are likely to become more frequent and/or more extreme[3,4]. Urban areas are significantly warmer than surrounding rural areas due to human activities, particularly at night, which is called "urban heat island" factor. The increase in frequency, intensity and duration of heat waves is amplified in the Mediterranean by the "urban heat island" effect[5].

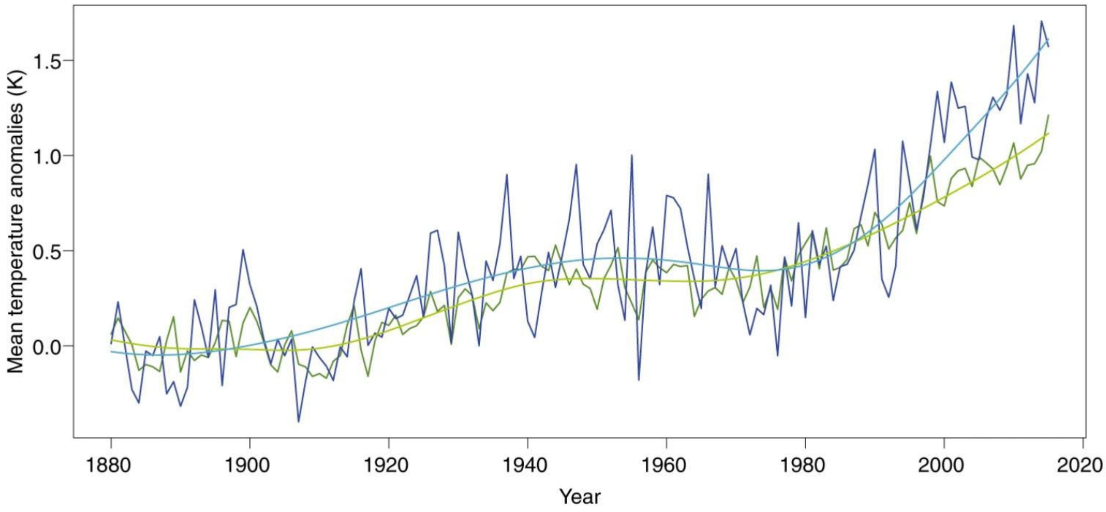


Figure 1

Warming of the atmosphere (annual mean temperature anomalies with respect to the period 1880-1899), in the Mediterranean Basin (blue lines, with and without smoothing) and for the globe (green line). In the Mediterranean region, average annual temperatures are now approximately 1.5°C higher than during the period 1880-1899, well above current global warming trends[6].

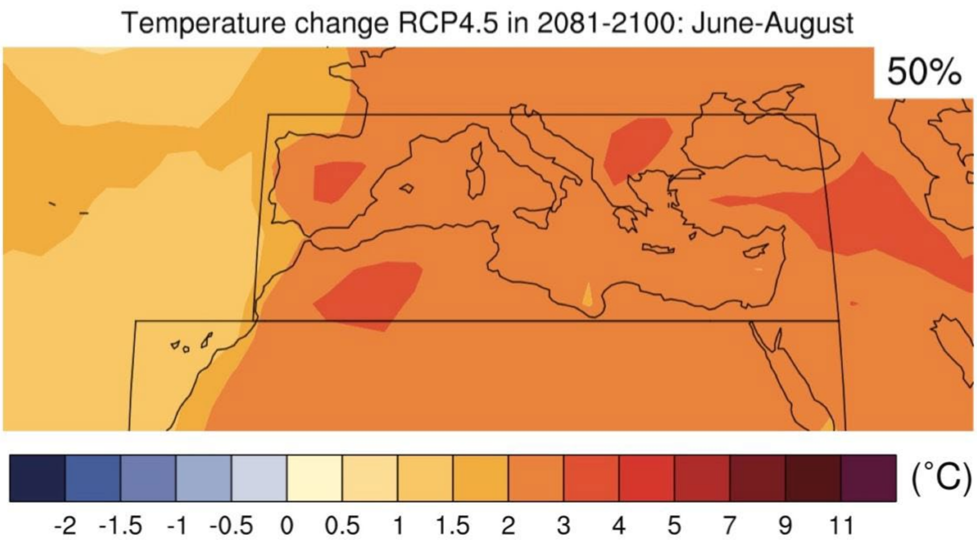


Figure 2

Expected future temperature change for the summer months in 2081–2100 vs 1986–2005 on the basis of the medium-low scenario, RCP4.5[7]. In order to obtain the warming in respect to the preindustrial period (1880-1899) about 0.85°C should be added.

Precipitation

Observed precipitation trends in the Mediterranean are characterized by high variability in space and in time, but climate models clearly indicate a trend towards reduced rainfall in coming decades[8]. The combination of reduced rainfall and warming generates strong trends towards drier conditions. Frequency and intensity of droughts have already increased significantly in the Mediterranean since 1950[9]. During 2008-2011, for example the Middle East underwent a strong drought due to a large deficit of precipitation amplified by high evapotranspiration related to a strong warming (the 1931-2008 period has warmed by 1°C) and by an increase of water demand related to a strong increase of the population.

A global atmospheric temperature increase of 2°C is expected to be accompanied by a reduction in summer precipitation of about 10-15% in southern France, northwestern Spain and the Balkans and up to 30% reduction in Turkey[10]. Scenarios with 2-4°C temperature increases in the 2080s for southern Europe would imply stronger and more widespread decreases in precipitation of up to 30% and a disappearance of a frost season in the Balkans[11]. For each degree of global warming, mean rainfall will likely decrease by about 4% in much of the region, particularly in the south[12]. Dry spells will likely lengthen by 7% for 1.5°C global average warming[13] (Fig. 3). Heavy rainfall events are likely to intensify by 10-20% in all seasons except for summer[14,15].

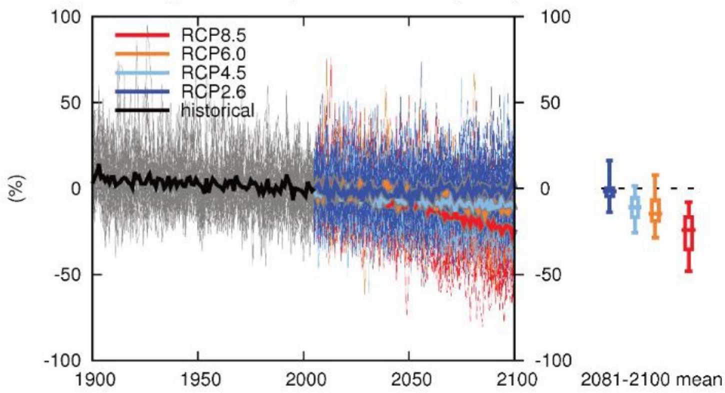


Figure 3
Change in precipitation relative to 1986-2005 in the region of southern Europe/Mediterranean (30°N to 45°N, 10°W to 40°E) in April to September under different scenarios[7].

Sea temperature

Warming of the Mediterranean Sea surface is currently estimated at 0.4°C per decade for the period between 1985 and 2006 (+0.3°C per decade for the western basin and +0.5°C per decade for the eastern basin). The increases in temperature are not constant throughout the year but occur primarily during May, June and July. Maximum increases of 0.16°C per year were found in June in the Tyrrhenian, Ligurian and Adriatic Seas and close to the African coast.

The Aegean Sea shows maximum change in sea surface temperature during August[16]. The projections for 2100 vary between +1.8°C and +3.5°C in average compared to the period between 1961 and 1990. The Balearic Islands, the northwest Ionian, the Aegean and Levantine Seas have been identified as the regions with maximum increase of sea surface temperature[17] (Fig. 4).

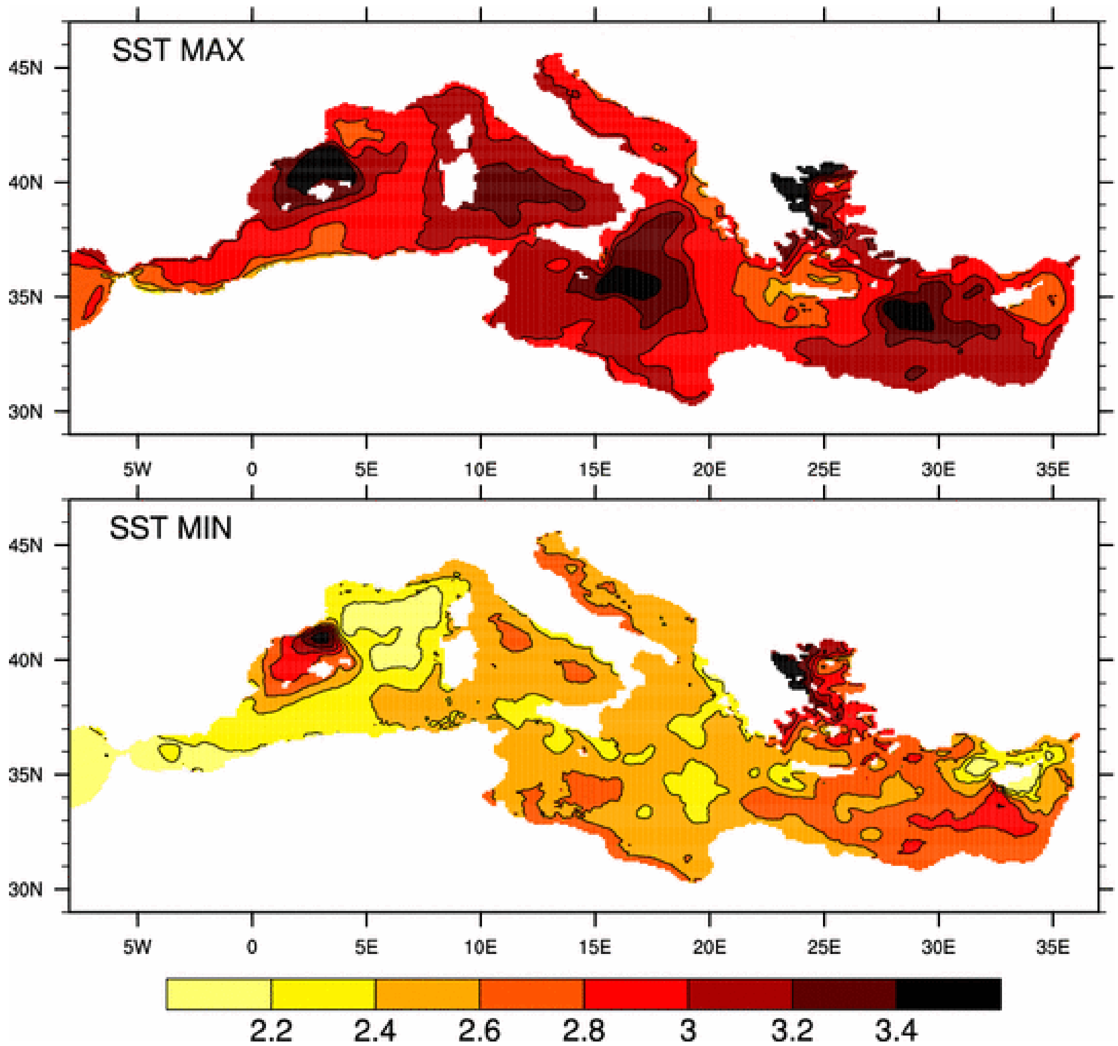


Figure 4

Expected minimum and maximum changes in sea surface temperature for the 2070–2099 period (vs. 1961–1990). The largest (maxima) or smaller (minima) anomaly out of the 6 scenario simulations is represented (°C)[17].

Sea level

Similar to worldwide trends caused by warming and loss of glacial ice, sea level in the Mediterranean has risen between 1945 and 2000 at a rate of 0.7 mm per year[18] and between 1970 and 2006 at the level of 1.1 mm per year[19]. There has been a sharp increase during the last two decades as sea level rise reached about 3 mm per year[20]. There are important uncertainties concerning global mean sea level rise in the future. Future projections range goes from 52 to 190 cm global mean sea level increase by 2100 depending on the method used. These uncertainties will largely influence the Mediterranean Sea level rise, because of the connection to the global ocean through the Strait of Gibraltar. The accelerating ice loss in Greenland and Antarctic ice sheets implies a significant risk for additional sea-level rise even if global warming was limited to 1.5°C, with a potential of multi-meter rises in sea level[13].

Regional projections of relative sea-level change are more uncertain than global projections, because of the reduced skills of global models and interactions between the Atlantic and the

Mediterranean Sea. For Mediterranean coasts, regional changes in river runoff, provoking salinity changes and also significant land movements in the eastern parts of the basin need to be considered additionally. In addition to the impacts of global sea level change, circulation patterns in the Mediterranean may also be modified and generate changing regional sea level patterns[17], with local differences in sea surface height of up to 10 cm. In southern Italy, substantial coastal inundation is expected by 2100[21]. Significant shoreline modifications are also expected in other areas, like Balearic Islands[22] .

Acidification

The world's oceans have absorbed about 30% of CO_2 emitted by human activities[23]. Absorbed CO_2 is combined with water to produce a dilute acid that dissociates and drives ocean acidification.

Ocean pH has decreased by 0.1 pH units since the preindustrial period, which is unprecedented during at least the last 65 million years.

Globally, CO_2 uptake by the oceans is expected to lead, by 2100, to acidification of 0.15-0.41 pH units below 1870-1899 levels[24]. Similar rates are expected for the Mediterranean, which is currently estimated to decrease by 0.018 to 0.028 pH units per decade[25,26].

OCEAN **pH** HAS DECREASED BY **0.1pH** UNITS SINCE THE **PREINDUSTRIAL PERIOD,** WHICH IS UNPRECEDENTED DURING AT LEAST THE **LAST 65 MILLION YEARS**

Impacts of climate and environmental changes and associated hazards

Climate change implies significant risks for ecosystems and for human well-being[27]. In addition to direct consequences of climate change, there are many combined consequences of different environmental changes resulting from human pressures, like pollution of air, water and soils, and degradation of land and ocean ecosystems due to industrial activities, urbanization, transport and unsustainable use of resources. Challenges resulting from these changes concern numerous domains, including safe access to natural resources (water and food), healthy state of ecosystems, human health and security with respect to natural disasters.

Water resources

Water availability in the Mediterranean Basin will reduce as a consequence of three main factors: (i) precipitation decrease, (ii) temperature increase, and (iii) population growth, especially in the countries already presently short in water supply.

Due to climate change alone, provoking enhanced evapotranspiration and reduced rainfall, fresh water availability in the Mediterranean region is likely to decrease substantially (by 2 to 15% for 2°C warming), among the largest decreases in the world[28,29,30].

The length of meteorological dry spells is expected to increase significantly[31,13] as well as the length and severity of droughts[32]. The Mediterranean population classified as 'water-poor' (i.e. having access to less than 1000 m3 per capita per year) is projected to increase from 180 million people in 2013 to over 250 million within 20 years[33]. Countries on the southern and eastern rim of Mediterranean with semi-arid climate are more subject to water shortage and high interannual variability of their water resources. People inhabiting river basins in the Middle East and Near East will be exposed to new chronic water scarcity even if the warming is constrained under 2°C warming. In Greece and Turkey water availability may fall below 1000 m^3 per capita par year for the first time in 2030[34]. The currently critically low water availabilities per capita in southeastern Spain and the southern shores (Fig. 5) may drop to below 500 m^3 per capita per year (situation of water scarcity) in the near future.

River flow is generally reduced, especially in the South and East where water is in critically short supply[11]. Water levels in lakes and reservoirs will decline. For example, the largest Mediterranean lake, the lake Beyşehir in Turkey, may dry out by the 2040s unless its outflow regime is modified[36].

The main source of fresh water in North Africa and the Middle East are shared aquifers. This resource is also threatened, as in the northwestern Sahara aquifer system, which has a renewal rate of only 40% of the withdrawals[37], causing high vulnerability of the oasis systems that depend on it. Intensive exploitation of groundwater resources has led to critical drops of groundwater levels in many areas[38,39]. Not only the quantity of groundwater decreases, but also its quality deteriorates because of overexploitation, pollution, increasing urbanization, and salt-water intrusion caused by sea level[40]. Increasing water pollution touches particularly the southern and eastern shores[34], because of new industries, urban sprawl, tourism development, migration and population growth.

Some arid regions depend to a large extent on water resources provided by snowmelt in mountain ranges. For these snow-dominated catchments (for example in the Atlas Mountains in Morocco or the Alps in Italy, France) climate change results in a decrease in spring runoff associated with reduced snow cover[41], reducing available water resources.

These increases in water scarcity are enhanced by increasing demand for water. Irrigation represents between 50% and 90% of the total Mediterranean water demand[42]. Irrigation water requirements in the Mediterranean region are projected to increase between 4 and 18% by the end of the century due to climate change alone (for 2°C and 5°C warming, respectively). Population growth, and increased demand, may increase these numbers to between 22 and 74%[43]. Water demand for manufacturing is also projected to increase between 50 and 100% until the 2050s in the Balkans and southern France[11]. The expected increase in population, particularly in the coastal areas of eastern and southern Mediterranean countries, and the increasing urbanization not only lead to higher water demand, but also to further deterioration of water quality. Satisfying the increasing demand for good quality drinking water and water for irrigation is a complex problem, often involving conflicts between users of groundwater and landowners, or between countries. Floods, which are expected to be more frequent, may actually diminish water availability, as they may provoke damage to water supply systems, insufficient drinking-water supplies and disruption of transport systems[44].

FRESH WATER AVAILABILITY
IN THE **MEDITERRANEAN REGION**
IS LIKELY TO **DECREASE** SUBSTANTIALY
By **2** to **15%**
for **2°C**
warming
AMONG THE **LARGEST**
DECEASES IN THE **WORLD**

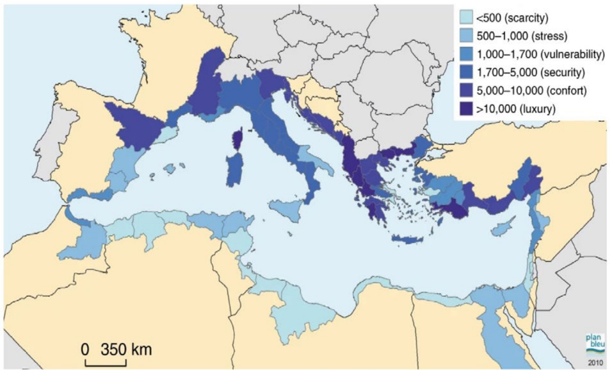


Figure 5
Annual natural renewable water resources per capita in the main Mediterranean watersheds, expressed as levels of shortage for human use[35]

Food resources

Ongoing climate, environmental and socioeconomic changes pose threats to food security in Mediterranean region. The pressures are not homogeneous across the region and sectors of production[45]. Factors affecting agriculture and livestock production around the Mediterranean basin include water scarcity, soil degradation and erosion[31]. Extreme events, such as droughts, heat waves and heavy rainfall may cause unexpected production losses and increase crop yield variability[46,47,48]. In river deltas currently of crucial importance for agricultural production (for example the Nile Delta), the area available for agriculture is reduced due sea-level rise and land subsidence[49,50]. Food safety is also threatened by pests and mycotoxins (toxic substances produced by a fungus and especially a mold) formed on plant products in the field or during storage. Their development is linked to climate conditions[51].

Yields for many winter and spring crops are expected to decrease due to climate change, especially in the South. By 2050 a reduction by 40% for legume production in Egypt, 12% for sunflowers and 14% for tuber crops in southern Europe have been estimated. Warming will also affect olive production by increasing the irrigation requirement[52], the risk of heat stress around flowering and by altering fly infestation risk[53]. Although these impacts are not projected to be large for overall production across the region, local and regional disparities will emerge[53]. Changes in the life cycle towards shorter duration and anticipated flowering are projected for grapevines, with associated increase in the exposure to extreme. Projected enhanced dryness throughout Europe, with severe water stress over several regions (e.g. southern Iberia and Italy), may locally lead to the reduction of yield and leaf area and increased demand for irrigation[54]. These conditions could affect not only yields but also the quality of grapevines. Anticipated flowering and insufficient time with cold weather (chilling accumulation) are expected to impact yields from fruit trees as well[55]. For vegetables such as tomatoes, reduced water availability will be the main yield-limiting factor[56]. In some crops, yield increases may occur, due to

CO_2-fertilization effects (increased rate of photo-synthesis and reduced sensitivity to drought, resulting from increased levels of carbon dioxide in the atmosphere), which could increase water use efficiency and biomass productivity[57,54]. However, complex interactions among the various factors and current knowledge gaps imply uncertainties[47,49]. For several cereals, these yield increases are expected to be combined with decreased quality (e.g. lower protein content)[48].

The current consumption patterns imply high ecological, carbon, and water foot-prints[58]. Within a period of 50 years, the population in the North Africa and Middle East region has increased by a factor of 3.5, while dietary habits have become more westernized (i.e. the diet include more meat). Livestock production, mainly located in the semi-arid and arid lands of the southern Mediterranean, has shifted from extensive modes to systems heavily dependent on feed grain, increasing poverty and rural exodus and rendering production sensitive to climatic shifts at the global scale. Dependence of these countries on imported food (estimated at around 50 % for all food products in the Maghreb[59]) is expected to increase.

Fisheries and aquaculture are essential for food security and the economy of the Mediterranean.

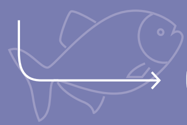
Fishing has been important in the Mediterranean Sea for millennia and has resulted in overexploitation of the main commercial species, with 90% of stocks categorized as overfished[60].

Aquaculture (mostly fish and mollusks) accounts for more than 50% of today's total fish catch and plays an important role in coastal communities, as it contributes to their socio-economic development[61,62]. The value of aquaculture production in the Mediterranean is 6% of the world total revenues of marine and brackish aquaculture production despite the fact that the Mediterranean represents only 0.8 % of the world ocean. Professional fishing is expected to decline at an uncertain rate at the Mediterranean regional level, contrasted by a 112% increase in aquaculture production in Mediterranean countries of the European Union between 2010 and 2030 (280,000 to nearly 600,000 tonnes)[61].

By 2040–2059 relative to 1991-2010, more than 20% of exploited fishes and invertebrates currently occurring in eastern Mediterranean are projected to become locally extinct under the most pessimistic scenario[63,64]. By 2070–2099, 45 species are expected to qualify for the IUCN Red List of threatened species, whereas 14 are expected to become extinct[65]. The maximum catch potential on the southern coast of the Mediterranean Sea is projected to decline by more than 20% by the 2050s relative to the 1990s under the most pessimistic scenario[64].

Fisheries and aquaculture are currently impacted mostly by overfishing and coastal development, but climate change and acidification may sometimes play an important role. Sprat, a cold water small pelagic species, has virtually disappeared from commercial catches of the northwestern Mediterranean. Landings of sardine and anchovy have declined in recent decades. On the other hand, warm water species, such as round sardinella have expanded[66]. The expected migration of species to cooler areas as the ocean warms up[67] is limited in enclosed seas like the Mediterranean Sea[65].

FISHING HAS BEEN IMPORTANT IN THE **MEDITERRANAN SEA** FOR MILLENNIA AND HAS RESULTED IN OVEREXPLOITATION OF THE MAIN COMMERCIAL SPECIES, WITH **90%** **OF STOCKS** CATEGORIZED AS **OVERFISHED**



Ecosystems

Looking from the human point of view, Mediterranean ecosystems provide numerous services, including renewable natural resources (food, medicines, timber and mushrooms), environmental services (maintenance of biodiversity, soils and water, regulation of air quality and climate and carbon storage) and social services (recreational, educational and leisure uses, traditional cultural values, tourism and hiking)[68]. However, these ecosystems now face unprecedented challenge due to climate and environmental changes resulting from human activities (overexploitation, pollution and changes in land and sea use), putting at risk the provisioning of most services they provide.

Land ecosystems

The Mediterranean basin is a hot spot of biodiversity. For example in case of tree species and shrubs, although the Mediterranean region represents no more than 1.8% of the world forest area, the region hosts 290 woody species versus only 135 for non-Mediterranean Europe[69]. There are also many endemic species (plants and animals that exist only in one geographic region). Land ecosystems are impacted not only by direct consequences of climate change (warming, drought), but also by changes in land use (including abandonment of pasture and extensive crop activities in some remote areas and mountains) and urbanization, which provoke landscape fragmentation[70]. Land ecosystems are also impacted by pollution, unsustainable tourism, overexploitation of resources and other practices (e.g. overgrazing, forest fires).

The coupled effect of warming and drought is expected to lead to a general increase in aridity and subsequent desertification of many Mediterranean land ecosystems (Fig. 6). During past centuries these ecosystems have adapted to a certain range of climate fluctuations. However, warming of 2°C or more above the preindustrial level is expected to generate conditions for many Mediterranean land ecosystems that are unprecedented in the last 10,000 years. Deserts would expand in southern Spain and Portugal, northern parts of Morocco, Algeria, Tunisia, Sicily, southern Turkey and parts of Syria[72].

In dry lands, oases, which occur on the southern and eastern rim of the Mediterranean, are also affected by ongoing climate change, despite their potential to tolerate several abiotic stresses typical of arid environment. The environmental change reinforced by oases overexploitation and strong anthropogenic pressures affect the date palm growth and development[73].

An important role of forests is to be a carbon sink, which means that they absorb more carbon than they release. If global temperatures are kept below 2°C above preindustrial values at the end of 21st century, most Mediterranean forest could resist to warming (except for some coniferous sites). However, the higher temperatures might reduce the CO_2 fertilization effects. In contrast, most western Mediterranean forests are vulnerable to a climate warmer than 2°C above preindustrial values if no unexpected physiological adaptation occurs[74]. This change would imply not only the loss of many resources drawn from forests but also a lost carbon sink, especially during the drought years[75,76].

WARMING OF **2°C** OR MORE ABOVE THE **PREINDUSTRIAL LEVEL** IS EXPECTED TO GENERATE CONDITIONS FOR MANY **MEDITERRANEAN LAND ECOSYSTEMS** THAT ARE UNPRECEDENTED IN THE LAST **10.000 YEARS**

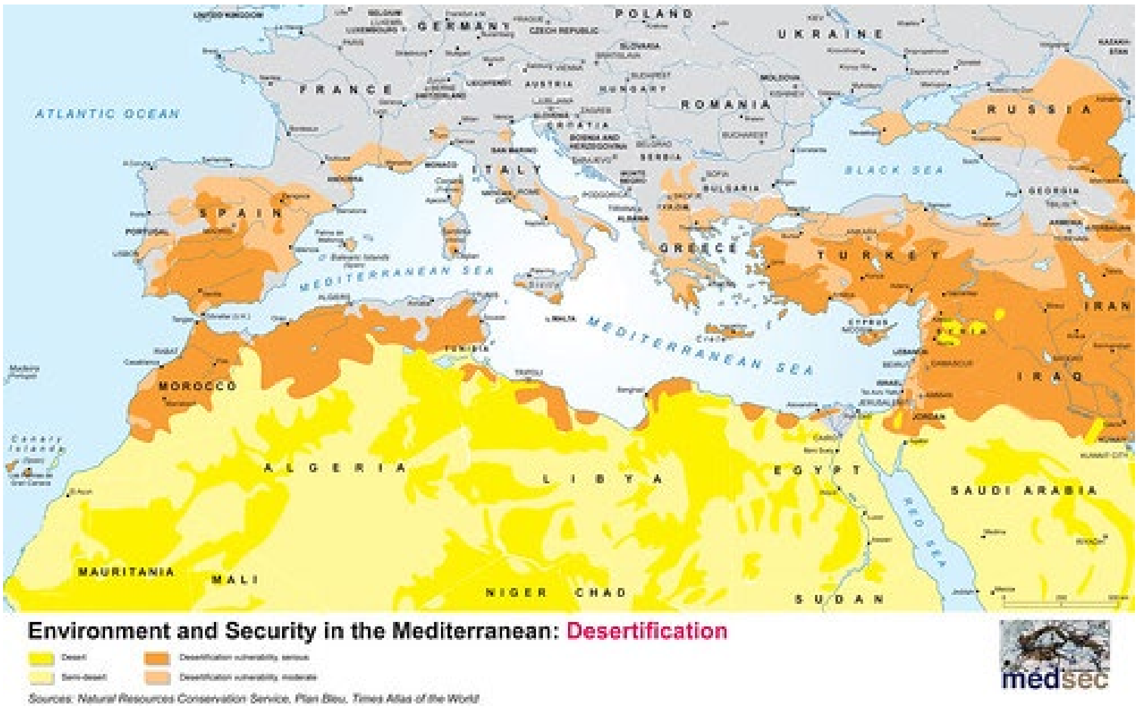


Figure 6
The vulnerability of the Mediterranean region to desertification[71]

In Mediterranean forests some species are particularly vulnerable to climate changes. The productivity has decreased and rates of mortality and defoliation (loss of leaves) have increased significantly in holm oak, a species currently dominating Mediterranean forests[77]. Italian oak stands located in southern Italy have shown symptoms of decline during the last three decades[78]. In arid and semi-arid lands, drought has increased tree mortality and resulted in degradation and reduced distribution of entire forest ecosystems, such as the Atlas cedar in Morocco[79] or Algeria[80].

Many plants and animals adapt to climate change at the level of phenology (the timing of periodic life cycle events such as flowering or leaf unfolding for plants). An observed advancement in spring phenology of about 2.8 days per decade in plants and animals in most of northern Hemisphere ecosystems in recent decades has been attributed to climate change[81]. Adaptation may have negative consequences, as there is a potential decoupling of plant responses and their interacting organisms such as insect pollinators or increasing risk of frost damage in the early spring season[82].

Forests, wetlands and coastal ecosystems in the Mediterranean Basin are also likely to be affected by changes in extreme temperature events and droughts[83,84]. Fire risk increases due to drought and heat waves but also to changed land management, bringing longer fire seasons, and potentially more frequent large, severe fires[85,86,87]. Fires are generally the result of fuel accumulation during the wet season and increased droughts during the dry season. The megafires triggered by extreme climate events, especially heat wave events, have caused record maxima of burnt area in some Mediterranean countries during the last decades[88,87] (Fig. 7)

Figure 7
The landscape of the Calanques National Park (south of France) after a large fire in September 2016. Photo: Thierry Gauquelin (IMBE)

Marine ecosystems

The Mediterranean Sea is a hotspot of biodiversity. It hosts 4% to 18% of the world's known marine species, which is considerable given that the Mediterranean Sea only accounts for 0.8% of the global ocean surface[89]. It is also becoming a hotspot of global change[90]. Increasing water temperatures in Mediterranean lead to changes in species composition and abundance. In general, cold-water species become less abundant or extinct and warm-water species become more abundant, leading to homogenization of the Mediterranean biota with warm-water species.

Most species from warmer regions enter the Mediterranean from the Red Sea through the recently widened Suez Canal (they are referred to as Lessepsian species), others are transported accidentally through ballast water from ships. More than 700 non-indigenous marine plant and animal species have been recorded so far in the Mediterranean[91], many of them are favored by the warmer conditions[92,93]. Of these, more than 600 have established populations in the Mediterranean[91].

Lessepsian species represent more than 50% non-indigenous species in the Mediterranean (Fig. 8). The eastern Mediterranean is the area displaying the most severe environmental effects of invasive species. Some tropical invasive species create heavy disturbances in ecosystems, like tropical rabbit fish, which devastate algal forests[94].

Consequently, the geographic distribution range of many native species has changed. Due to the warming of the Mediterranean, warm-water species, like the blue runner, the Mediterranean parrotfish, the common dolphinfish, the grey triggerfish and the barracuda are moving northwards[93]. Over the last several decades, the extent and intensity of jellyfish outbreaks have increased favored by increasing water temperature, in particular outbreaks of a purple-striped jelly-fish, a planktonic predator of fish larvae and of their zooplankton prey[95]. Also seagrass meadows (which represent an important habitat but also a carbon sink) are vulnerable to seawater warming[96].

The effects of global change are particularly serious in areas where range shifts of species are physically constrained such as in the Ligurian Sea, one of the coldest sectors of the Mediterranean[97]. The substitution of species has been reported in Mediterranean submarine caves, which are confined biotopes with highly specific biodiversity. The endemic cave crustacean mysids cold-water species are replaced by species with warmer affinities[98] (Fig. 9).

Water acidification in Mediterranean is well documented and will continue in the future[25]. It has negative impacts on many pelagic and benthic organisms with calcareous body parts, such as corals, mussels, pteropods, sponges and coccolithophores[100,101,102,26]. Effects include biological (e.g. reduced early stage survival) as well as ecological processes (e.g. loss in biodiversity, changes in biomass and trophic complexity)[103]. At the community level, modifications in species composition and abundance shifting from assemblages dominated by calcifying species to non-carbonated species (e.g. erect macroalgae) have been reported even under moderate decrease in pH[104].

Increased water temperatures also lead to mass mortality events, in coralligenous[105] (Fig. 10), but also in sponges or molluscs[106]. Coralligenous bleach under warm temperature, because they expel the algae living in their tissues. The most dramatic events occurred 1999 and 2003. Since 1999 almost every year mass mortality events concerning different species have occurred[107]. While recovery is possible, this process takes a long time and may be inhibited by more frequent heat waves or increasing acidity.

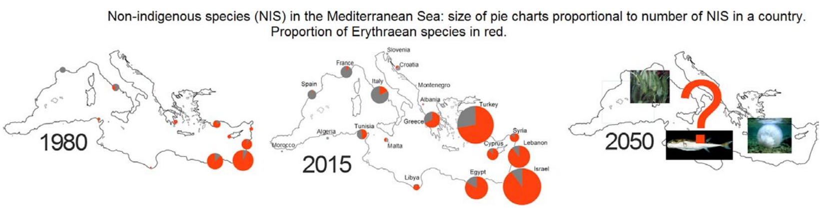


Figure 8
Non-indigenous species (NIS) in the Mediterranean Sea; size of pie charts proportional to number of NIS in a country; proportion of Lessepsian species in red[91].

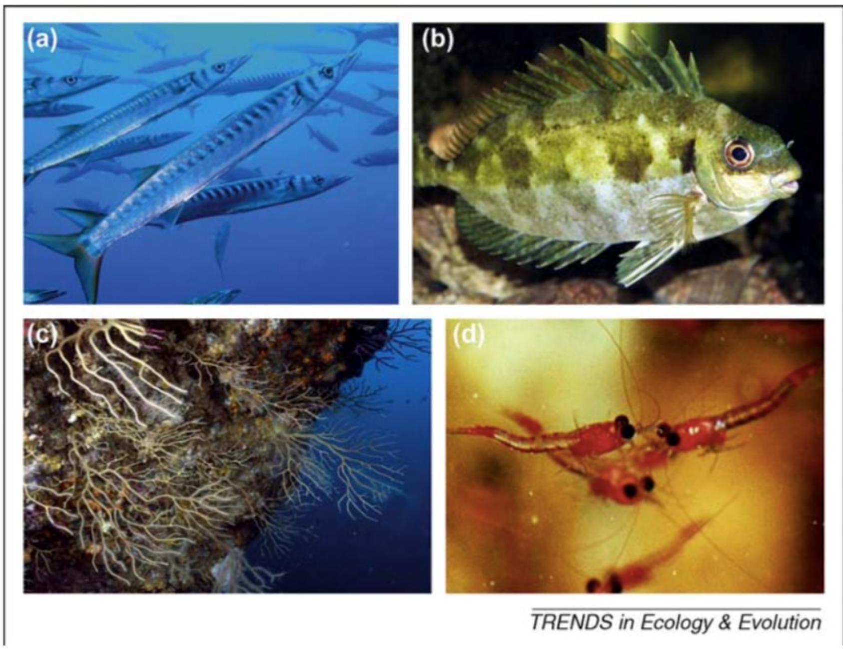


Figure 9

Representative examples of marine species responding to climate change in the Mediterranean. (a) the barracuda greatly increased its natural distribution range over the last 30 years, (b) the Lessepsian herbivorous rabbit fish is affecting the eastern Mediterranean ecosystems, and is increasing its introduced range area. It was found in 2008 in the Gulf of Lions (Carry-le-Rouet, France), (c) a seascape of dead sea fans, purple gorgonian, after the 2003 thermal anomaly in the northwestern Mediterranean, (d) the crustacean mysids are a classical example of a species shift in relation to climate change. Photos by T. Pérez (a), J.G. Harmelin (b) and R. Graille (c, d)[99].

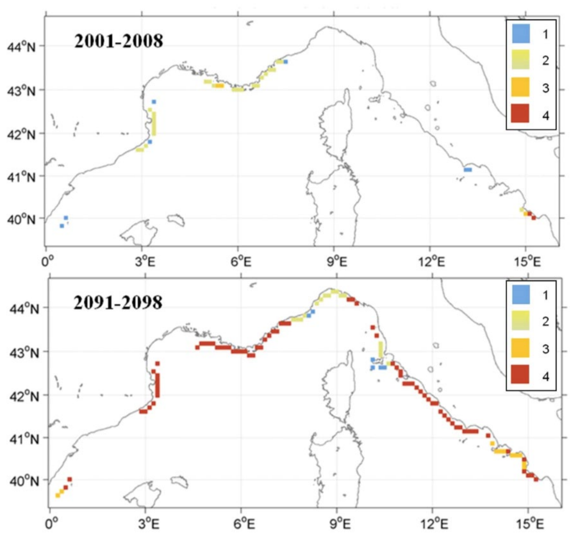


Figure 10

The risk of mortality outbreak for the purple gorgonian at the beginning (top) and end (bottom) of the 21st century along the continental coastal stripe north of 39°N in the northwestern Mediterranean Sea. The color scale, from 1 to 4, corresponds to sublethal, moderate, high and extreme lethal impacts respectively[108].

In all ecosystems species are connected with others through the food web. Therefore, changes in the abundance of one species may have an important and sometimes irreversible impact on many other species. For example seawater warming will lead to a shift in dominant species towards smaller species (picophytoplankton and nanoflagellates) and a decrease in diatoms. The acidification will result in a decrease in the biomass of calcifying plankton organisms such as coccolithophorids[109]. Shifts in plankton composition will provoke changes in the abundance on organisms feeding directly on plankton and then on all levels of the food web. Primary production (90% of ocean productivity is ensured by phytoplankton) is critical to maintain biodiversity and the support of fishery catches[110]. Increasing water temperature provokes an increase in the proportion of small-sized species, young age classes and a decrease in size-at-age (Bergmann's rule). As a consequence, in the Mediterranean Sea, the average maximum body weight of fish is expected to shrink by 4 to 49% from 2000 to 2050 due to water warming and decreased oxygenation, and also because of overfishing [111].

Surface water warming in the relative shallow Mediterranean may reduce vertical exchange in the water column. This is expected to favor the formation of marine mucilage, large marine aggregates representing an ephemeral and extreme habitat[112]. Several species of algae constitute the principal components of mucilaginous aggregates in the Mediterranean. Mucilage is a threat to gorgonians, because it becomes entangled in projecting branches provoking the death of gorgonians[113].

IN THE **MEDITERRANEAN SEA,** THE AVERAGE MAXIMUM BODY WEIGHT OF FISH IS EXPECTED TO SHRINK BY

4 to **49%** FROM **2000** to **2050**

DUE TO **WATER WARMING** AND **DECREASED OXYGENATION**, AND ALSO BECAUSE OF **OVERFISHING**

The distribution range and abundance of several toxic planktonic species (dinophytes) increase with the increase of water temperature in the Mediterranean. Some of them can form floating clusters at the sea-water surface and release marine aerosols, causing thereby respiratory problems and irritations. The most extensive sanitary events of this type have occurred in Italy (2005–2006), Spain (2004), Algeria (2009) and France (2006–2009)[114]. The introduction and spread of the pathogenic bacterium Vibrio, provoking disease outbreaks in gorgonians and starfish, may have been caused by climate warming[115,116,117].

Coastal ecosystems

Coastal ecosystems, due to their special position at the interface of the land and the sea, are very exposed to climate and environmental change. Human activities, like urbanization and tourism, have a strong impact on these areas. Chemical pollution also affects these ecosystems, as overall 101 pollution 'hot spots' have been identified in the Mediterranean, generally located in semi-enclosed gulfs and bays near important harbours, big cities and industrial areas[118]. These factors, combined with climate and environmental change, provoke coastal erosion due to sea level rise, extreme events, sedimentation decrease, salt intrusion in coastal aquifers and degradation of some habitats (e.g., coastal dunes, coastal cliffs or coastal terraces). Coastal wetlands, such as the Camargue (France), the Nile Delta (Egypt) and other similar regions, are particularly affected[119,120]. Construction in coastal regions, sand erosion and instabilities in beaches have destructive effects on fauna and flora and, in particular, on endemic species (e.g. monk seal and loggerhead sea turtle)[121].

Some species are particularly threatened by the sea level rise, such as the calcified cushion-like red alga (Lithophyllum byssoides), which forms algal rims highly resistant to waves and storms. The bioconstruction of these rims is only possible under a stable or slightly rising sea level. Today, these algal rims have begun to be submerged. As the current rate of sea level rise appears to be accelerating, the rims would seem to be condemned[122].

The primary production of some coastal areas may be impacted by the reduction in freshwater discharge from the rivers[123].

Freshwater ecosystems and wetlands

Mediterranean freshwater ecosystems and inland wetlands are affected by falling water levels and reduced water quality[124]. Climate change increases flood risk and streamflow variability. As a consequence more dykes and dams are constructed, which influences freshwater ecosystems[125]. Mediterranean stream biota responses to climate change include shifts of organisms to higher latitudes and/or elevations and subsequent changes of community composition often resulting in homogenization and loss of diversity. Short-lived and small species, which are resistant to low stream flow and drying, seem to provide better resilience and resistance than others[126]. Inland wetlands are particularly vulnerable to climate change, but also to human activities[28], which alter flooding regimes and affect the vital rates, abundance and distributions of wetland-dependent species. Wetlands in dry environments are hotspots of biological diversity and productivity, and their ecosystems are at risk of extinction if runoff decreases and the wetland dries out[119].

Human health

Climate, along with other environmental changes, has both direct and indirect effects on human health. Direct effects include those caused by higher temperatures, increased UV radiation, droughts and other extreme events such as storms and floods. Heat-related illnesses and fatalities can occur when high ambient temperatures (in particular combined with high relative humidity) exceed the body's natural ability to dissipate heat. For example, a recent analysis for Barcelona (Spain) found an increased risk in mortality due to natural, respiratory, and cardiovascular causes during hot nights with temperatures higher than 23°C[127]. In general, elderly people, children, people with pre-existing chronic conditions (i.e. respiratory diseases, cardiovascular disease, diabetes) are most affected[128,129]. Increased mortality was found among people over 65 years in Athens, Greece at high and very high temperatures[130]. During the severe heat wave in France (summer 2003) most of the extra deaths occurred in the elderly population[131]. Recent studies suggest that extremely high temperatures are associated with an increase in intimate partner violence against women[132].

Although most Mediterranean populations are relatively well acclimatized to high temperatures, an increase in the intensity and frequency of heat waves, or a shift in seasonality, all imply significant health risks for vulnerable population groups, in particular those who live in poverty with substandard housing and restricted access to air-conditioned areas[133]. The degree to which heat-related morbidity and mortality rates will increase in the next decades thus depends on the adaptive capacity of the Mediterranean population groups through acclimatization, adaptation of the urban environment to reduce heat island effect, implementation of public education programs and health system preparedness[134]. Increased population life expectancy implies that the health protection of elderly people will become a major challenge for all Mediterranean countries under heat wave conditions.

In recent years, several outbreaks of different vectorborne diseases have been documented in the Mediterranean region. Climate change contributes to their transmission potential since the life-cycle dynamics of the vector species, pathogenic organisms and the reservoir organisms are all sensitive to weather conditions. It is highly certain that the warming, as well as increasing frequency of extreme events, like floods[135,136], will contribute to the future transmission potential of vector- and water-borne diseases in the region. During recent years, dengue fever cases were reported in Croatia, France, Greece, Italy, Malta, Portugal and Spain. Although most cases were probably imported, in 2010 local transmission of dengue was reported in Croatia and France. During the hot summer of 2017, outbreaks of chikungunya were reported in France and Italy[137]. However, it is difficult to predict the consequences of climate change for infectious disease severity and distributions, especially for vector-borne diseases, because of complex interactions between hosts, pathogens and vectors or intermediate hosts[138]. Areas with elevated probability for West Nile infections, linked to climate change, will likely expand and eventually include most of the Mediterranean countries[139,140].

Indirect health effects are related to the deterioration of air, soil and water quality changes in food provision and quality or other aspects of the social and cultural environments[141]. The concentration of gases and particles in the air increases because of desertification and wildfires resulting from climate change[142], as well as due to direct human activity, especially in large cities. Air quality degradation also impacts climate change, because many air pollutants are greenhouse gases[143] or are produced in larger quantities when temperature is higher (e.g. ozone).

Other health aspects include the climate change driven modifications in the geographic distribution range of some plant species, extension of the pollen season, and increased production of pollen and pollen allergens[144]. Saltwater intrusion into groundwater caused by sea level rise[40], may deprive some population of drinking water, which may have serious health consequences. Floods cause personal injuries, enteric infections, allergies and asthma, increase in mental health problems and potential contamination by toxic chemicals[142,145]. Human activities, like transportation of goods, animals and people, disappearance of natural wetlands, coastal planning, dam construction on large Mediterranean rivers, may enhance natural cycle transmission of infectious agents[146,147] .

Human health in the Mediterranean is much conditioned by societal trends and political situation. In some countries and regions poor sanitary conditions increase a risk of consuming contaminated food or drinking water (for example countries impacted by conflicts in the Middle East and North Africa). Urbanization and growing human population density in coastal areas exacerbate air pollution and increase transmission of many contagious illnesses. Social instability and political conflicts lead to human migrations, which influence the risk of disease proliferation[148].

Human security

Climate and environmental changes, as well as societal, economic and political instabilities threaten human security in multiple ways. In the Mediterranean region nearly 40% of the coastline is built up[119]. A third of the population (about 150 million people) lives close to the sea and the infrastructures are often very close to mean sea level, because of limited storm surges and small tidal range[149]. As a consequence, rising sea levels, storm-surges, flooding, erosion and local land subsidence impact harbors, port cities and other coastal infrastructures, as well as wetlands and beaches around the Mediterranean[150,151] (Fig. 11). About 15 mega cities (port cities with a population greater than 1 million in 2005) are at risk from flooding due to sea level rise, unless further adaptation is undertaken[152,153].

By 2050, for the lower sea-level rise scenarios and current adaptation measures, cities in the Mediterranean will account for half of the 20 global cities with the highest increase of the average annual damages[153]. For social and economic reasons, the adaptive capacity of southern and eastern regions of Mediterranean is generally lower than of the one of the northern regions, making these regions particularly vulnerable to the consequences of coastal impacts[154]. The areas at extremely high risk are predominantly located in the southern and eastern Mediterranean region including Morocco, Algeria, Libya, Egypt, Palestine, and Syria[155]. In North African countries 1 m sea-level rise would impact approximately 41,500 km^2 of the territory and at least 37 million people (~11%)[156].

The assessment of the Mediterranean UNESCO World Heritage Sites (WHS) located in coastal areas at risk from coastal flooding and erosion under sea-level rise scenarios showed that of 49 cultural WHS located in low-lying coastal areas of the Mediterranean, 37 are at risk from a 100-year flood (flooding event which has a one per cent chance of happening in any given year) and 42 from coastal erosion, already today.

Another consequence of climate change and human activities threatening human security is salinization of groundwater resources[158]. Coastal areas suffer from intrusion of salt water and this will increase as sea level rises. In Egypt, about 30% of the irrigated farmlands are affected by salt intrusion[159].

ABOUT **15** MEGA **CITIES**
ARE AT RISK
FROM FLOODING
DUE TO SEA LEVEL RISE,
UNLESS
FURTHER **ADAPTATION**
IS UNDERTAKEN

Away from the coast, parts of the Mediterranean region are regularly affected by flash floods which are a consequence of short and local heavy rains in small catchments, many of them in densely populated areas[119]. Flood risk due to extreme rainfall events, will increase due to climate change in these areas, but also due to non-climatic factors such as increasingly sealed surfaces in urban areas and illconceived storm water management systems[161]. In the eastern Iberian Peninsula, observations indicate an increase in convective and heavy precipitation concentrated in fewer days, consistent with expected climate change[162,163]. Not only the intensity, but also the timing of floods changes, towards earlier floods by up to 14 days per decade in the north of Italy, south of France, eastern Greece, or later floods (1 day per decade) near the northeastern Adriatic coast, eastern Spain, the south of Italy, and Greece[164].

Increased frequency and severity of fires, due to warming and changing land management, especially at the periphery of the inhabited areas[87] also represents a significant additional security risk for the Mediterranean population.

With respect to social instability, conflict and migration, human security around the Mediterranean is much dependent on socio-political situation but is also impacted by environmental change. Overall, climate change provokes decrease in available natural or financial resources and thereby tends to exacerbate conflicts. The Syrian up-rising, which began in March 2011, is the outcome of complex but interrelated factors[165,166]. While the main subject of the multi-sided armed conflict has been a political regime change, it is likely that the uprising was also triggered by social, economic, religious and political factors leading to a disintegration of the Syrian rural economy, enhancing trends of a growing rural-urban divide, rising unemployment, and more wide-spread poverty[167]. The hypothesis that climate has played a significant role has been fiercely contested. Although causality cannot be found in such a simple direct relationship, it is considered likely that the recent droughts have played a significant role in triggering the crisis, as these droughts were among the longest and the most intense in the last 900 years[168].

UNTIL 2100
FLOOD RISK
MAY INCREASE BY **50%** AND EROSION RISK BY **13%**

Beyond the case of Syria, it is widely recognized that both environmental and socio-political changes now lead to forced human migrations toward regions less exposed to risks in many parts of the world[169].

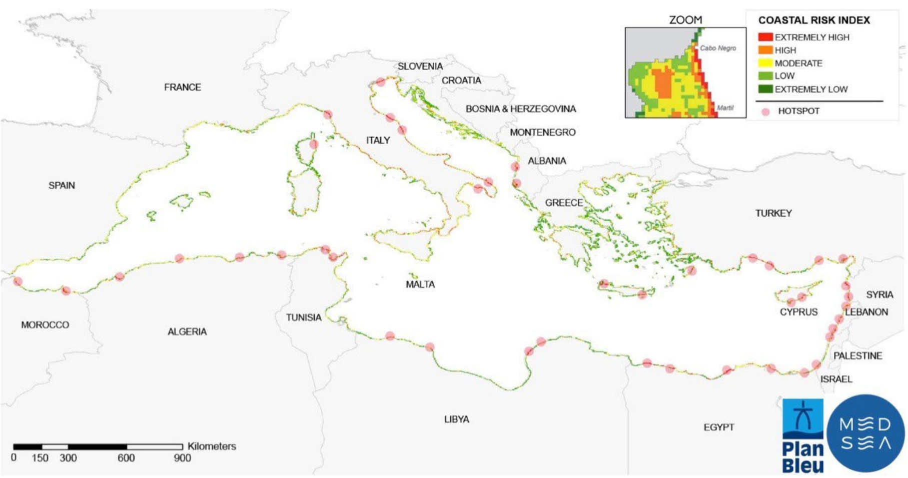


Figure 11
Coastal risks in the Mediterranean[157]

MedECC: Towards a Mediterranean Science-Policy Interface

The preliminary analysis has demonstrated that substantial risks are associated to climate and environmental change in the Mediterranean Basin[6]. It is a widely accepted consensus that issues of mitigation of environmental changes and adapting to the unavoidable components of their impacts is a priority for public and private decision-makers concerned with the future of the Mediterranean. Policy responses to climate change need to be based on scientific evidence.

Although substantial scientific knowledge exists and research has been intensified in the recent years through numerous small studies but also several large collaborative projects (MISTRALS, MedCLIVAR, CIRCE or Med-Cordex), the results of this research remain often not easily accessible to policy-makers. A comprehensive synthesis and assessment of recent trends, likely future development and the consequences of environmental change for natural systems, the economy, and the human well-being, is still lacking. Existing assessments cover only parts of the region in disconnected chapters (e.g. the reports of the Intergovernmental Panel on Climate Change, IPCC, and the Intergovernmental Platform on Biodiversity and Eco-systems, IPBES) or only some topics (e.g. climate variability). Research activities, monitor-ing data and other knowledge generation about climate change and other environmental changes are not sufficiently coordinated. Moreover, even the current large research effort leaves significant parts of the region without adequate information. Some of the most vulnerable regions and economic sectors are insufficiently studied, notably in the South and the East.

Regional political frameworks on these issues exist. The Mediterranean Action Plan (MAP), developed under the auspices of United Nations Environment Programme (UNEP) was adopted four decades ago in 1975, as the institutional framework for co-operation in addressing common challenges of marine environmental degradation. Under this framework, the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention) and its seven protocols brings together the 21 Mediterranean riparian countries and the European Union, as Contracting Parties to the Barcelona Convention. The MAP-Barcelona Convention system is a legally-binding set of instruments, policies and action plans for addressing common issues and challenges of environmental degradation and protecting marine and coastal ecosystems of the Mediterranean Sea.

In February 2016, the 19th Ordinary Meeting of the Contracting Parties to the Barcelona Convention (COP19) adopted the Mediterranean Strategy for Sustainable Development (MSSD) 2016-2025, as a strategic guiding document for all stakeholders and partners to translate the 2030 Agenda for Sustainable Development (2030 Agenda) at the regional, sub-regional and national levels. The MSSD provides an integrative policy framework for securing a sustainable future for the Mediterranean region consistent with the Sustainable Development Goals (SDGs). The MSSD recognizes climate change as a priority issue for the socio-economic development and environmental sustainability of the Mediterranean and calls for increasing scientific knowledge, raising awareness, and developing technical capacities to progress towards a green, low-carbon and climate-resilient Mediterranean region. The Flagship Initiative for the MSSD Objective 4 (Addressing climate change as a priority issue for the Mediterranean) recommends "the establishment of a regional science-policy interface mechanism (...) with a view to preparing consolidated regional scientific assessments and guidance on climate change trends, impacts and adaptation and mitigation options". MedECC directly contributes to this MSSD Flagship Initiative. The Mediterranean Commission on Sustainable Development (MCSD) is the advisory body that assists the Contracting Parties to the Barcelona Convention to integrate environmental issues in their socioeconomic programmes and to promote sustainable development policies in the Mediterranean region. As a forum for debate and exchange of experiences, the MCSD is unique in its composition as it gathers on an equal footing government and local authorities representatives, socio-economic actors, civil society/NGOs, IGOs, scientists, and Parliamentarians. The MCSD is a key structure within the MAP-Barcelona Convention system for supporting the development, implementation and monitoring of the MSSD. Plan Bleu is the UNEP/MAP Regional Activity Center in charge of activities aiming to support the MSSD implementation and monitoring.

The need of robust science-policy interfaces in the Mediterranean has also been stated in the Regional Climate Change Adaptation Framework for the Mediterranean Marine and Coastal Areas (UNEP/MAP) approved by the Contracting Parties to the Barcelona Convention in 2016.

The Union for the Mediterranean (UfM) is an intergovernmental institution created in 2008 and bringing together all 28 countries of the European Union and 15 countries of the southern and eastern Mediterranean. UfM's mission is to enhance regional cooperation, dialogue and the implementation of projects and initiatives with tangible impact on citizens, addressing three strategic objectives: stability, human development and integration. The UfM Climate Change Expert Group (UfM CCEG) was established at the first UfM Ministerial Meeting on Environment and Climate Change in May 2014 in Athens, Greece. During this meeting the Ministers acknowledged an urgent need to address the impact of climate change in the Mediterranean region and shift towards sustainable consumption and production patterns for a green and low emission economy. The role of the UfM CCEG is to advance discussion on climate change priority actions and accelerate the identification and development of concrete projects and initiatives. The UfM Ministerial Declaration of Athens expressed the need for a Mediterranean regional vulnerability assessment regarding climate change impacts.

In the Ministerial Declaration of the Union for the Mediterranean (UfM) Water Ministers released in April 2017, it has been agreed that climate change exacerbates pressures on existing, limited water resources in the Mediterranean. The importance of regional cooperation, supporting valorization and sharing of existing knowledge has been underlined.

The Mediterranean Experts on Climate and Environmental Change (MedECC)

The network of Mediterranean Experts on Climate and Environmental Change (MedECC) was launched during a side event organized at the Conference 'Our Common Future un-der Climate Change' (CFCC) in Paris, (France) in July 2015. MedECC is an open and independent network of more than 600 scientists working towards a regional science-policy interface for climatic and other environmental changes across the Mediterranean.

MedECC's work is fully oriented towards the highest possible scientific standards, with full participation of experts from all involved regions and required scientific disciplines. It is inspired by the Intergovernmental Panel on Climate Change (IPCC), which aims at providing the world with an objective, scientific view of climate change and its political and economic impacts. The two coordinators of MedECC are Lead Authors of the Special Report of IPCC on 1.5°C warming, published in October 2018. Several authors and coordinators of MedECC are authors for the next 6th IPCC report. A cross-chapter on Mediterranean Basin of the 6th IPCC report will be coordinated by one of the MedECC coordinators and will thus build on MedECC's efforts and results.

The objectives of MedECC

- To update and consolidate the best scientific knowledge about climate and environmental changes in the Mediterranean Basin and render it accessible to policy-makers, key stakeholders and general public in order to facilitate ownership of scientific knowledge by them.
- To gather the scientific community working on climate change in the Mediterranean basin.
- To contribute to future IPCC (Intergovernmental Panel on Climate Change), IPBES (Inter-governmental Science-Policy Platform on Biodiversity and Ecosystem Services) or related assessments in the Mediterranean Basin.
- To bridge the gap between research and decision-making, contributing to the improve-ment of policies at all levels.
- To identify possible gaps in the current research on climate change and its impacts in the Mediterranean.
- To help building the capacity of scientists from southern and eastern Mediterranean Countries.

MedECC works in two complementary directions

- Publishing scientifically robust assessment and synthesis of climate and environmental change and its impacts in the Mediterranean Basin, based on published research.
- Building a relevant regional science-policy interface on climate and environmental change in the Mediterranean.

Appropriate interactions between MedECC and decision-makers and stakeholders are developed, through a relevant science-policy interface. Following the adoption of the 2017-2022 work program of the UfM CCEG, UfM Member States agreed to rely on MedECC for the assessment of climate and environmental impacts on the Mediterranean. It has been decided that given the cross-sectoral nature of the MedECC and its strong environmental dimension, any possible UfM contribution to the MedECC activities will be elaborated in an inclusive way, by involving jointly the Environment and Climate Change representatives of the UfM Member States and in coordination with all relevant UfM structures.

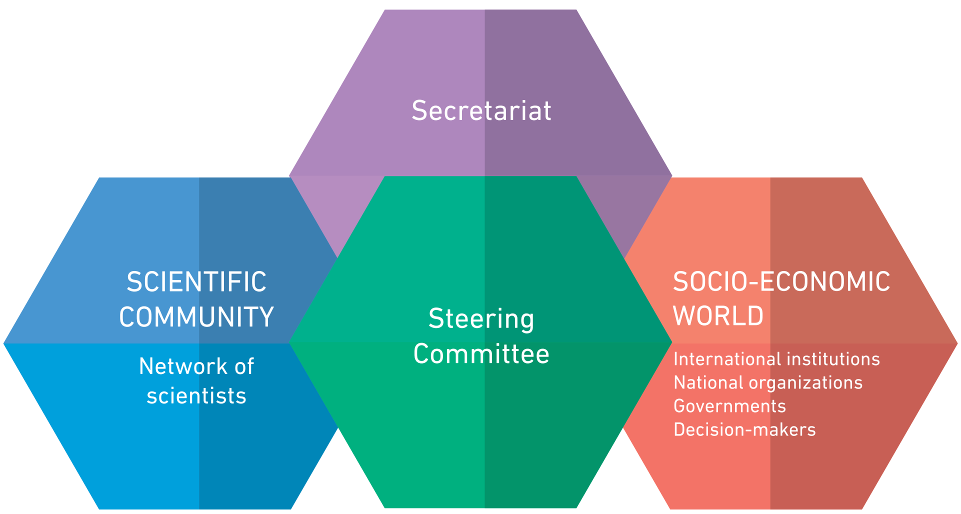
The synergies with other policy dialogue structures are built, especially with the MAP-Barcelona Convention system via the MCSD and Plan Bleu Focal Points. The MAP Programme of Work and Budget for 2018-2019 (adopted at COP 20 in Tirana in December 2017) include specific activities that strengthen interface between science and policy-making through enhanced cooperation with global and regional scientific institutions and knowledge sharing platforms, including MedECC.

The Secretariat of the Union for the Mediterranean signed an agreement with Plan Bleu Regional Activity Center (UNEP/MAP) to jointly support MedECC. The secretariat of MedECC is funded by the Swedish International Development Cooperation Agency (SIDA) through Union for the Mediterranean and is hosted by Plan Bleu in Marseille, France.

First MedECC Assessment Report (MAR1)

The publication of the first MedECC report on the current state and risks of climate and environmental changes in the Mediterranean is planned for the beginning of 2020. This report will assess drivers of climate and other environmental changes, associated challenges for key sectors, focusing on water, food, energy, ecosystems and ecosystem services, development, health and human security. Best practices for adaptation and mitigation for enhanced resilience will also be presented. The Summary for Policymakers of the report will be presented for discussion and approval by decision-makers.

Structure of MedECC



The history of MedECC

- **07/2015** — Creation of MedECC during "Our Common Future under Climate Change" conference in Paris (France)
- **12/2015** — Side event during 21st session of the Conference of the Parties the United Nations Framework Convention on Climate Change (COP 21 – UNFCCC) in Paris (France)
- **04/2016** — MedECC Steering Committee meeting in Barcelona (Spain)
- **07/2016** — Presentation of MedECC during MedCOP CLIMAT in Tangiers (Morocco)
- **10/2016** — 1st MedECC Assessment Report (MAR1) Scop-ing Workshop in Aix-en-Provence (France)
- **12/2016** — Side event during 22nd session of the Confer-ence of the Parties the United Nations Framework Convention on Climate Change (COP 22 – UNFCCC) in Marrakesh (Morocco)
- **04/2017** — MedECC Steering Committee meeting in Barcelona (Spain)
- **05-07/2017** — 3 thematic workshops (production of the report's outline, "Challenges" chapter)
- **10/2017** — Workshop on human impacts on Mediterranean marine ecosystems and the economy (with Plan Bleu and Scientific Centre of Monaco)
- **03/2018** — Workshop on drivers of climate and environmental change
- **05/2018** — Establishment of MedECC secretariat
- **10/2018** — Appointment of Coordinating Lead Authors and Lead Authors of 1st MedECC Assessment Report (MAR1)

MedECC has also been presented during numerous scientific and public events.

MedECC foundation article

A few scientists representing the MedECC network have published recently the first synthesis of multiple changes in the environment that impact the livelihoods of people in the entire Mediterranean Basin:

REVIEW ARTICLE
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nature climate change

Climate change and interconnected risks to sustainable development in the Mediterranean

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Recent accelerated climate change has exacerbated existing environmental problems in the Mediterranean Basin that are caused by the combination of changes in land use, increasing pollution and declining biodiversity. For five broad and interconnected impact domains (water, ecosystems, food, health and security), current change and future scenarios consistently point to significant and increasing risks during the coming decades. Policies for the sustainable development of Mediterranean countries need to mitigate these risks and consider adaptation options, but currently lack adequate information — particularly for the most vulnerable southern Mediterranean societies, where fewer systematic observations schemes and impact models are based. A dedicated effort to synthesize existing scientific knowledge across disciplines is underway and aims to provide a better understanding of the combined risks posed.

Local Mediterranean science-policy interfaces

Some local initiatives support science-policy interface on climate change. The Regional Group of Experts on Climate in the "South Region" of France (Provence-Alpes-Cote d'Azur), GREC-SUD in France aims to centralize, transcribe and share scientific knowledge on climate and climate change in the region. The priority objective of the group is to inform the decision-makers (elected representatives, local authorities) of the territory, so that scientific results are taken into account in public policies. 7 thematic booklets on climate change in the region have been published so far.

The Advisory Council for the Sustainable Development of Catalonia (CADS) is an advisory body of the Catalan Government which main instrumental aim is being an effective and successful interface between scientists, policy makers and stakeholders. Since 2005, CADS has been in charge of the elaboration of the periodic Report on Climate Change in Catalonia. The most recent one has been published in September 2016. It has involved 150 experts and more than 40 reviewers.

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The complete list of references may be found in the online annex on the MedECC website:

http://www.medecc.org

Authors of this report

This document has been developed by W. Cramer (IMBE, CNRS; MedECC), J. Guiot (CEREGE, CNRS; MedECC) and K. Marini (MedECC). It is to a large extent based on:

Cramer W, Guiot J, Fader M, Garrabou J, Gattuso J-P, Iglesias A, Lange MA, Lionello P, Lla-sat MC, Paz S, Peñuelas J, Snoussi M, Toreti A, Tsimplis MN, Xoplaki E (2018) Climate change and interconnected risks to sustainable development in the Mediterranean. Nature Climate Change 8, 972-980, doi: 10.1038/s41558-018-0299-2

The report also includes results of discussions among MedECC scientists during workshops and meetings, which have taken place since 2016. It has been prepared in collaboration with Arnault Graves (UfM Secretariat) and Elen Lemaître-Curri (Plan Bleu Regional Activity Centre, UNEP/MAP).

This booklet is also a part of a contribution of MedECC to the 2019-Report on the State of the Environment and Development in the Mediterranean (SoED 2019) prepared by UNEP/MAP and key partners at the request of the Mediterranean riparian countries and the European Union. In close co-operation with Plan Bleu, MedECC co-leads the "Climate change" chapter of the SoED 2019.

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MedECC

Mediterranean Experts on Climate and environmental Change

Supporting institutions

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