RACE AGAINST THE CLIMATE CLOCK

Climate change and extreme weather events in Spain

GREENPEACE

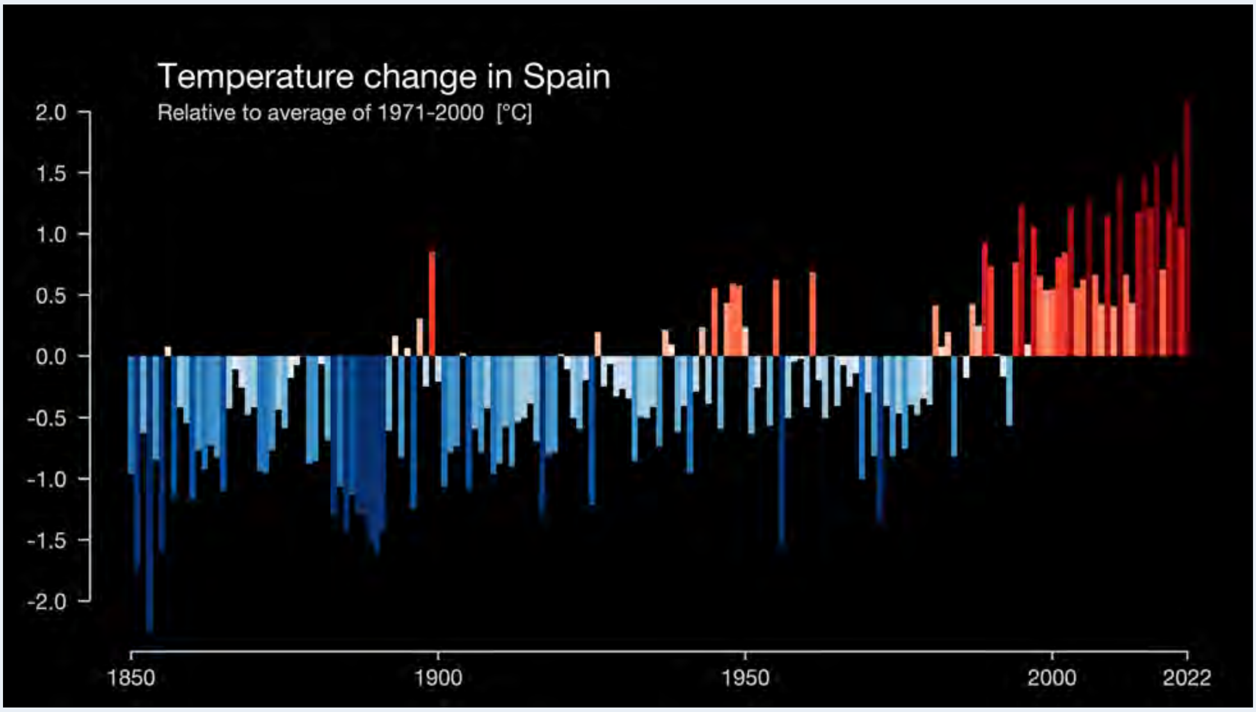
TABLE OF CONTENTS

06/19/2023. Tablas de Daimiel National Park, Ciudad Real. Spain

07/01/2023. Greenpeace evidences the drought in the Doñana National Park, Andalusia.

GLOSSARY

- **Biome:** is a community of plants and animals living together under a specific climatic regime.
- **Ecological drought:** episodic deficit in water availability that pushes ecosystems beyond vulnerability thresholds, impacts ecosystem services, and triggers reactions in natural and/or human systems.
- **Evapotranspiration:** loss of moisture from surfaces by evaporation together with the loss of water through transpiration from vegetation.
- **Forest fuel:** all the organic matter found in the forests in conditions of availability for combustion in a potential fire.
- **Heat wave:** episode of at least three consecutive days, in which at least 10% of the stations considered register maximums above the 95% percentile of their series of daily maximum temperatures for the months of July and August of the 1971 - 2000 period.
- **Hydrological year:** in Spain it is considered to begin on October 1 and end on September 30
- **Hydroperiod:** it is defined by the duration and frequency of flooding of a wetland. Three types: permanent, temporary and tidal.
- **Marine heat wave:** if the sea water temperature is above 90% of the historical data for that area and time of year for at least five days.
- **Morbidity:** number of people who contract or exhibit a disease or a medical condition in a given time period.
- **Phylum:** a group classifying animals and plants, intermediate between a kingdom and a class, which groups organisms on the basis of their fundamental characteristics
- **Radiative forcing** by a climate variable is the change in the balance of energy reaching the earth from solar radiation and that re-emitted from the earth as infra-red radiation. Increases in the atmospheric concentration of the greenhouse gasses carbon dioxide and methane cause increased retention of heat in earth systems.
- **Storm surge:** coastal flooding commonly associated with a low pressure weather system. Generally, a storm surge is a product of high-altitude winds that push the ocean surface above levels of normal astronomical tides in combination with atmospheric pressure and local water depths.
- **Vector-borne diseases:** human diseases caused by bacteria, viruses or parasites, that are transmitted by vectors such as mosquitoes, ticks, flies, fleas, and lice.
- **Wet bulb temperature:** an indicator of how much the human body can cool itself by sweating. It is measured by using a thermometer with the bulb wrapped in damp muslin cloth and allowing the water to evaporate naturally.



Observed warming in Spain, visualised as a graph that shows how the country's average annual temperature has changed over the decades from 1850–2022 (with respect to the 1971–2000 average). Each bar represents one year; years that are warmer than the average annual temperature during the reference period (1971–2000) are red and cooler years are blue. The graphic was developed by Professor Ed Hawkins from the National Centre for Atmospheric Science at the University of Reading's Department of Meteorology in the United Kingdom. Billions of pieces of data were used to create hundreds of images that cover every country in the world and which are available to download free of charge. #ShowYourStripes

To create a climate stripes graphic for other countries, regions and states, or for the global overview, visit: https://showyourstripes.info

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RACE AGAINST THE CLIMATE CLOCK

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Greenpeace Research Laboratories Technical Report (Review) 01 2023

Publication date: July 4, 2023

The Mediterranean, which includes Spain, is heating faster than many other regions of the world and has already experienced climate change impacts such as drought, floods, heatwaves, temperature extremes and increased forest fire risk. This Greenpeace Spain briefing outlines the main reasons for concern and what urgent action can be taken to help to mitigate future impacts. It is time to accelerate the climate action that has already begun to achieve the rate of emissions reductions essential to avoid the worst consequences of climate change. The moment to take action is today – not tomorrow.

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1.0 INTRODUCTION

05/27/2011. Cadiz, Andalusia, Spain.

Flood esplanade of the Las Aletas marshes.

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Since the 1980s, the rate of climate warming in the Mediterranean region, which includes Spain, has exceeded the global average. The Mediterranean region is expected to reach 2°C warming within the next 20 years – unless immediate and severe cuts are made to global greenhouse gas emissions (Zittis et al., 2019). Every region of the globe is affected by climate change, and many regions are experiencing weather and climate extremes (IPCC, 2023). Climate impacts are becoming more severe and devastating and those trends are projected to continue – what is more, extreme weather events will be more severe with every incremental increase in global average temperature (IPCC, 2023, Fig. SPM.2).

Spain's residents have already experienced the impact of declining annual rainfall at a rate of about 3–11 mm per decade since the 1950s (Cherif et al., 2020). In the recent past (1961–2018), Spain has faced three extended multi-year periods of high intensity droughts (AEMET, 2020; Table 5). The year 2021 was the Iberian Peninsula's third driest year in a row (WMO, 2022). Eleven of the country's 15 river basins are experiencing water stress (Vargas & Paneque, 2019), leading to concerns about water levels in reservoirs and the impact both to farmers for agricultural crops and for domestic use. In 2023, Spain recorded its hottest ever April day (McGrath & Hedgecoe, 2023), and last year, 2022, was Spain's warmest year on record (WMO, 2023). Hot days take their toll on human life – the World Health Organisation estimated that heat stress contributed to an estimated 4,000+ excess deaths in Spain in 2022 (WHO, 2022; WMO, 2023).

Droughts, heatwaves and torrential rain events (responsible for floods) seem to be increasing in frequency and intensity – not just in Spain but globally. A simplified explanation of the broad impacts of climate change on extreme weather is that continued greenhouse gas emissions make the Earth's lower atmosphere warmer and wetter, which increases the risk of more intense heatwaves and more intense periods of rain/snow (Royal Society, 2020). With regards to Spain, research suggests that in future decades the country will experience more frequent and prolonged extreme weather events. The crucial point is that irrespective of future global greenhouse gas concentrations and global responses, the climate in Spain is expected to become warmer. However, the rate and extent of the changes will depend on future emissions trajectories. We understand from research that human activities, primarily burning fossil fuels, have caused the present global average temperature to increase. The figure from the IPCC suggests that human-induced warming has increased the global average annual temperature by 1.15°C in comparison to the second half of the nineteenth century (WMO, 2022; IPCC, 2023). However, a slightly higher figure is arrived at by Haustein et al. (2017) through a real-time index that estimates the level of human-induced warming since the reference period 1850–1879 is 1.27°C (as of May 2023) (https://www.globalwarmingindex.org). In 2022, data show that greenhouse gas emissions continued to increase, further contributing to increasing the Earth's land and ocean surface temperature. Figures from 2021 (the most recent data available) show that the global atmospheric carbon dioxide concentration has increased 50% in comparison to pre-industrial levels (WMO, 2023).

Extreme weather events in Spain have had, and will continue to have, widespread impacts. Extended periods of drought and heat reduce the availability of freshwater and threaten agricultural yields. This, in turn, can lead to water shortages and increased food prices. In addition, it adds to the stressors such as habitat loss from land-use change which impact upon ecosystems and biodiversity.

1.1 Past trends and the current situation

1.1.1 Land

During the 2021 summer heatwave that affected much of western Europe, Montoro in the Córdoba Province in north-central Andalusia recorded a national record breaking temperature of 47.4°C on August 14 (WMO, 2022).

Globally, the annual average temperature is around 1.15°C warmer than the late nineteenth century, according to data analysis. This estimate has been arrived at by comparing the years 2011–2020 with the years 1850–1900 (WMO, 2022; IPCC, 2023). However, global averages do not present the full picture because not all parts of the world are warming at the same rate. As a result, some regions are experiencing greater changes to mean weather patterns and extremes than others, and this is the case for the Iberian Peninsula including Spain. The rate of atmospheric warming in the Mediterranean region, which includes Spain, has, since the 1980s, exceeded the global average rate of climate warming. This is being seen through observations of such events as the heatwave across southern Spain in spring 2023 – an unusual event for the time of year – that saw air temperatures at Córdoba airport reach 38.8°C on April 27, making it the country's hottest ever April day (McGrath & Hedgecoe, 2023). World Weather Attribution considers that Spain's April 2023 heatwave would have been impossible without climate change (WWA, 2023).

The observed rainfall trends in the region vary and are mostly controlled natural climate variability (Cherif et al., 2020). Over the past few decades, many parts of Spain – especially in the south and central regions – have experienced a decrease in the amount of rain (or snow) that falls each year. The decline in rainfall has been primarily during the summer months, although not all regions of Spain have been equally affected. There has, for example, been an increase in the amount of annual rainfall in Galicia and Asturias in the north of the country (Arias et al., 2021 p130; Senent-Aparicio et al., 2023).

Even though some places in the north of the country have, on average, not been severely impacted by drought, many regions of Spain are experiencing what is called 'water stress'. Analysis published in 2019 found that 11 of Spain's 15 river basin districts were under water stress and that while the reason was partly because of changing weather patterns, major drivers were the increase in agricultural demand for water to grow crops (approximately 80%), water demand in towns and cities (16%), and water use by industry (4%). Only four districts (Cantábrico Occidental, Cantábrico Oriental, Galicia Costa, and Miño-Sil) had little or no water stress at the time of the study. The three districts considered to have extremely high water stress are Duero, Tajo, and the interior basins of Catalonia (Vargas & Paneque, 2019). In 2023, the three districts considered to have the highest water stress so far are Guadiana, Gualdalquivir, and the interior basins of Catalonia.

Above. **04/26/2023. April Fair, Seville, Andalusia, Spain. According to Meteored, Spain had never exceeded 21ºC in April, and maximum temperatures that exceed 40ºC were reached in some areas of the Guadalquivir Valley.** ©Greenpeace/G.J.CARAZO

Below. **11/26/2021. La Axarquia, Malaga, Andalusia, Spain. New avocado plantations and irrigation ponds.** ©Greenpeace/Pedro Armestre

1.1.2 Sea

It is estimated that the average sea surface temperature of the Mediterranean Sea has risen at around three times the global average between 1982–2018 and that this temperature increase of approximately 0.4°C per decade has been associated with an appreciable increase in marine heatwaves since the beginning of the twenty-first century. Over the entire Mediterranean basin, the 2015–2019 period was considered to be the warmest since records began in 1982, and these conditions have continued in the region. In turn, some of these periods of anomalously high sea temperatures have been the cause of ecological damage through, among other things, mass mortalities of marine species.

8/19/2021. Mar Menor, Murcia, Region of Murcia, Spain. Episode of fish mortality due to anoxia in the Mar Menor.

©Greenpeace/Virginia Rabal

1.2 Climate projections

1.2.1 Temperature

The rate of warming in most parts of Spain will continue to be faster than the global average. For example, for every additional degree of global warming, the regional response will be up to 1.5°C with more pronounced changes expected for the inland parts of the country (Tebaldi et al., 2021).

On average, mean annual temperature in Iberia is projected to increase by 1.1 to 2°C (with reference to 1980-1999), with the highest values expected for high-emission pathways (Cherif et al., 2020). In such scenarios and with current policies, warming is projected to exceed 4°C by the end of the 21st century – unless actions are taken to increase the rate of emissions reductions.

With a projected global average temperature rise of 1.5°C, Spain's hottest day is projected to be around 2°C (or more) hotter than the hottest day during the reference period (1850–1900). If the global annual average temperature increases by 2°C, the annual hottest day in Spain is projected to be approximately 3°C (at least) hotter than the reference period (1850–1900) by the middle of this century, rising to more than 4°C hotter than the baseline period under a 3°C rise in global average temperature (IPCC 2023, in Figure SPM.2).

As with the rest of the Mediterranean, the Iberian Peninsula is expected to warm more strongly during the summer season compared to wintertime (Cherif et al., 2020).

1.2.2 Precipitation (rain, snow, hail)

Many regions of Spain are projected to become drier when considering the annual rainfall totals. Paradoxically, although most climate projections for Spain agree on less annual rainfall overall, at shorter timescales rainfall events will likely be increasingly associated with short but high intensity events (Zittis et al., 2021). Such events, in synergies with extensive land use changes, can cause localised flooding. Moreover, these torrential rains are not always useful in replenishing the depleted groundwater reserves over time. The reason that heavy rain does not necessarily replenish groundwater stores is because soils that have become degraded by drought and fire have

03/09/2018. Lepe, Huelva, Andalusia, Spain. A storm that hit the coast of Huelva left extensive damage in La Antilla, Lepe, in the province of Huelva.

reduced capacity to infiltrate water, therefore extreme precipitation events bring increased risk of runoff and erosion. Climate projections suggest that periods of rainfall will probably become more intense, particularly in high-emission pathways and despite the reduction in the number of rainy days. For example, the volume of rain (or snow/hail) that falls on the annual wettest day in Spain expected to increase by up to 10% in comparison to the baseline period (1850–1900) under all global average temperature rise scenarios (from 1.5°C to 4°C above the baseline) (IPCC, 2023 in Figure SPM.2). This could increase the risk of flooding (Douville et al., 2021) and poses additional challenges regarding water management.

The overall projected trend is for reduced precipitation in Spain concentrated into fewer, more intense events. This scenario is in line with other countries bordering the Mediterranean. Modelled projections of rainfall patterns are more uncertain than those for temperature change in part because of the complexity of the interactions between weather systems and geography and orography in landscapes in which rainfall is already scarce. The scientific consensus suggests, however, that ongoing drying throughout this century is likely.

Besides changes in mean conditions, climate change will also impact the variability of rainfall in this region (Zittis et al., 2019). This means that the year-to-year variability will increase, resulting in more extreme dry and wet seasons or years, impacting ecosystems, agriculture and other socio-economic activities.

1.2.3 Sea state

This section considers marine temperature increases and sea-level rise. Between 2015 and 2019, the exceptional temperature conditions experienced in the Mediterranean Sea resulted in five consecutive years of mass mortality events in various locations. These mass mortality events affected thousands of kilometers of coastline across a range of marine ecosystems, including those in Spanish waters, involving species from up to eight plant and animal phyla (Garrabou et al. 2022). Overall, the average sea surface temperature in the Mediterranean Sea is expected to rise by between +1.8°C and +3.5°C by 2100, with hotspots expected on the east coast of Spain and in the eastern Mediterranean Sea (UNEP, 2020).

1.2.3.1 Marine heatwaves

The marine heatwaves and rapid average air temperature warming considered together reduce the scope for adaptive changes by organisms and could drive shifts in their geographical distributions to remain within preferred temperature conditions. This could result in local extinctions and large scale changes in distribution and ranges (Templado, 2014). Elsewhere along the Spanish coastline, in the central Cantabrian Sea which is largely influenced by the Atlantic, marine heatwaves have been recorded although trends in frequencies and intensities are much less clear. Nonetheless, such events are predicted to increase in the future and there is a clear upwards trend in sea surface temperatures in the Bay of Biscay (Izquierdo et al., 2022). Marine heatwaves are expected to become more intense and frequent in the future, although there is likely to be a high degree of variation across the Mediterranean as a whole.

Waters of the Spanish Exclusive Economic Zone, waters surrounding the Balearic islands and those extending further north to the mainland Spanish coast may be particularly vulnerable to increasing intensity of marine heatwave events. (Garrabou et al., 2022; Dayan et al., 2023; Pastor & Khodayar, 2023). A particularly extreme heatwave impacted on the Mediterranean Sea during 2022. Sea water temperature anomalies of up to 5°C were observed through the ESA-funded CAREHeat project (ESA, 2022). This marine event coincided with the 2022 terrestrial heatwave which affected much of Europe. Maps based on European Union Copernicus Marine Service information (TMEDNet 2023) that are based upon both historical and new data confirm that marine heatwaves are continuing to occur in 2023. The recent terrestrial heatwave that affected the western Mediterranean area at the end of April 2023 and which was similar to events that have driven past marine heatwaves was judged by World Weather Attribution (WWA, 2023) to have been almost impossible without the contribution of human induced climate change. If average temperatures continue to rise more quickly in the region than the global average and the frequency and intensity of marine heatwaves continues to increase as a consequence, profound impacts upon marine biodiversity seem to be inevitable.

Reversing or stopping the ocean temperature increase requires a timescale of hundreds to thousands of years. Increased sea surface temperatures lead to coral bleaching and sea-level rise. Continued release of greenhouse gases such as carbon dioxide and methane contribute to heating and, in the case of carbon dioxide, acidification of the ocean (WMO, 2023).

1.2.3.2 Sea-level rise

A rise in global sea level will have impacts on coastal regions and islands. By the end of the century, the scale and extent of impacts will depend upon the extent of regional sea-level rise and resultant periodic flooding and permanent inundation. The Mediterranean region could be particularly vulnerable because of the high percentage of people living in coastal regions – one estimate is that in the Mediterranean, 34% of people live in coastal regions whereas globally around 10% of the population live in coastal regions (Luque et al., 2021) **(Table 1)**.

Sea-level rise, particularly in synergy with extreme weather phenomena such as storm surges, could impact critical infrastructure such as seaports and thus affect maritime operations. Under high-emission pathways, the Canary and Balearic Islands, which strongly rely on marine means for transporting goods and passengers, will face an increased risk of maritime transport disruption (Zittis et al., 2023).

11/08/2007. La Manga del Mar Menor, Murcia, Spain.

Greenpeace showed in the book "Photoclima" the transformation that Spain will suffer if action is not taken against climate change. Photoclima puts in images the reports of the UN Intergovernmental Panel on Climate Change to warn of the urgency of reducing CO2 emissions.

Table 1 | Projected changes of mean sea-level rise and sea surface temperature (rel. to 1995–2014) for the Mediterranean (including the Atlantic coast of Iberia) according to the CMIP6 ensemble mean (26 models). Source: https://interactive-atlas.ipcc.ch/

	Mean sea level rise (m)		Sea surface temperature (°C)	
Scenario	SSP1-2.6	SSP5-8.5	SSP1-2.6	SSP5-8.5
Near Term (2021-2040)	0.1 (0.1-0.2)	0.1 (0.1-0.2)	0.7 (0.5-1.1)	0.8 (0.5-1.2)
Medium Term (2041-2060)	0.2 (0.1-0.3)	0.3 (0.1-0.4)	1.0 (0.7-1.5)	1.6 (1.0-2.1)
Long Term (2081-2100)	0.4 (0.2-0.7)	0.7 (0.4-1.0)	1.1 (0.6-1.9)	3.5 (2.5-4.5)

2.0 SUMMARY OF IPCC FINDINGS

This section outlines findings from the Synthesis Report of the Intergovernmental Panel on Climate Change Sixth Assessment Report (AR6), and findings from the three working groups (Working Group I – The Physical Science Basis; Working Group II – Impacts, Adaptation and Vulnerability; Working Group III – Mitigation of Climate Change). See **Table 2**.

The main findings from AR6 build upon previous Assessment Reports that climate changes are already happening, most global land areas will become hotter through the twenty-first century, and that many of the changes are as a result of human activity. One of the main findings is that the average global surface temperature has warmed by 1.1°C when comparing the period 1850–1900 with the period 2011–2020. Additionally, the past five years (2016–2020) have been the hottest on record since at least 1850.

Since AR5 there has been an increased frequency of extreme weather events on a global level, such as precipitation (rain, snow and hail) that cause floods, tropical cyclones, and heat extremes that lead to drought and to increases in wildfires. In relation to Spain, AR6 projections indicate a likely decrease in total precipitation in the southern and central regions, with increasing aridity and drought. Climate heating will bring an increased risk of extreme heat events to the Mediterranean region, including Spain. The IPCC WGIII suggests that changes will need to be both structural and cultural. Societal responses will need to involve consideration of variables such as problem awareness, perceived risk, and subjective and social norms and values. The IPCC interactive atlas (https://interactive-atlas.ipcc.ch) is a useful visual tool to see how regions might be affected by heat and precipitation under different climate warming scenarios.

Key overall climate risks for Spain

by 2100 if greenhouse gas emissions are not rapidly stopped:

- **(risks to) marine ecosystems;**
- **(risks to) terrestrial ecosystems;**
- **inland flooding;**
- **coastal sea-level rise;**
- **(risks to) human health and well-being (extreme heat or flash floods);**
- **water scarcity and drought;**
- **wildfires; and**
- **decreased crop yield.**

The important factor to note is that swift action to stop greenhouse gas emissions and move to green energy sources and technologies can have a positive impact to reduce the effect on the climate. Climate heating-induced risks can be mitigated with adaptations and, crucially, can be reduced by stopping further emissions (Ali et al., 2022 in Figure CCP4.7).

Table 2 | Key points copied verbatim from the Technical Summaries of the IPCC AR6 reports in more detail, with reference to the relevant section numbers of those summaries.

Region	Topic	Observed changes	Projected changes
AR6 Synthesis Report – Climate Change 2023 (Lee et al., 2023)			
Global	**Human activities**	"Human activities, principally through emissions of greenhouse gasses, have unequivocally caused global warming." (Lee et al., 2023, section 2.1)	
Global	**Temperature**	"Global surface temperature reach[ed] 1.1°C above 1850-1900 in 2011-2020." (Lee et al., 2023, section 2.1	
Global	**Extreme weather**	"Human-caused climate change is already affecting many weather and climate extremes in every region across the globe." (Lee et al., 2023, section 2.1)	
Global	**Vulnerable communities**	"Vulnerable communities who have historically contributed the least to current climate change are disproportionately affected." (Lee et al., 2023, section 2.1)	
Europe	**Flooding**		"At 1.5°C global warming, heavy precipitation and flooding events are ected to intensify and become more frequent in most regions in ... Europe (medium confidence)." (Lee et al., 2023, section 3.1.1)
Europe	**Drought**		"At 2°C or above, these changes expand to more regions and/or become more significant (high confidence), and more frequent and/or severe agricultural and ecological droughts are projected in Europe ... (medium to high confidence)." (Lee et al., 2023, section 3.1.1)
Europe	**Adaptation**		"With increasing global warming, more limits to adaptation will be reached (high confidence) and losses and damages, strongly concentrated among the poorest vulnerable populations, will increase (high confidence)." (Lee et al., 2023, section 3.2)
Europe	**Heat stress**		"Adaptation to address the risks of heat stress, heat mortality and reduced capacities for outdoor work for humans face soft and hard limits across regions that become significantly more severe at 1.5°C, and are particularly relevant for regions with warm climates (high confidence)." (Lee et al., 2023, section 3.2)

Region	Topic	Observed changes	Projected changes
Working Group I – The Physical Science Basis (Arias et al., 2021)			
Global	**Human activity**	“Human-caused climate change has driven detectable changes in the global water cycle since the mid-20th century (high confidence).” (Arias et al., 2021, box TS.6)	
Mediterranean	**Water cycle**		“Projected increases in evapotranspiration due to growing atmospheric water demand will decrease soil moisture over the Mediterranean region (high confidence).” (Arias et al., 2021, box TS.6)
Mediterranean	**Water cycle**		“The total land area subject to increasing drought frequency and severity will expand (high confidence), and in the Mediterranean ... future aridification will far exceed the magnitude of change seen in the last millennium (high confidence). (Arias et al., 2021, box TS.6)
Mediterranean	**Climate drivers**		“With 2°C global warming, and as early as the mid-21st century, a wide range of [climatic impact-drivers], particularly related to the water cycle and storms, are expected to show simultaneous region-specific changes relative to the recent past with high or medium confidence. In a number of regions (... the Mediterranean ...), increases in one or more of drought, aridity and fire weather (high confidence) will affect a wide range of sectors, including agriculture, forestry, health and ecosystems.” (Arias et al., 2021, section TS.4.3.2)
Mediterranean	**Climate drivers**		“ ... increasing dry [climatic impact-drivers] (aridity; hydrological, agricultural and ecological droughts; fire weather) are projected in the ... Mediterranean ... (medium to high confidence). (Arias et al., 2021, section TS.4.3.2.1)
Mediterranean	**Wet and dry**	“Trends towards increased hydrological droughts have been observed in the Mediterranean (high confidence) .... These trends correspond with projected regional increases in aridity and fire weather conditions (high confidence).” (Arias et al., 2021, section TS.4.3.2.1)	“Precipitation declines and ar idity trends in ... the Mediterranean co-occur with trends towards increased agricultural and ecological droughts ... (medium confidence).” (Arias et al., 2021, section TS.4.3.2.1)
Mediterranean	**Wind**		“Mean wind, extreme winds and the wind energy potential in ... the Mediterranean are projected to decrease across all scenarios (high confidence).” (Arias et al., 2021, section TS.4.3.2.1)
Mediterranean	**Wind**		“The frequency of Medicanes (tropical-like cyclones in the Mediterranean) is projected to decrease (medium confidence).” (Arias et al., 2021, section TS.4.3.2.5)
Mediterranean	**Drought**	“... observed increases in ... hydrological and agricultural/ecological droughts in the Mediterranean (high confidence), ... have been attributed to human influence with medium confidence” (Arias et al., 2021, section TS.4.3.2.5)	“Aridity, agricultural and hydrological droughts and fire weather conditions will increase in the Mediterranean region starting from 2°C [global warming level] (high confidence).” (Arias et al., 2021, section TS.4.3.2.5)
Mediterranean	**Flooding**		“Pluvial flooding will increase everywhere with ... medium confidence in the Mediterranean” (Arias et al., 2021, section TS.4.3.2.5)

Region	Topic	Observed changes	Projected changes
Working Group II – Impacts, Adaptation and Vulnerability (Pörtner et al., 2021)			
Mediterranean	**Water systems and water security**		"Drought risks and related societal damage are projected to increase with every degree of warming (medium confidence)." (Pörtner et al., 2021, section TS.C.4.4)
Europe	**Water systems and water security**		"In southern Europe, more than a third of the population will be exposed to water scarcity at 2°C, and the risk doubles at 3°C, with significant economic losses (medium confidence)." (Pörtner et al., 2021, section TS.C.4.4)
Mediterranean	**Water systems and water security**		"Over large areas of … the Mediterranean … the frequency of extreme agricultural droughts is projected to be 150% to 200% more likely at 2°C and over 200% more likely at 4°C (medium confidence)." (Pörtner et al., 2021, section TS.C.4.4)
Mediterranean	**Hydropower**		"In the Mediterranean and parts of Europe, potential reductions of hydropower of up to 40% are projected under 3°C warming, while declines below 10% and 5% are projected under 2°C and 1.5°C warming levels respectively." (Pörtner et al., 2021, section TS.C.4.6)
Europe	**Vector-borne disease**		"Higher temperatures combined with land use/land cover change are making more areas suitable for the transmission of vector-borne diseases (high confidence)." (Pörtner et al., 2021, section TS.B.5.6)
Europe	**Vector-borne disease**		"Climate change and variability are facilitating the spread of chikungunya virus in … Europe … (medium to high confidence); tick-borne encephalitis in Europe (medium confidence); … Lyme disease vectors in … Europe (medium confidence) (Pörtner et al., 2021, section TS.B.5.6)
Global	**Sea-level rise**		"Under all climate and socioeconomic scenarios, low-lying cities and settlements, small islands … and deltaic communities will face severe disruption by 2100, and as early as 2050 in many cases (very high confidence)" (Pörtner et al., 2021, section TS.C.5.3)
Europe	**Heat-related death**		"In Europe the number of people at high risk of mortality will triple at 3°C compared to 1.5°C warming, in particular in central and southern Europe and urban areas (high confidence)." (Pörtner et al., 2021, section TS.B.6.3)
Europe	**Globalisation**		"Europe faces climate risks from outside the area due to global supply chain positioning and shared resources (high confidence). Climate risks in Europe also impact finance, food production and marine resources beyond Europe (medium confidence)" (Pörtner et al., 2021, section TS.C.11.6)
Working Group III – Mitigation of Climate Change (Pathak et al., 2022)			
Global	**Paris Agreement**	"[Greenhouse gas] emissions continued to rise to 2019, although the growth of global Greenhouse gas emissions has slowed over the past decade (high confidence)." (Pathak et al., 2022, section TS.2)	"Meeting the long-term temperature goal in the Paris Agreement, however, implies a rapid inflection in [greenhouse gas] emission trends and accelerating decline towards 'net zero'. This is implausible without urgent and ambitious action at all scales." (Pathak et al., 2022, section TS.2)
Global	**Greenhouse gas emissions**	" … the implied global emissions by 2030, still exceed pathways consistent with 1.5°C by a large margin and are near the upper end of the range of modelled pathways that limit warming to 2°C … or below." (Pathak et al., 2022, section TS.2)	"Achieving the global transition to a low-carbon, climate- resilient and sustainable world requires purposeful and increasingly coordinated planning and decisions at many scales of governance including local, sub-national, national and global levels (high confidence)." (Pathak et al., 2022, section TS.2)

15/6/2023. Alfajarín, Zaragoza. Spain. Monegros desert.

3.0 THE IMPACT OF FUTURE CLIMATE CHANGE AND EXTREME WEATHER ON SPANISH SOCIETY

7/11/2021. Córdoba, Andalusia, Spain. A new heat wave breaks the temperature record in southern Spain. Greenpeace warns that the extreme temperatures reached in Córdoba will continue to be exceeded in the next heat waves.

Climate projections are based on the results of climate models and should be viewed as a 'best guess' of possible future pathways. Climate models use observational data coupled with possible future emissions trajectories to produce their results. It is, therefore, important to note that there may be (a) discrepancies in possible future projections between different climate models (mainly for precipitation), and (b) that the magnitude and range of expected changes depends greatly on the emissions scenarios and the degree of mitigation that can be achieved.

Spain is expected to experience more frequent and prolonged extreme weather events in future decades (e.g., heatwaves or droughts). It seems very likely, therefore, that these will affect many communities throughout the country. The effects of extreme weather, such as an extended period of drought, can be amplified if more than one extreme weather event occurs at the same time or sequentially. For example, intense rainfall onto dry soil can result in increased flooding. Combinations of extreme weather scenarios can place a huge burden on people and ecosystems. For example, if drought, fire weather and high rainfall events take place within a short period, many different sectors such as agriculture and forestry, as well as natural ecosystems, can simultaneously be negatively affected (Arias et al., 2021; AR6 WGI TS.4.3.2).

Climate projections and the associated impacts for Spain vary between regions and seasons, but compared to present-day standards, extreme heatwave characteristics in the Mediterranean are projected to increase tremendously. For all future emissions scenarios, by the end of this century, the average annual global warming is projected to be around 2°C warmer than pre-industrial levels, and in some Mediterranean regions the summertime heat increases could be well in excess of this (Zittis et al., 2019). The sections to follow outline some of the ways in which Spanish communities might be affected by changing weather patterns.

3.1. Human survival in a hot and humid future

Humans have adapted to be able to live within a broad temperature range of between 4°C and 35°C. However, research has found that since the mid-Holocene (6,000 years before the present day) a majority of humans have chosen to live in regions with an average annual temperature of -11°C to 15°C (Xu et al., 2020). The average annual temperature in the past decade in Spain is at the upper limit of the 'preferred' range, at 15.6°C (based on the average annual ambient temperatures recorded by AEMET 2008–2019).

Increased heat exposure is of particular concern because it affects human health. Exposure to extreme heat can exacerbate underlying health problems. Hot weather can also be particularly risky for vulnerable groups including babies and the elderly. In addition, a loss of productivity is anticipated with sustained periods of heat particularly if combined with high humidity (Levy et al., 2016; Perkins-Kirkpatrick & Gibson, 2017). Studies analysing exposure to extreme temperatures found that extreme heat events can cause excess mortality to become evident within a few days. By contrast, extreme cold weather events cause excess mortality if they persist over a longer time period of up to 25 days (Anderson & Bell, 2009).

3.1.1 Heat stress

Deaths can and do occur during and following periods of extreme heat, and while many people can cope with one single day of extreme temperatures, mortality rates increase during prolonged heatwave events that last for more than two days. The greatest health problems are during extended periods of extreme heat, when temperatures during both the night and the day are high, because there is then no period in which humans can recover or recuperate (Perkins, 2015).

Projections for Spain suggest that under continued climate heating, the proportion of the country that will experience between 1 and 10 days of extremely hot and humid conditions is expected to grow, with the potential for even more frequent high risk days for those living along the eastern and southern coasts of the country (IPCC 2023, in Figure SPM.3). Such events markedly increase the risk of death from overheating (hyperthermia).

The human body maintains a core temperature at typically 36.5°C–37.5°C. A wet-bulb temperature of 35°C marks the upper physiological limit for human survival (Raymond et al., 2020). Typically, overheating happens with fever but can also happen if the external temperature is hot for a long period and the body is not able to cool down. A core body temperature of 38°C is considered high and if it reaches 40°C it becomes life threatening (NHS, 2020). If the ambient temperature is more than 37°C then the body will accumulate heat and is prone to dangerously overheat. Sweating to dissipate heat becomes ineffective at high relative humidity, which means that in high humidity even a lower ambient temperature can be deadly (Mora et al., 2017).

Heat-related health impacts can include increased morbidity through ischemic heart disease, ischemic stroke, cardiac dysrhythmia, dehydration, acute renal failure, heat illness, diarrhoea and heat stroke (Hopp et al., 2018). High excess human morbidity and mortality rates are associated more with sustained periods of moderate temperature increases rather than one-off very hot days (Gasparrini et al. 2015; Perkins-Kirkpatrick & Gibson, 2017).

Extreme heat is also expected to adversely impact labour productivity. By the end of the twenty-first century, under the high radiative forcing pathway (RCP8.5), southern Europe, including parts of Spain, is projected to experience a widespread loss of working hours by at least 15%, reaching more than 50% in some locations (Casanueva et al., 2020). Spain is projected to be one of the countries that will experience significant financial losses attributable to heatwaves (García-León et al., 2021). These losses are estimated to be up to 3% of the country's gross domestic product (GDP) by 2060.

3.2 Urban environments and climate change

Built up areas – particularly those along the coastlines – are expected to be affected by climate change and the attendant risks from extreme events such as torrential rainfall (and resulting flash flooding) and extended periods of heat. Overall, the risks are higher in urban than in rural areas. The combination of high temperature and high humidity can, at best, make life increasingly uncomfortable for human populations, especially disadvantaged groups without access to natural shade and green spaces or to air conditioning, and at worst can present serious threats to health. These risks could be particularly severe in large cities in which the 'urban heat island' effect exacerbates such exposures, especially during periods in which high temperatures are sustained through the nights (see also section 3.2.1, below).

Warming over land in Spain is expected to be accompanied by increases in humidity in coastal regions because the ocean waters, including those in the Mediterranean Sea, are also warming. Research that compared data from 1951–1985 with data from 1986–2020 suggests that the sea surface in the north-west Mediterranean Sea is currently losing less heat than it has lost in past decades (Josey & Schroeder, 2023).

A warmer sea could increase the risk of winter storms and of summer heatwaves. The lower heat loss is due to warmer air temperatures than in the past and this more effectively 'insulates' the underlying water.

Increased demand for air conditioning in buildings is expected to increase demands for energy and for water. Energy saving measures, partly in response to the energy price rise caused by the ongoing Ukraine–Russia war, set by the Spanish government in August 2022 and due to last until November 2023, introduced restrictions on setting the temperature of air conditioning to no lower than 27°C and heating no higher than 19°C in public buildings, shopping centres, theatres, cinemas, railway stations and airports (Jones, 2022). The energy saving measures implemented by the Spanish government do not take into account humidity, which can have a detrimental effect on human health when combined with heat (see section 3.1 of this report). Overall, action across the whole country and indeed the surrounding region will be necessary to ensure that densely populated urban environments are focused on meeting the needs for human health and comfort and that they are better protected from the threats of flooding from sea level rise and extreme events such as intense rainfall (and flash flooding) and from heatwaves.

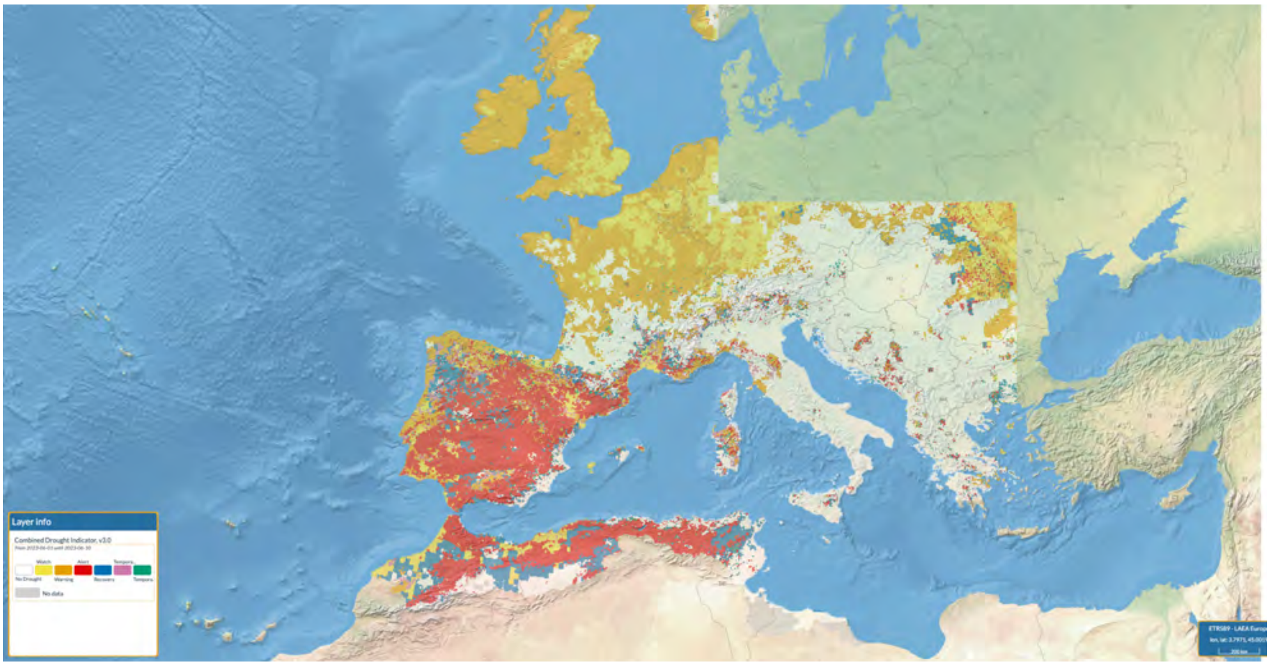
05/23/2020. Promenade of the Barceloneta Beach, Barcelona, Catalonia. Spain. ©Greenpeace/Pedro Armestre

3.2.1 The urban heat island effect – a case study of Barcelona

Cities commonly lack both green spaces to absorb rainfall and trees to provide shade and evaporative cooling. For example, a study of 101 cities in Asia and Australia found that the urban centres were 3°C to 4°C hotter than the surrounding rural areas (Santamouris, 2015), a phenomenon described as the 'urban heat island' effect. A number of factors cause urban heat islands, including: (i) heat trapped by buildings during the day and released at night; (ii) human-produced heat such as from cars, trucks or factories; (iii) tall buildings preventing ventilation; (iv) hard, dry surfaces such as pavements retaining heat; (v) hard surfaces not retaining moisture that would otherwise cool the area through evaporation (Martin-Vide & Carmen Moreno-Garcia, 2020). The impact of the urban heat island phenomenon can be particularly exacerbated during hot nights. Residents typically want to sleep in a cool environment and the use of air conditioning units, which use energy and generate heat, add to the overall problem (Salamanca et al., 2014).

A study of Barcelona's urban heat island (Martin-Vide & Carmen Moreno-Garcia 2020) recorded an average night-time air temperature in Barcelona City almost 2°C higher than the reference point at Barcelona airport. The airport is considered to be a suitable non-urban observatory due to its altitude and distance from the city. The data were analysed for a ten-year period between 2004 and 2013. The greatest discrepancy in temperature between the urban and non-urban locations was 7.4°C on a day in February 2012, which the authors suggest could have been because the weather during that season tends to be dry with calm nights. On 90% of the days analysed (data were obtained for almost every day over the ten-year period), the temperature in the city was equal to or higher than at the reference location. This illustrated the prevalence of the 'urban heat island' effect. Increased air temperature in cities, particularly those with a compact arrangement of buildings and few parks such as Barcelona, is of particular concern during heatwaves. In future decades, as the frequency and intensity of extreme heat events is projected to increase due to climate change, there is a significant increased risk to human health that is exacerbated by the urban heat island effect. The authors suggest that the most effective solution is to increase urban greening. They also suggest reducing road traffic and urban air pollution, and promoting the use of sustainable energy systems.

Other Spanish cities that expand and replace natural vegetation with buildings and urban constructions made from materials such as brick, asphalt and concrete, run the risk that an urban heat island effect will persist and become worse. The overall effect is likely to be exacerbated by climate-related extreme weather events such as heatwaves (Román López et al., 2017).



European Drought Observatory. https://edo.jrc.ec.europa.eu/tumbo/edo/map/

3.3 Drought

Widespread loss of soil moisture is projected for Spain under continued global heating (see: IPCC 2023, Figure SPM.2).

As global warming approaches 2°C above the baseline period (1850–1900), more than one-third of the population in southern Europe will begin to experience water scarcity, with the risk of more frequent and/or severe agricultural and ecological drought (Ali et al., 2022; IPCC, 2022). Water scarcity and associated extreme events such as drought negatively impact ecosystems because they can reduce the area of habitats and slow the growth rate of trees and other plants. For example, areas of scrubland and forest – the area of which increases following rural abandonment – is affected by climate change, generating a drier, hotter territory that is more prone to burning. The risk of soil erosion is increased from drier soils and there is also an increased risk of wildfires (Ali et al., 2022 in CCP4.1.2).

The Iberian Peninsula had a particularly dry 2021–2022 winter season and the year 2022 saw the Mediterranean region in general experience a rainfall deficit (WMO, 2023). As the land warms, rainfall or water in wetlands and reservoirs evaporates more rapidly, which can exacerbate soil dryness, or aridity. Drying of soils increases the risk that crop production and yields will decline (Arias et al., 2021 in AR6 WGI Box TS.6)

"Many regions of Spain will experience an increase in drought conditions in all scenarios and a fundamentally different climate in the high impact scenarios with future droughts more than ten times worse than the ones in the recent past."

There is a strong consensus in future climate projections that southern European cities, including many regions of Spain, will experience an increase in drought conditions in all scenarios and a fundamentally different climate in the high impact scenarios with future droughts more than ten times worse than the ones in the recent past (Guerreiro et al., 2021).

3.4 Agriculture, food and water security

As outlined elsewhere in this report, environmental changes in the Mediterranean region, which includes Spain, have led to increased temperatures in the region and increased risk of drought and extreme weather events. Changes, in particular to rainfall patterns and replenishment of groundwater resources, will have an impact on agricultural yields – both for rain-fed and irrigated crops.

For example, future (2041–2070) olive yields are projected to be reduced by up to 15–20% in many regions of Spain including Andalucía, Extremadura and Castilla la Mancha (Fraga et al., 2020). This is the case for both intermediate and high-emission pathways. Similar reductions in the yields of other crops of financial importance (e.g., wheat and sunflower) are expected for the southern provinces of Spain (Abd-Elmabod et al., 2020)

The agricultural sector is heavily dependent on natural resources – particularly land and water – both of which are under increasing pressure from changes to the climate. Water resources in Spain are also subject to increased demands from other sectors such as industry, the urban environment and tourism.

The Spanish agriculture sector faces climate change challenges but also societal changes such as urbanization. Climate challenges to the Mediterranean basin as a whole include changing weather patterns, increased risk of drought and an expected increase in demand for irrigation and a likely loss of fertile agricultural soils (MedECC, 2020). Specific societal changes in Spain include rural depopulation, an aging farming community and diversification of the rural economy, which in turn challenges the potential to develop a sustainable farming system. Policies are needed to foster regional development by encouraging sustainable agricultural practices that increase production, incorporate sustainable management of natural resources and ultimately protect biodiversity (Mili & Martínez-Vega, 2019). Such practices involve the engagement of rural populations in systems changes, and ensure rural socio-economic stability.

Achieving food security in the future will require adaptation in the agricultural sector because the changes to the weather patterns are taking place at an unprecedented rate. Crop cultivation and livestock rearing will be affected by land degradation and water availability, but there are other consequences. For example, climate change can see insect vectors and invasive plants expanding their geographical range and weather patterns affecting pollinators. Such changes are not isolated to the Mediterranean region but are near-global in scope. Drawing on age-old traditional farming practices and cultivating crop varieties (and livestock breeds) that are resilient to climate variations will be essential. Research into landraces and preserving genetic diversity should be a priority to facilitate adaptation to changing conditions (FAO, 2015).

09/06/2022. Verin, Ourense, Galicia, Spain. The drought last summer and early autumn is resulting in towns without water all over Spain, from the areas most accustomed to water cuts, to those that have always had an abundance and could not even imagine that they would have to face a shortage like the one reached last year. National reservoirs were at an average of 35% of their capacity and far from being a problem of just a lack of rain, water management is presented as one of the main steps to focus on to solve these problems.

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11/26/2021. Alcaudete, Jaén, Andalusia, Spain. On November 2, 2021, a drought was officially declared in the Guadalquivir basin. Andalusia serves to show some of the widespread water problems in other regions of our country such as lack of rain, pollution, waste or theft of water. Poor water management could make this resource scarce in the coming decades, being essential for our survival.

3.5 Threats to biodiversity

As well as being one of the most biodiverse countries in Europe with examples of four of the nine biogeographical regions found in the European Union, Spain is part of an area designated as one of the 25 global biodiversity hotspots. A combination of geographical factors support this high biological diversity as well as supporting a high number of endemic species.

Spain is home to around half of the 142,000 animal species estimated to live in Europe (ClimateADAPT 2021). Currently, it is estimated that around 30% of Spanish vertebrates and 1,200 species of vascular plants are threatened and in the past decades, biodiversity has suffered a significant decrease. Spanish coastal waters also have a high level of biodiversity but are arguably in the worst state of conservation. Nonetheless, compared to other countries, there are large areas of scrub, heath and grassland that are still in a natural or semi-natural state. Finally, although relatively small in size, wetlands are very important centres of biological diversity in Spain (CBD, undated). Against this extremely varied background, teasing out and documenting the current and likely impacts of climate change is a highly complex task. Mediterranean terrestrial systems are sensitive not only to progressive warming and extreme events but also to changes in water availability. Modelling suggests that without strong mitigation measures, climate change will alter ecosystems to an extent that is without precedent in the past 10,000 years (Guiot & Kramer, 2016). One of the major risks that has been identified in Spain is that of desertification (Martinez-Valderrama et al., 2022).

06/20/2023. Doñana National Park, Huelva. Spain
Greenhouses in Almonte, Huelva
©Greenpeace/Pedro Armestre

3.5.1 A case study of the Doñana wetland

Changes in both terrestrial and aquatic ecosystems are not simply driven by increasing aridity and increased temperatures under climate change but also by unsustainable agricultural practices that deplete water reserves and degrade soil health (e.g., extensive use of pesticides). The tensions are starkly illustrated by the current situation in the Doñana wetland. Located in southwest Spain, Doñana is one of the largest wetland complexes in western Europe. It is located in the Guadalquivir River delta and comprises a matrix of seasonal marshlands and aquifer-fed dune ponds together with up to 3,000 or so temporary ponds in sandy depressions in rainy years. The wetlands are surrounded by scrublands, pine forests and a dune ecosystem together with areas under cultivation. The hydrology of the wetlands is highly seasonal with substantial inter-annual variation. Estimated as having an original historical area of 180,000 hectares, it has been vastly reduced to th current remaining 32,000 hectares, with the balance either having been permanently drained or used as cultivated marshland. The National Park (of which the wetlands are a part) now consists of an area of 110,000 hectares.

Doñana has a biodiversity that is considered unique in Europe with a highly diverse combination of European and African flora and fauna and is a refuge and feeding ground for millions of migratory birds. Water stresses caused by ground water extraction from thousands of wells and continued drainage of marsh areas together with eutrophication pose major threats to Doñana (Green et al., 2016). Almost 60% of the pond network was lost between 1985 and 2018, with studies suggesting that the exploitation of groundwater resources was unsustainable (de Felipe et al., 2023). Computer modelling studies have suggested, moreover, that recharge of the important Almonte-Marismas aquifer could be significantly reduced under climate change (Guardiola-Albert & Jackson, 2011).

A sense of where increased evaporation, more extreme weather events (both wet and dry) and reduced rainfall could ultimately lead can be gathered from government reporting of the 2021–

04/18/2023 Doñana National Park, Huelva, Andalusia, Spain. Strawberry plantations, in the vicinity of the Doñana National Park, one of the Spanish emblems of poor water management. We will have less and less water, so the little we have, we should protect it. Far from it, the park suffers from numerous problems (drought, pollution, excess irrigation, illegal wells...) and the administrations are acting negligently (the European Union Court of Justice itself already condemned Spain in 2021 for failing to comply with the Water Framework Directive (2000/60/CE) and the Habitat Directive (92/43/CEE).

This April, Doñana has returned to the headlines because the Junta de Andalucía intends to continue legalizing irrigation, which condemns the park to practically certain death. Numerous lagoons have already dried up and 60% of those studied by the Doñana Biological Station have not flooded since 2013.

The overexploitation of groundwater for intensive irrigation is depleting and polluting water resources and endangering this unique ecosystem, vital for wildlife between Europe and Africa.

2022 hydrological year (ICTS, 2023), which was dominated by the landmark European drought and heatwave. Rainfall was very low and resulted in one of the driest of the past 43 years and follows a sequence of four dry years. In August 2022, a record high temperature of 46.3°C was recorded in the park and the average temperature over the year as a whole was 18.5°C. The Santa Olalla lagoon, the last of the permanent lagoons, dried up while the overall hydroperiod across the park was very short. As a result, recorded overwintering waterbird numbers were the second lowest in the historical record. Numbers of rabbits, an important prey item in the park, also fell to one of the lowest numbers in the historical series. It seems that the globally important and biodiverse Doñana wetlands are under multiple pressures through unsustainable use of groundwater and the increasingly severe hydrological pressures caused by climate change. The survival of the wetlands and their rich biodiversity into a climate changed future is looking increasingly uncertain.

08/27/2021. Navalacruz, Avila, Castilla y Leon, Spain. Forest firefighters and residents of the area observe the flames in the Navalacruz forest fire, in Avila, where almost 22,000 hectares were affected

3.6 Wildfires

The 2023 fire season in Spain got off to an early start with an intense fire in Villanueva de Viver in the eastern Castellón province in late March (NASA, 2023). The fire led to the eviction of 2,000 people from the municipalities of Castellón and Teruel due to the proximity of the flames. The major contributing factors appear to have been three previous years of poor rainfall coupled with high winds that fanned the flames. This was followed by a fire started deliberately in northern Extremadura that was again driven by high winds and forced the evacuation of three villages (Jones, 2023). This came as Spain recorded its hottest and driest April on record (WWA, 2023), part of a regional extreme heat event which would have been almost impossible without the influence of human-induced climate change. In 2022, a year of heatwaves and of drought, the fire season was the worst in more than a decade. While there were a large number of relatively small fires as early as January, the major damage occurred in the summer months with over 300,000 hectares burnt (EFFIS, 2023) of which around 135,000 hectares was on Natura2000 sites. A variety of biomes were affected and in the largest fire alone, over 30,000 hectares were burnt. While the number of fires were considered to have broadly decreased between 2009–2018 (Fernandez-Anez, et al., 2021) since 2018 there seems to have been a progressive increase in numbers. The exception is in 2017, when 130,000 hectares burned – that year also coincided with high air temperatures and low annual rainfall in Spain. In 2018, around 12,000 hectares burnt, rising to 84,000 in 2021 through to the near record figures recorded for 2022 (San-Miguel-Ayanz et al., 2023). The trend appears to be continuing in 2023: the total area of around 66,000 hectares burned as of May 2023 was some 81% of the annual average between 2006 and 2022 (EFFIS, 2023), while the number of fires over 30 hectares in extent was over one and a half times the recorded annual average over the same period.

Studies carried out in Galicia, northwest Spain, which represents 6% of Spanish territorial area but has 40% of recorded wildfires suggests that most fires (99%) have human-related causes, with some 75% being deliberately lit. The majority are lit for vegetation clearing while arson accounts for a relatively low, but still significant, proportion (Calviño-Cancela & Cañizo-Novelle, 2018). Decreases in farming and rural activities (rural abandonment and population decline) resulting from socioeconomic change have led to increases in the quantities of fuel able to support fires as land becomes overgrown and less managed. Due to climate change, moreover, the annual period of high risk meteorological conditions has become longer and with a less marked seasonality in Spain. Taken together, climate change and extreme weather events appear to have led to an increase in the intensity of fires, in their possible impacts and in increased difficulty in extinguishing them (De Diego et al., 2023). Wildfires can have profound effects on ecosystems and upon the fauna associated with them (Garces & Pires, 2023).

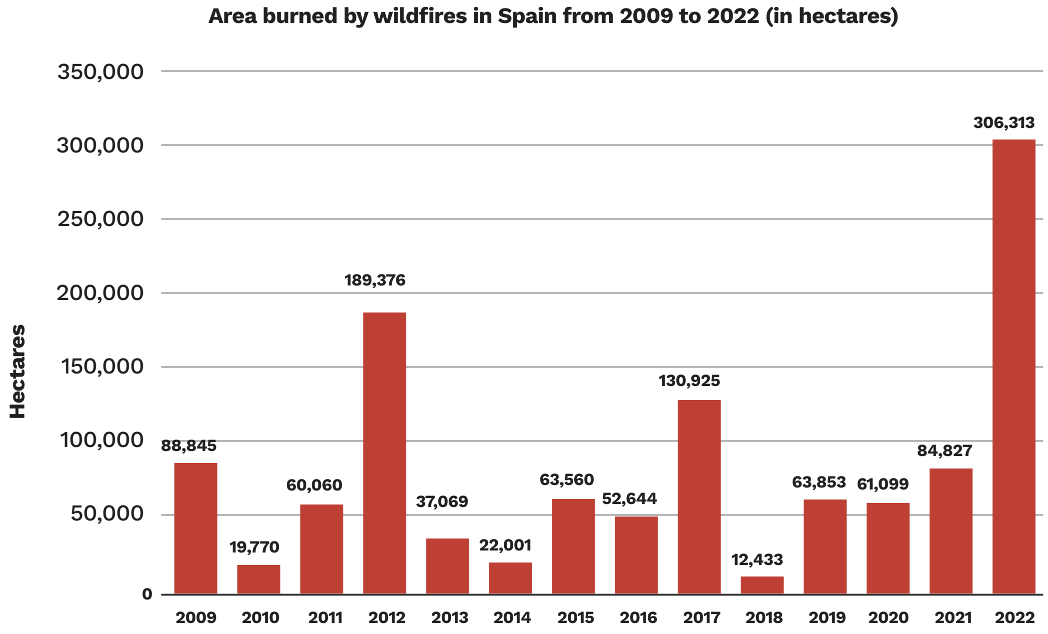
Multiple factors contribute to wildfires in Spain. It appears that one of the drivers of wildfires in Spain is the predominant Mediterranean climate. Frequent annual and interannual drought during the summer mean that more vegetation has become more combustible over large parts of the country. Add to this the socioeconomic changes over the past decades driving the build-up of fuel for wildfires and even though emergency responses and risk management/prevention measures may have improved, the risk of having large and intense fires has nonetheless increased (San-Miguel-Avanz, 2023).

In the absence of effective climate change mitigation it is projected that Spain will continue to become hotter and more arid. Seasons will become less defined with a lengthening of the fire season (see World Bank 2023). Inevitably, this will be reflected in an increased number of wildfires and their increased intensity.

Data from the European Forest Fire Information System (https://effis.jrc.ec.europa.eu/about-effis) report the number of hectares burned by forest fires in Spain over the past 14 years **(Fig. 1)**. The year 2017, in which 130,000 hectares burned, also had the highest annual average temperature in the 12 years to 2019 coupled with the lowest annual average rainfall in the eight years to 2020. The following year, 2018, had fewer forest fires, which could be due to extensive burning the previous year, but 2018 also had the highest annual average rainfall in the eight years to 2020 and a slightly lower annual average temperature than the previous year.

Fig. 1 | Hectares burned in forest fires in Spain, 2009–2022.

Source: European Forest Fire Information System. "Area burned by wildfires in Spain from 2009 to 2022 (in hectares)." Chart. August 22, 2022. Statista. Accessed May 14, 2023. https://www-statista-com.ezproxy.lancs.ac.uk/statistics/1265354/area-burned-by-wildfire-in-spain.



4.0 Canary Islands

The climate in the Canary Islands is distinct from mainland Spain and therefore the climate changes described in the report that apply to the mainland are not applicable; the Canary Islands have a subtropical, arid climate with no major fluctuations in temperature through the year and irregular rainfall. The islands are highly dependent on marine transport for goods, and the tourism sector attracts around 12 million visitors each year, bringing in approximately 85% of the archipelago's gross value added (Leon et al., 2021).

Research using climate modelling suggests that the Canary Islands could experience increased severity and duration of drought at the end of the twenty-first century in comparison to the beginning of this century. In addition, the change in the climate conditions are expected to be more extreme at higher altitudes (Carillo et al., 2022).

Changes to the climate – with symptoms such as increased air temperature, sea-level rise and changes to precipitation – are anticipated to affect the tourism, infrastructure and energy sectors in the Canary Islands. A key point to note regarding modelling projections for islands such as the Canaries is that there may be inaccuracies because climate models are generally applied to large geographical regions, and do not adequately resolve relatively smaller regions such as islands. Projections for two future pathways in the Canary Islands by Leon et al. (2021) look at a low-emissions scenario, in which the rise in global temperature is below 2°C, and a high-emissions scenario.

Human health is a major concern under conditions of combined high temperature and humidity, which together are a threat to life. Climate change can cause an increased number of hot, humid days – the Humidex Index is a metric to measure such conditions. In a study by Leon et al. (2021) the comparison between low- and high-emission scenarios in the Canary Islands used a Humidex index above 35°C (under these conditions, people will feel discomfort and are advised to avoid extreme exertion). At the end of the twenty-first century under a low-emissions scenario, almost 13 days are projected to meet Humidex 35°C; under the high-emissions scenario, 75 days are projected to meet Humidex 35°C. The impacts will be felt not only by Canary Islands residents but could negatively impact income from the tourist industry. Other impacts to the Canary Islands include those to mean sea-level rise, which is projected to be around 27cm and 75cm under low- and high-emissions scenarios, respectively, by the end of the century in relation to the reference period 1986–2005. Under mean conditions, at the end of the century (2081–2100), sea-level rise could correspond to a loss of beach surface by around 48% under the low-emissions scenario but almost double that at a loss of 80% of beach surface under a high-emissions path (Leon et al., 2021).

The urgency and importance of meeting climate goals is stark when considering possible natural and socio-economic impacts for the Canary Islands.

05/09/2018. El Guro neighborhood in El Cercado, La Gomera, Canary Islands, Spain.

The 2012 fire affected this area and several houses burned in the El Guro neighborhood. Hundreds of people were trapped in the port when the fire traveled downward, in less than an hour, throughout the valley, fed by the katabatic winds. There was entrapment of operational units and civilians. They were taken out by boat.

5.0
The heat is on...

Climate change is already a reality in Spain. **Globally**, the annual **average temperature is 1.27°C above** the preindustrial average. As the Mediterranean temperature **trajectory hurtles towards 2°C** warming by midcentury, the consequences for Spain seem worryingly close. The preparation phase for climate change has passed – **now we must work to prevent the worst-case scenarios taking place.**

Current situation at 1.27°C of global warming

Drought and rainfall

2022 was **Spain's warmest year** on record. Water for agriculture contributed to extremely high **water stress** in the river basins of **Duero, Tajo** and the internal basins of **Catalonia.**

Heatwaves and temperature

Montoro in the Córdoba Province in north-central Andalusia recorded a **national record-breaking temperature of 47.4°C** on August 14 2021.

Wildfires

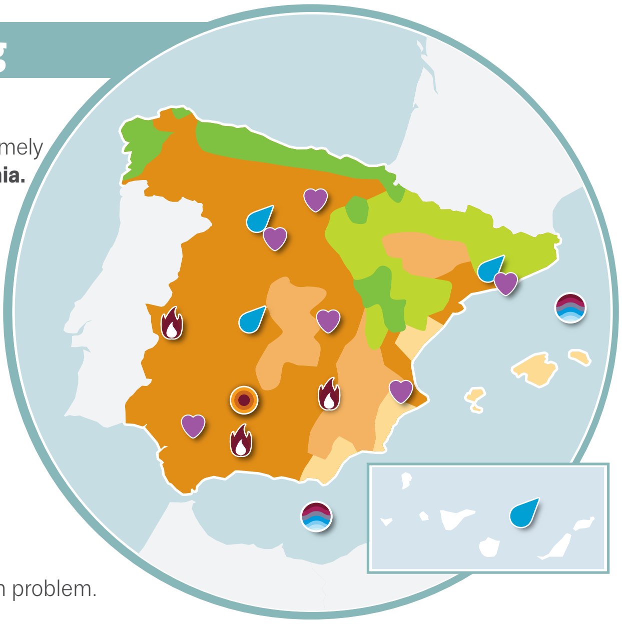
In 2022, wildfires in Spain burned across more than **300,000 hectares.**

Marine heatwaves

Since the 1980s, the average **Mediterranean Sea surface temperature** rose by up to **0.4°C per decade** with longer, more intense periods of abnormally warm water.

Urbanisation and human health

The World Health Organisation estimates that in Spain **heat stress** contributed to **4,000+ excess deaths** in 2022. The urban heat island effect in cities is a huge health problem.



Map source: IPCC (2023) AR6 WGII, Fig. 13.7. Baseline map = 1995–2014. Future map = 2076–2100 under approximately 4°C global warming.
Desert and semi-arid (hot) · Desert and semi-arid (cold) · Mediterranean · Humid subtropical · Temperate Oceanic

Future trends in an ever-warming world

Drought and rainfall

Desertification is expected **to spread inland** from the south-east, combined with **more intense periods of rain** bringing **increased risks of local flooding.**

Heatwaves and temperature

With a global average annual temperature increase of 1.5°C, **Spain's hottest day** is projected to be around **2°C hotter** than the hottest day between 1850–1900.

Wildfires

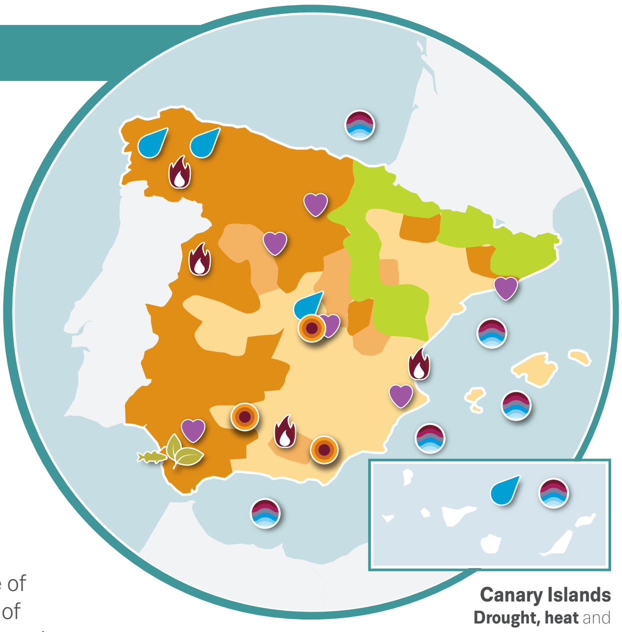
Fire risk from increased **aridity**, extended **drought** and **unmanaged land** following rural abandonment. Additional risks are from **clearing vegetation and arson**.

Marine heatwaves

The average **sea surface temperature** in the Mediterranean Sea is expected to rise by between **+1.8°C and +3.5°C** by 2100, which could be damaging to biodiversity.

Biodiversity

The **survival of** the internationally important **Doñana wetlands is uncertain** because of unsustainable use of groundwater for agriculture, evaporation and low rainfall. **60%** of the pond network has already been **lost since 1985** due to human activity and climate change.



Canary Islands
Drought, heat and **sea-level rise** are projected to **increase.**

What can we do?

- **Transit** much more rapidly from fossil fuels to renewable energy.
- **Establish** early warning systems to alert citizens to health risks from extreme weather events.
- **Promote** urban greening in cities to mitigate the impact of the urban heat island effect.
- **Stop** human-lit fires and arson, and control groundwater extraction.

References: de Felipe et al. (2023); EFFIS (2023); Haustein et al. (2017); IPCC (2023); Leon et al. (2021); MedECC (2020); UNEP (2020); WMO (2022, 2023).
Commissioned by Greenpeace International. Infographic design: Nigel Hawtin, Text by Kathryn Miller.

6.0 CONCLUSION

10/8/2019. La Losa, Segovia, Castilla y León, Spain.

Agricultural and livestock activities are the first to suffer the effects of the lack of rainfall. ©Greenpeace/Pedro Armestre

It is imperative to rapidly transit from fossil fuels to more renewable forms of energy and take every possible action to limit future temperature increase. Spain will not be affected in isolation – climate heating is global and this demands urgent action and a collaborative effort. Adaptation options are less effective with increased warming, and the decrease in effectiveness occurs from 2°C warming. In other words, measures to reduce climate risk for a given sector (such as agriculture, energy, ecosystems or forests, for example) work best when the global annual average increase in temperature does not exceed 1.5°C because the greater the increase to the global annual average temperature, the greater the loss and damage to the system. On a positive note, long-term planning, especially that which takes into account the needs and vulnerabilities of different communities, can help to manage the risk. An example of risk management therefore will be seen in responses to sea-level rise – sea level will continue to rise but the amount of increase, and management measures required such as relocating coastal communities, will depend upon greenhouse gas emissions now and in the future (Lee et al., 2023, p43-46). Infrastructure design, particularly in built-up areas, will help to mitigate the impacts of extreme weather events such as flash flooding (Zittis et al., 2021).

Attempts are being made to adapt to the changing climate, but there are also examples of poor adaptation or maladaptation. Some positive land-related adaptation actions such as sustainable food production, improved and sustainable forest management, soil organic carbon management, ecosystem conservation and land restoration, reduced deforestation and degradation, and reduced food loss and waste are being undertaken, and can have mitigation co-benefits (high confidence). There is however also increased evidence of maladaptation in various sectors and regions. Examples of maladaptation in agriculture includes, for example, using high-cost irrigation in areas projected to have more intense drought conditions (IPCC SYR 2023, Long report).

Climate change is a threat multiplier and therefore actions that reduce pressures from other human activities, such as chemical pollution and the physical degradation and loss of ecosystems, will be vital to increase the resilience of the natural systems and processes on which both wildlife and humans depend. An increased focus on monitoring and documenting Spain's ecosystems, and the threats to them arising from a range of human activities, will provide a sound scientific evidence base from which to improve projections of future change and to help design strategies to reduce impacts and work towards a more sustainable future.

GREENPEACE SPAIN DEMANDS AND RECOMMENDATIONS

09/24/2021. Madrid, Community of Madrid, Spain.

Global Climate Action Day promoted by Fridays for Future–Youth for Climate in Spain.

The day demanded justice in the face of the climate emergency and showed support for the so-called Trial for the Climate, which already has more than 48,000 supporters; the complaint before the Supreme Court presented by Greenpeace and several organizations against the Government for its lack of commitment and ambition in the matter.

The path we embark on after the new election cycle will need to lead us to a society that **places people's well-being and care for the planet at its heart**. The science tells us that the remaining seven years of this decade are absolutely essential to act against the climate emergency and the loss of biodiversity. All projections indicate that we are in for a warmer, drier, more arid, more flammable country, with greater flooding and high intensity fires and will also be affected by rising sea levels. Extreme weather events will become more frequent and extreme, which will clearly affect society and various economic sectors.

As the conclusions of the report clearly indicate, **mitigation** is the fundamental measure for action, that is, the reduction of emissions, mainly due to the burning of fossil fuels, to prevent global warming from exceeding the dangerous limit of 1.5ºC indicated by science and included in the Paris Agreement. To achieve this reduction in emissions, Greenpeace is calling for a wide range of actions, the most essential and urgent of which are outlined here. Furthermore, given that some aspects of climate change are already underway, it is essential to initiate **adaptation** measures to minimize the damage of those elements of climate change that we can no longer avoid, which are listed here and classified according to impact.

Demands to mitigate climate change

1. **Reduce net greenhouse gas emissions to zero by 2040** across the EU if we are not to experience the worst effects of climate change and biodiversity loss. To achieve the Paris Agreement target of a maximum warming of 1.5ºC, Spain must also commit to a 55% reduction in emissions by 2030 as compared to 1990 emissions. We must reach an efficient, smart and 100% renewable electricity system by 2030 and a fully decarbonized energy system by 2040.

2. **No more money for gas.** Stop new investments and subsidies for gas and other fossil fuels and instead devote the resources to finance an energy refurbishment plan for all homes to reduce gas demand.

3. **No more barriers to self-consumption and energy communities.** Not a single village, neighborhood or city without its self-consumption and energy community, whether by citizen or public initiative (independent of corporations), so that everyone can benefit from individual or collective self-consumption or participate in the development of renewable energies and solutions for efficient energy use, paying special attention to the needs of women and vulnerable people.

4. **Renewables by and for people.** The imperative deployment of renewable energies to replace fossil fuels and nuclear energy must be carried out in an orderly, participatory and biodiversity-friendly manner, through stakeholder inputs on the definition of areas unsuitable for renewable development (due to their high environmental value) and priority areas for their accelerated implementation (due to their proximity to consumption points or because they are areas of low environmental sensitivity).

5. **Affordable, accessible and attractive public transport.** Consolidate the current travel pass as a statewide, integrated, affordable and permanent public transport fare scheme that includes climate targets, reducing polluting journeys in favor of the use of a single transport travel pass.

Demands to adapt to climate change

1. **Implement the National Adaptation Plan for climate change threats** with an adequate budget. Go beyond structural measures, and include long-term nature-based solutions with the aim of increasing resilience and enhancing ecosystem services, social and cultural conditions and mitigation potential.
2. Carry out **further research and attribution studies** to determine whether extreme weather events are related to climate change and to quantify their increased likelihood of occurrence in, and for, Spain.
3. **Expand protection and recovery of ecosystems and species to reach at least the threshold of 30% of the terrestrial and marine area protected by 2030.** Carry out the required planning and management instruments. The Government should also support **the urgent adoption of an ambitious EU Nature Restoration Regulation** that is adequate to address the twin climate and biodiversity crises, ensuring the inclusion of robust targets and effective measures, guaranteeing the long-term non-deterioration of restored ecosystems and taking into account the sectors that manage and use the land.

Demands to limit the consequences of rising temperatures and heatwaves

1. **Assessment of climate change and especially heat waves** on endangered species and protected areas. Elaboration and implementation of adaptation plans.
2. Promote **ecological connectivity** (facilitating the connection of living beings to ecosystems with better conditions), as well as a better network of natural ecosystems that serve to cushion the impacts of heatwaves through territorial and sectoral planning.
3. Adopt legislation obliging companies and public administrations to adapt infrastructures and buildings, also to **assess and prevent occupational risks associated with climate change**, especially heatwaves and abnormally high temperatures.

Demands to alleviate droughts

1. Reduce our vulnerability to the risk of drought, **reducing the total amount of water consumed, mainly by intensive and industrial irrigation**, as this is the largest consumer (80% of the total), by establishing a plan for the reduction of the area of intensive and industrial irrigation.
2. **Fight against the serious state of overexploitation and pollution of our waters and pay special attention to groundwater**, as it is a strategic reserve and still largely unknown, and improve the control of illegal water use.
3. Overcome the traditional water policy, focused on the execution of large-scale works, and **address a true hydrological transition that responds to the current context of climate change.**

Demands to prevent forest fires

1. **Intensify coordination with the Regional Governments** in the prevention of forest fires, following the common guidelines and criteria for the preparation of the prevention plans of Royal Decree Law 15/2022.
2. Establish **a budget fund to support fire prevention and forest management** in order to strengthen the work of all administrations and actors and thus help to fulfil the obligations in terms of forest fire prevention.
3. **Promote adaptive forest management to shape landscapes with a different response to fire and its spread** by encouraging activities such as extensive livestock farming that reduce combustible materials. In other situations, management should aim to increase the resilience of forests by favoring ecological succession towards more mature stages, allowing for forest structures that are more resilient to wildfires.

Demands to confront the intensity of torrential rain and flooding

1. **Implement Article 28 of the National Hydrological Plan**, which refers to urban planning exposed to flooding episodes and establishes that the State must "eliminate constructions and other facilities located in the public water domain and in flood zones that could imply a serious risk to people and property".
2. **Flood risk should be included in all urban and land development planning.** As stated in Law 7/2021 on climate change and energy transition, all planning should consider the risks arising from changes in frequency and intensity of extreme events associated with climate change (including floods and the rise in sea level).
3. **Prohibit the construction of housing or infrastructure and declassify development land in flood zones.**

Demands to confront the increase in marine heatwaves

1. The **protection of marine and coastal ecosystems through the establishment of well managed marine protected areas** in at least 30% of Spanish waters by 2030, can help to conserve and protect ecologically and biologically important marine habitats. Develop new monitoring tools to predict and control marine disease outbreaks. Protecting pristine coastal areas by prohibiting development can minimize damage from flooding and coastal erosion. This will regulate human activities in these habitats and prevent environmental degradation.
2. **Strengthening scientific research.** Both central and regional governments must increase investment in scientific research to measure and monitor ocean warming and its effects on the species and sectors most affected, such as fishing and tourism.
3. **Improve human adaptation.** Governments must comply with existing policies to maintain fish production by following the maximum sustainable yield of individual fish stocks and setting precautionary, science-based catch limits, modernizing the fleet to reduce emissions, and eliminating pernicious subsidies that only increase fleet capacity so as to avoid overfishing.

Top left. 06/19/2023. The Saladillo, Murcia. Spain. Camposol Urbanization

Down left. 03/09/2018. Lepe, Huelva, Andalusia, Spain. The storm that hit the coast of Huelva leaves extensive damage in La Antilla, Lepe.

Fotos ©Greenpeace/Pedro Armestre

Down right. 08/04/2018. Madrigal de la Vera, Cáceres, Extremadura, Spain. In the image, children bathe in a fountain in Madrigal de la Vera.

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Acknowledgements
Parts of this report that cover the impacts of heat on human health are taken from a report produced by the Greenpeace Research Laboratories and Greenpeace Africa that was published in 2020 titled 'Weathering the Storm: Extreme weather events and climate change in Africa'.

Suggested citation
Kathryn A. Miller, David Santillo & Paul Johnston. Race against the climate clock: Climate change and extreme weather events in Spain (2023). Greenpeace Research Laboratories Technical Report (Review) 01 2023.

Back cover. 7/11/2021. Cordoba, Andalusia, Spain.

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