Nature Net Zero

Part 2: Review of climate change impacts & risks on high-carbon habitats

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Part 2. Executive summary

Natural England's Nature Net Zero (NNZ) research aims to assess the potential for England's ecosystems to deliver the greatest increase in biodiversity in ways that preserve carbon storage, increase carbon sequestration rates and reduce greenhouse gas emissions. The research seeks to identify the habitats and geographical locations that would make the best return on investment to deliver biodiversity targets and achieve long term functional recovery of "carbon in nature".

Natural England commissioned TEP to carry research and spatial analysis. Part 2 of the research evaluates the vulnerability of habitats with significant carbon reservoirs and sequestration capacities to climate change risks and identifies strategies to mitigate these risks and bolster habitat resilience.

Escalating global warming underscores the urgency of addressing climate change impacts on England's ecosystems. The UK Climate Projections (UKCP18) (Met office, 2018) highlight these continuing trends.

This document provides an overview of climate change scenarios and their potential impacts on various habitats in England, particularly focusing on high carbon habitats. It uses three Representative Concentration Pathways (RCP) scenarios: RCP2.6 (+1.6°C), RCP6.0 (+2.8°C), and RCP8.5 (+4.3°C). These anticipate hotter and drier summers, alongside warmer and wetter winters, with more intense and frequent effects as warming projections increase.

High carbon habitats, such as blanket bogs, woodlands, grasslands, heathlands, coastal saltmarsh and wetlands, face unique risks due to climate change. These risks include habitat degradation, carbon release, changes in species composition, and increased sensitivity to extreme weather events like droughts and floods. Coastal habitats may be particularly sensitive and are threatened by sea-level rise and coastal squeeze, where land between the sea and shore diminishes.

This report considers the sensitivity of these habitats to climate change, accounting for habitat condition, as degraded habitats are usually more sensitive to climate change than those in good condition.

To mitigate these risks and enhance adaptive capacity, the report suggests tailored management strategies for each habitat type. These strategies include:

- improving habitat quality and condition,
- increasing patch size,
- enhancing ecosystem functioning,
- working at a landscape scale to reduce fragmentation.
- expansion of high-carbon habitats to create nature networks that support biodiversity and ecosystem resilience.

The report highlights specific approaches for habitat restoration to facilitate climate change adaptation, such as nature-based solutions (NbS). These approaches aim to restore natural processes, increase habitat connectivity, and create resilience to fluctuating weather conditions. Emphasis is placed on understanding ecosystem boundaries and allowing natural dynamism to support species adaptation.

In summary, while high carbon habitats in England play a crucial role in carbon sequestration and storage, climate change poses significant threats to their integrity and functioning. To maintain their effectiveness as carbon sinks and enhance their resilience, it is essential to implement adaptive management practices, tailored to habitat location and climate risks, and foster landscape-scale conservation efforts.

The 'Resist, Accept, Direct' (RAD) Framework for making decisions about landscape-scale action to boost habitat resilience is described, with a reference to blanket bog habitats to provide a worked example.

Blanket bog habitat is highly sensitive to projected climate change, especially when in degraded condition. Sensitivity is primarily due to summer temperature increases and droughts, which accelerate oxidation and increase risks of catastrophic damage from wildfires and peat erosion. Blanket bogs in southwest England on Bodmin Moor, Dartmoor and Exmoor represent about 9% of the English total habitat. Under the RCP6.0 projection, these areas are expected to undergo much more extreme and anomalous summer changes than blanket bogs in north England.

If a 'Resist' approach is taken to management and restoration of blanket bog on the south western moors to preserve their carbon store and current habitat status, intervention would be required, at landscape-scale, to restore and expand existing bog habitats and their hydrological functioning so that they are all in good condition and thus more resilient to future summer droughts.

For example, hydrological works at catchment scale to re-wet the bog alongside measures to re-vegetate exposed peat would be needed. This intervention would need to be rapid, given the extended timeframes needed to achieve bog restoration at a landscape scale. Ongoing monitoring and maintenance work would then be needed over the subsequent decades using an adaptive management approach.

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1. Introduction

The Environment Partnership (TEP) was commissioned by Natural England in November 2023 to undertake an assessment of England's ecosystems to deliver biodiversity targets in ways that also prioritise reducing greenhouse gas emissions and increasing carbon sequestration rates; in short a rapid review of the contribution that semi-natural habitats can make to the Net Zero mission. The project seeks to identify those habitats and geographical locations that would make the best return on investment to achieve long term functional recovery of carbon in ecosystems.

The project has four strands:

Part 1: A national assessment of the range of carbon storage and sequestration values in existing priority habitats, generating a short-list of high carbon habitats.

Part 2: An assessment of the impacts of climate change on high carbon habitats to determine the risks to their mitigation value and potential adaptation measures to reduce vulnerability at 1.5, 2 & 4 degrees of heating.

Part 3: An evaluation of the potential of new habitats & ecosystems restoration to deliver the greatest increase in biodiversity while retaining carbon storage and increasing sequestration rates. Based on the above evidence, analysis of what types of landscapes are needed to achieve the functional restoration of these ecosystems and be most effective in delivering carbon & biodiversity outcomes in the long term. Part 3 also includes Nature Net Zero 'pathways'; in other words various scenarios which deliver carbon benefit and nature recovery.

Part 4: An outline of the trade-offs and synergies between different land uses and where good integrated delivery can achieve better outcomes.

This Part 2 report assesses the risk of climate change to priority habitats with high carbon storage values and/or sequestration rates and considers ways to reduce the vulnerability of the habitats and the consequential loss of climate mitigation they provide. It also considers the climate change adaptation benefits that can be gained from increases in the areas of habitat and the landscape types which would provide the best climate change adaptation benefits such as coastal salt marsh to provide protection against storm surges and coastal flooding.

2. Background

The climate of the UK has warmed significantly since the pre-industrial period. Over the last 30 years the average temperature has been 0.9°C warmer than the preceding 30 years (Met Office 2021). All the ten warmest years for the UK, in the series from 1884, have occurred since 2002 (Met Office 2022).

Even with immediate, sustained, and very rapid reductions in greenhouse gas emissions globally, the latest UK climate projections (UKCP18) suggest the country will experience an additional warming of around 0.6°C between now and 2050. This is since it will take time for the world to reduce emissions down to Net Zero even under the most optimistic scenarios.

The major terrestrial carbon stores in nature that this investigation focuses on, are already being impacted and this report looks to highlight the risks the natural carbon stores are under.

The UKCP18 climate projections (Met Office, 2018) highlight continued warming of all areas, warmer and drier summers, and wetter winters, notably with increased intensity and frequency of winter precipitation. There is also a projected increase to coastal water levels driven mainly by increases in mean sea level rise, with potential additional changes to sea level from storm surges.

The impacts of these changes on the natural environment can already be seen (Morecroft and Speakman, 2015). Models of future climate show that these trends will continue and potentially increase with the potential for more frequent and intense summer drought and winter and summer flooding (Crick et al, 2020).

The twin crises of climate change and biodiversity loss are inextricably linked and as well as mitigating climate change, nature can provide critical solutions for helping us to adapt to climate change (Brotherton et al. 2021).

Definitions of key terms used in this report can be found in the glossary.

3. Data Sources

This section of the report provides an overview of the key datasets used in the GIS analysis detailed in the Methodology section.

A number of open source data sources and reports were used to assess the risk of climate change to England's priority habitats – see Table 1.

Table 1. Data Sources

Dataset	Download Date	Dataset Currency
Priority Habitats Inventory (England)	21-11-2023	28-07-2023
Wood Pasture and Parkland (England)	28-11-2023	28-05-2020
Peaty Soils Location (England) (Ref: NE257)	04-12-2023	25-04-2022
UK Climate Projections	22-01-2024	14-11-2023
Re-evaluating the sensitivity of habitats to climate change (NECR478)	23-02-2024	05-06-2023
Climate Change Adaptation Manual (NE751)	15-03-2024	28-04-2020

Priority Habitats Inventory

A spatial dataset providing the geographic extent and locations of 25 habitats of principal importance (Section 41- NERC Act 2006) in England. These "priority habitats" are of principal importance for biodiversity conservation and enhancement. The selection of UK habitats for the priority list followed consideration by expert working groups against a set of criteria, based on international obligations, risk, and the importance for key species. The listing was last revised in 2007.

This study used PHI User Guide 3.0 which provides habitat codes and guides to habitat features.

This study used the PHI as the basis for estimating "carbon in nature". England's framework for habitat protection and restoration is focussed on safeguarding, enhancing, restoring and creating priority habitats.

The PHI allows for nationwide spatial analysis of habitat carbon data, as it is the only nationally consistent inventory of habitat types. Thus Nature Net Zero Task A is focussed on calculating carbon stored in, and sequestered by, priority habitats. Some of the habitat carbon literature uses the PHI as a framework for estimating carbon stores, and other carbon literature can be "read across" to the priority habitats.

Wood Pasture and Parkland (WPP)

WPP is listed within the UK Biodiversity Action Plan and is regarded as a s41 habitat. However, it is not currently in the PHI. It is available as a separate dataset of provisional priority habitat. The dataset provides the spatial locations of large open-grown or high forest trees within a matrix of grazed grassland, heathland or woodland floras. It is likely to be a high carbon habitat, so was added to the PHI dataset for analysis.

Non-Priority Habitats

Spatial Datasets were also accessed for the following non-priority habitats:

- Good quality semi-improved grassland
- Fragmented heath
- Grass Moorland
- Priority Habitat Inventory - No main habitat but additional habitat exists

The non priority habitats inventory for Fragmented Heath, Grass moorland & No Main Habitat were extracted from Farm Environment Plan surveys & HLS data when surveying and setting up HLS agri-environment schemes (Natural England, 2010). Although not considered to meet the quality criteria for priority habitats, these habitats hold potential importance for conservation of biodiversity in England.

For example, they can indicate a mosaic of habitat which may contain priority habitats, have restoration potential and/or contribute to ecological networks. Where evidence indicates the presence of unmapped or fragmented priority habitats within such polygons, these are attributed as additional habitats.

These non-priority habitats were included in the study due to their potential for high carbon storage values and/or high rates of carbon sequestration. Edwards and others (2020) identify these habitats as potentially capable of restoration to priority types in the National Habitat Network Maps. For example, fragmented heath and/or grass moor where on deep peat; and “no main habitat” with blanket bog present are all considered to be restorable to blanket bog.

Peaty Soils

The Peaty Soils dataset provides the spatial locations of 3 different categories of soils supporting peat reserves. These categories are Deep Peaty Soils (above 40cm peat depth), Shallow Peaty Soils (below 40cm peat depth), and Soils with Peaty Pockets (soils with Peat present).

An understanding of carbon in priority and non-priority habitats needs to take account of the presence and extent of underlying peat which is the largest terrestrial habitat carbon store. The carbon literature often provides upper and lower range estimates of carbon in soil beneath habitats; with the higher ranges reflecting soils with high organic carbon content.

Some priority habitats are dependent on and/or found almost exclusively on peat, whereas other habitats may be found on other soil types. It is also recognised that much peat, even underlying priority habitat, is not in favourable nature conservation condition and is suffering from oxidation and emission of carbon dioxide, so its restoration is a priority for both nature recovery and climate mitigation.

The study analysed the co-incidence of habitat types and peat soils in order to refine the nationwide habitat carbon estimates and to inform the ranking and short-listing of habitats for future consideration in Natural England's Nature Net Zero workstream.

Met Office UK Climate Projections

Data was downloaded from UKCP18 (UK Climate Projections (UKCP) - Met Office), providing a spatial dataset that builds on previous datasets to provide the most up to date assessment on how the UK climate may change over the course of the 21st century. The following climatic parameters were downloaded using the 1961-1990 as a baseline period, and projecting for 2070-2098:

- Summer Maximum Temperature Anomaly (90th percentile)
- Summer Mean Temperature Anomaly (90th percentile)
- Summer Mean Precipitation Anomaly (10th percentile)
- Winter Maximum Temperature Anomaly (90th percentile)
- Winter Mean Temperature Anomaly (90th perc2.6entile)
- Winter Mean Precipitation Anomaly (90th percentile)

Each parameter was downloaded for three Representative Concentration Pathways (RCPs). RCPs specify concentrations of greenhouse gases that will result in total radiative force increasing by a target amount by 2100, relative to pre-industrial levels (Met Office, 2018). They are a method for capturing assumptions about the economic, social, and physical changes to the environment that will influence climate change within a set of scenarios. The RCP pathways represent a broad range of climate outcomes and are used to model and predict future climate.

Datasets were selected and downloaded for RCP2.6, RCP6.0, and RCP8.5. These RCPs broadly reflect temperatures increases of 1.6, 2.8 and 4.3 degrees respectively.

Re-evaluating the sensitivity of habitats to climate change (NECR478)

The report considers the sensitivity of UK habitats to climate change, offering insights into which ecosystems are most vulnerable to environmental shifts. Through expert consensus, it identifies differences in sensitivity, with managed agricultural lands, grasslands, and dry habitats generally deemed less sensitive, while habitats dependent on water availability, coastal areas, montane regions, and those in northern distributions are considered more susceptible.

It advocates for prioritizing interventions to support habitats with the highest sensitivity, such as montane, freshwater, wetland, and coastal areas, especially those already degraded. Addressing degradation factors exacerbating climate impacts is highlighted as crucial, emphasizing targeted actions to tackle underlying causes rather than broad approaches to habitat improvement.

It is used in this report to derive habitat sensitivities across the UK and assign them to the priority habitat dataset to give an overview of the spatial distribution of sensitive priority habitats so that this can be considered alongside projections for climate change.

Climate Change Adaptation Manual (NE751)

The report considers the growing acknowledgment of the need for climate change adaptation in the last two decades. It highlights the environmental sector's early efforts in developing adaptation strategies, initially focusing on establishing general principles. However, it stresses the importance of integrating adaptation into specific decision-making processes tailored to local contexts and consolidates recent scientific findings and practical experiences to facilitate decision-making in land conservation and management.

Targeting nature reserve managers, conservation advisors, and government agency staff, the manual covers various topics, including habitat and species management. It was developed collaboratively by Natural England, the RSPB, and other organizations to address pressing adaptation challenges.

It is used here to inform how climate change may impact the different high-carbon priority habitats, considering each of the climate change parameters in turn, and the adaptive capacity of habitats in the wake of climate change.

Data limitations

All datasets used for this study are subject to a general caveat that the input field data was collected and subsequently digitised at varying times, so may not reflect the current status. There is also no national assessment of the condition of all priority habitats so the assessment in this study is generic in terms of habitat condition. This is not considered a significant limitation for this study which collates and presents data on national and landscape-scale bases.

The Met office climate projections are collated by pooling together data sources to provide the most up to date model of climate projections across the UK. However, these projections have limitations due to uncertainties in modelling techniques, future emission scenarios, and natural variability in the climate system.

They may also lack fine-scale spatial resolution and cannot predict extreme events with certainty, requiring consideration of a range of scenarios for effective planning. It is recognised that the higher RCP values may have greater uncertainty due to the nature of these predictions. Likewise, there are uncertainties with the response of habitats to these climate projections, as well as the adaptation responses which may be most suited towards improving resilience.

The assessment focuses on specific habitats so cannot capture the full range of ecosystems and their sensitivities to climate change. While interventions targeting highly sensitive habitats are recommended, such as blocking drainage features in blanket bog, the effectiveness of these interventions may vary depending on local conditions and the underlying causes of habitat degradation. Careful consideration of these limitations is essential for informing effective conservation and adaptation strategies.

The report does not attempt to calculate habitat vulnerability, which is a combination of climate change exposure, sensitivity and adaptive capacity but focuses on Climate Risk to these Carbon Stores. This work has not tried to repeat previous work by Natural England in developing the National Biodiversity Climate Change Vulnerability Model to calculate habitat vulnerabilities, as this is presently being updated in a separate piece of work.

4. Methodology

This chapter outlines the methodology used to analyse the risks of climate change to England's Priority Habitats that have high carbon storage values and sequestration rates i.e. the habitats identified in Part 1 of the Nature Net Zero project.

Stage 1: Assemble a dataset of habitats and conduct carbon analysis

The aim of stage 1 was to produce a baseline dataset of 'high-nature, high-carbon' habitats suitable for analysis against climate projections. These are the top 10 habitats for carbon that are assessed for their climate risk and adaptation responses.

The methodology for obtaining these habitats is outlined in Part 1 of this report.

Stage 2: Assigning Sensitivity to Climate Change to Habitats

Stage 2 Aim:

To visualise and understand the spatial distribution of priority habitats' sensitivity to climate change values across England.

Stage 2 Analysis:

The baseline habitat dataset created in Stage 1 was used to assign sensitivity values to habitat types depending on their sensitivity to climate change, as described by Staddon and others (2023).

Sensitivity here is defined as the degree to which a system is affected by climate change. The sensitivity values were ranked on a 1-5 scale, where 1 represents low sensitivity and 5 represents a very high sensitivity, providing a detailed view of habitat sensitivity and allowing differentiation between low and low-medium, medium, and medium-high to very high. This was done for habitats in good and degraded condition.

Degraded habitats are defined by various pressures threatening UK ecosystems, exacerbating their sensitivity to climate change. These include agricultural intensification, hydrological management, pollution, urbanization, invasive species establishment, changes in woodland management, and physical modifications such as engineering works (roads, rail, dams etc). These factors disrupt natural processes and reduce habitat functionality, highlighting the need to address degradation for safeguarding ecosystem health and resilience against climate change and other environmental challenges.

These values are given in Table 2. For habitats not found within the priority habitat dataset, such as fragmented heath, good quality and semi-improved grassland and grass moorland, values are not given. This is also the case for the classification "No main habitat but additional habitats present".

Habitat sensitivity can be visualised, as shown at Figure 1 and Figure 2 below for the Lake District National Park. These plans highlight the different sensitivity values for the different habitats for both good (Figure 1) and degraded (Figure 2) condition, where darker reds indicate increased sensitivity to climate change.

The increased sensitivity to climate change for habitats in degraded condition is made apparent from comparison of Figures 1 and 2.

Stage 2 Outputs:

A baseline habitat dataset incorporating values for climate change sensitivity, ranked on a scale from 1 to 5, where 1 represents low sensitivity and 5 represents a very high sensitivity.

Table 2. Climate Change Sensitivity of Habitats ranked on a 1-5 scale, where 1 represents low sensitivity and 5 represents a very high sensitivity.

Habitat	Climate Change Sensitivity - Good Condition	Climate Change Sensitivity - Degraded Condition
Calaminarian grassland	1	2
Traditional orchard	1	2
Deciduous woodland	2	3
Limestone pavement	2	3
Lowland calcareous grassland	2	3
Lowland dry acid grassland	2	3
Reedbeds	2	3
Upland calcareous grassland	2	3
Wood pasture and parkland	2	3
Lowland meadows (dry)	2	3
Upland heathland (dry)	2	3
Blanket bog	3	5
Coastal sand dunes	3	5
Coastal vegetated shingle	3	5
Lowland raised bog	3	5
Maritime cliff and slope	3	3
Upland hay meadow	3	4
Upland heathland (wet)	3	4
Coastal and floodplain grazing marsh	4	5
Coastal saltmarsh	4	5
Lowland fens	4	5
Mudflats	4	5
Purple moor grass and rush pastures	4	4
Saline lagoons	4	5
Upland flushes, fens and swamps	4	5

Habitat	Climate Change Sensitivity - Good Condition	Climate Change Sensitivity - Degraded Condition
Lowland heathland	4	4
Lowland meadows (wet)	4	4
Mountain heaths and willow scrub	5	5
Fragmented heath	No available data	No available data
Good quality semi-improved grassland	No available data	No available data
Grass moorland	No available data	No available data
No main habitat but additional habitats present	Not applicable	Not applicable

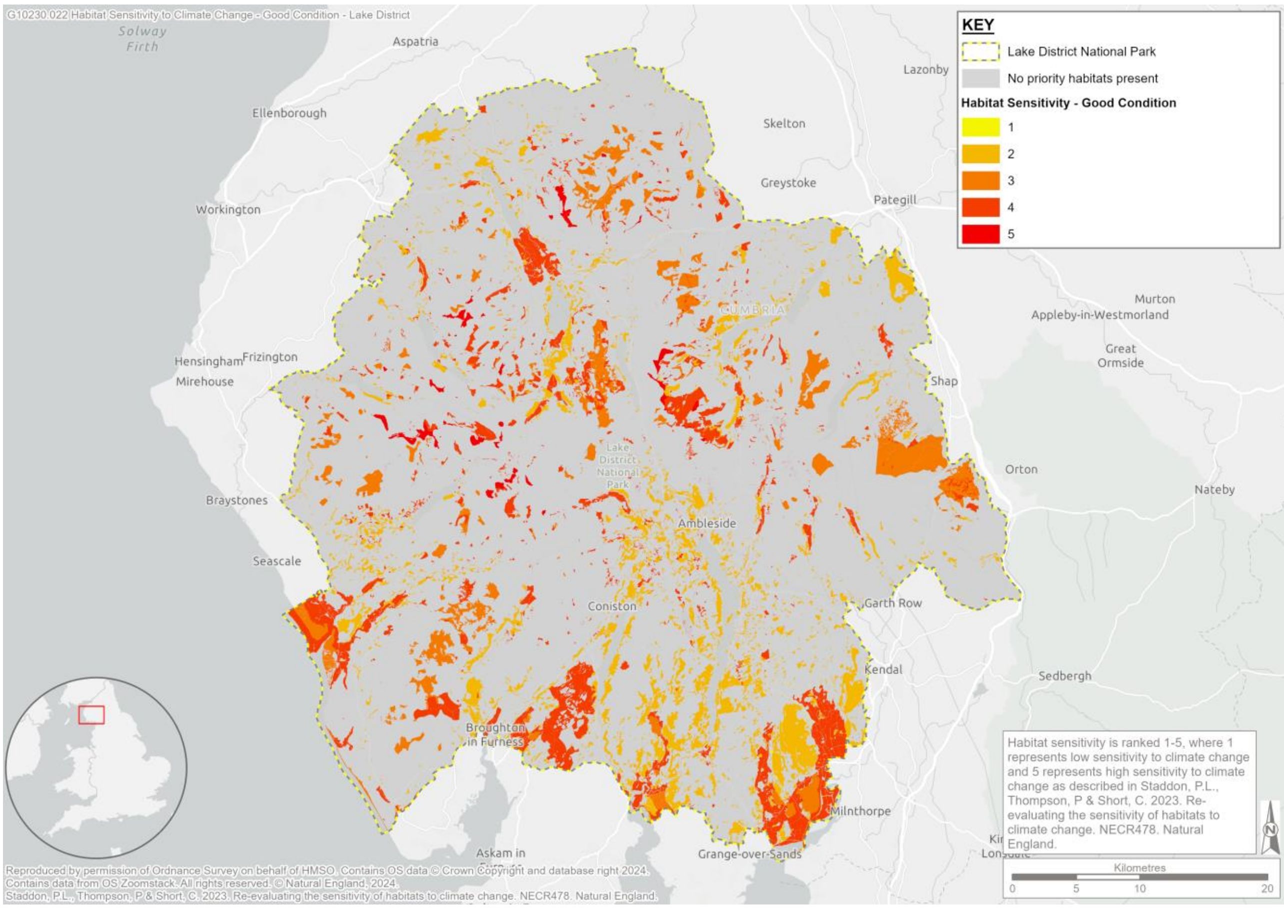

Figure 1. Habitat sensitivity values to climate change ranked on a 1-5 scale, where 1 represents low sensitivity and 5 represents a very high sensitivity, for habitats in good condition. Deeper red values indicate increased sensitivity to climate change. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All***

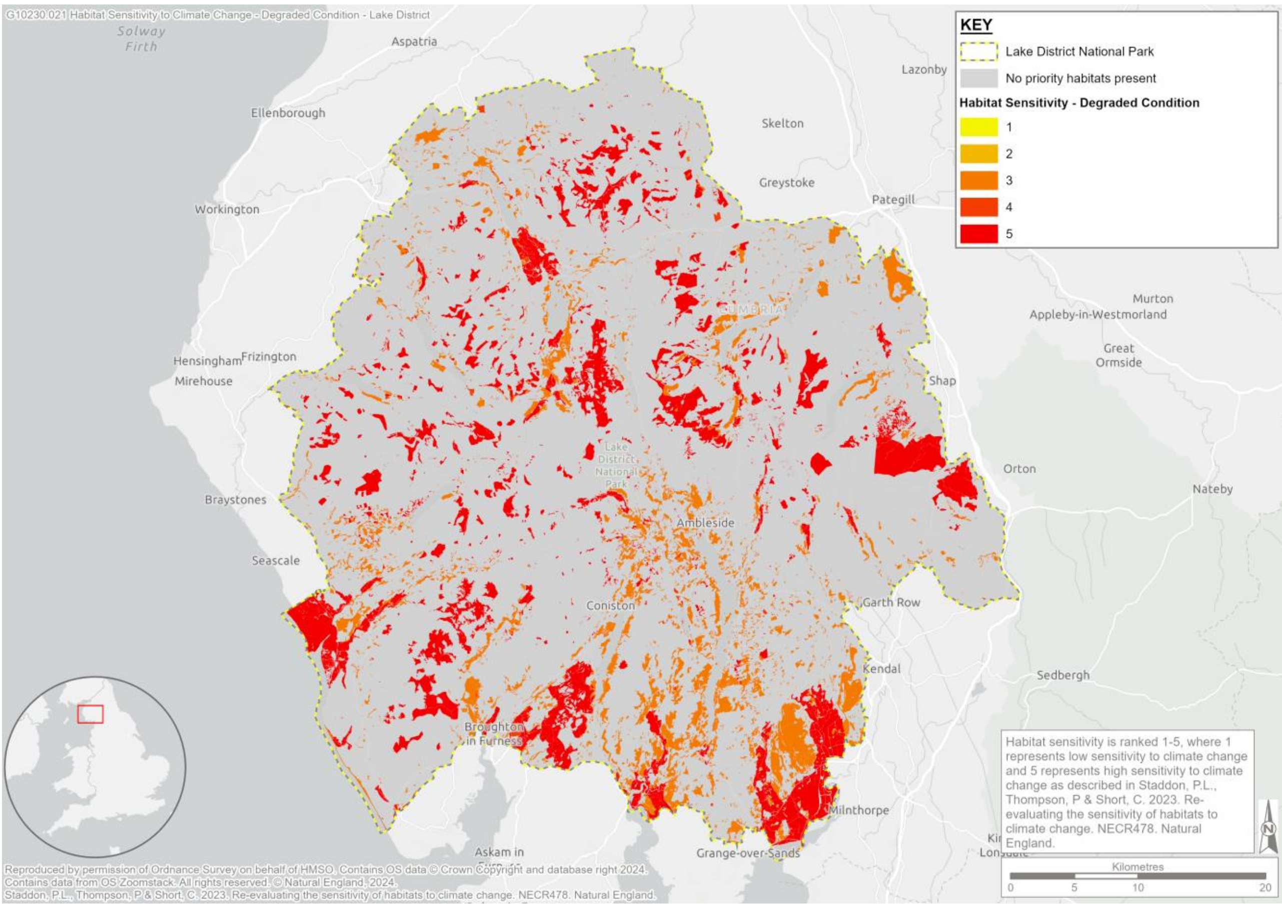

Figure 2. Habitat sensitivity values to climate change ranked on a 1-5 scale, where 1 represents low sensitivity and 5 represents a very high sensitivity, for habitats in <u>degraded</u> condition. Deeper red values indicate increased sensitivity to climate change. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under* the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Stage 3: Assessing UK Climate Change Scenarios

Stage 3 Aim:

To understand the different climate change scenarios and the possible changes to climate variables such as temperature and precipitation. This includes:

- an understanding of the spatial distribution of changes to climate variables resulting from climate change in different parts of England
- an understanding of how climate variables change with different climate change scenarios used in the Met Office UK Climate Projections 2018 (UKCP18).
- How this relates to the distribution of existing priority habitats.

Stage 3 Analysis:

The climate change scenarios used were defined by different Representative Concentration Pathways (RCPs) (Met Office, 2018). These outline four distinct trajectories for greenhouse gas (GHG) emissions, atmospheric concentrations, air pollutant emissions, and land-use throughout the 21st century. These pathways encompass a stringent mitigation plan (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0), and one scenario characterized by very high GHG emissions (RCP8.5).

Baseline scenarios, which do not involve additional efforts to limit emissions, fall within the range of pathways between RCP6.0 and RCP8.5. RCP2.6 represents a scenario where global warming is limited to below 2°C above pre-industrial levels.

RCP 2.6, 6.0 and 8.5 were used in this analysis.

The RCPs used broadly match the following temperature change scenarios:

- RCP2.6: +1.6°C by 2081-2100
- RCP6.0: +2.8°C by 2081-2100
- RCP8.5: +4.3°C by 2081-2100

Data was downloaded from the UK Climate Projections (Met Office, 2018) for the following six climate variables:

- Summer Maximum Temperature Anomaly (90th percentile)
- Summer Mean Temperature Anomaly (90th percentile)
- Summer Mean Precipitation Anomaly (10th percentile)
- Winter Maximum Temperature Anomaly (90th percentile)
- Winter Mean Temperature Anomaly (90th percentile)
- Winter Mean Precipitation Anomaly (90th percentile)

These use 1961-1990 as a baseline and project a 30 year average from 2070 up to and including 2098 across England. Summer was defined as the months June, July and

August, while winter was defined as December, January and February. Percentiles were used following guidance from Natural England's scientific officer, giving an overview of the worst possible outcome. This meant using 90th percentiles for temperature and winter precipitation, which are all expected to increase, and the 10th percentile for the summer precipitation, which is expected to decrease.

Each parameter was downloaded for RCP2.6, RCP6.0, and RCP8.5, giving a total of 18 datasets.

This data was then processed by collating the different climate variables and scenarios into one comprehensive geodatabase. This data was then presented spatially across a series of maps to display the change over the three different RCP scenarios.

This data is shown in Figure 3 below, and highlights the three different climate change scenarios, for the summer mean temperature anomaly climate variable.

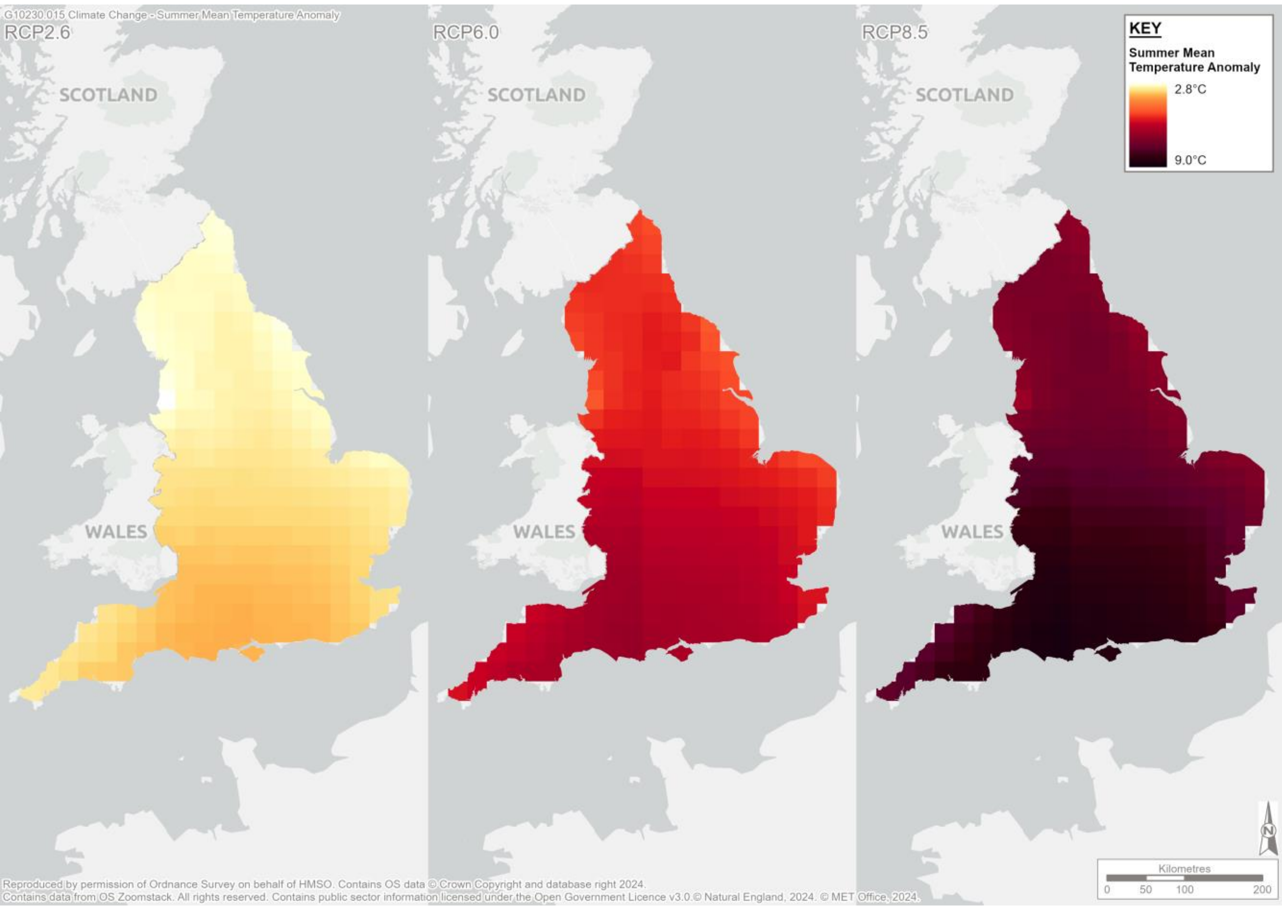

Figure 3. Summer mean temperature anomaly for RCP 2.6 (+1.6°C by 2081-2100), RCP6.0 (+2.8°C by 2081-2100), and RCP8.5 (+4.3°C by 2081-2100) across England. Deeper red tones indicate increased warming. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Stage 3 Outputs:

A catalogue of maps displaying the changing climate change scenarios for the different climate change scenarios, for the 6 different climate variables.

Stage 4: Assessing the Risk of Climate Change to High Carbon Habitats

Stage 4 Aim:

To bring together information on habitat sensitivity and risks arising from different climate change scenarios to understand how climate change may impact high carbon habitats, as well as management practices that may be adopted to improve the resilience of habitats to climate change. Resilience here is defined as the ability of an ecological system to absorb disturbances while retaining the same basic ways of functioning, and a capacity to adapt to stress and change.

Stage 4 Analysis:

A review of documentation provided in Climate Change Adaptation Manual (NE751) provided an overview of how each habitat may be influenced by climate change into the future, with a focus on the different climate variables (such as drought resulting from increased temperatures and decreased rainfall in summer).

Stage 4 focused on utilising all the prior stages to bring together evidence regarding how high carbon habitats may respond to the different climate change scenarios. This collated data from the prior stages as follows:

- Stage 1 – Identification of high carbon habitats across England, considering their carbon storage and sequestration potential from an enriched habitat dataset.
- Stage 2 – Assigning climate change sensitivity values to each of the different habitats to understand which habitats may be more sensitive to climate change.
- Stage 3 – Illustrating the different climate change scenarios and how climate variables may change depending on the scenario.

Bringing this together, Stage 4 aims to identify the key high carbon habitats and understand how they might respond to climate change, and the different management practices that could be adopted to help improve the resilience of habitats.

Blanket bog, for example, was identified as a high carbon habitat. This is assigned a sensitivity value of 3 when in good condition, and 5 when in degraded condition, where 1 represents low sensitivity and 5 represents a very high sensitivity, indicating that blanket bog is highly sensitive to climate change.

Following a review of the Climate Change Adaptation Manual (NE751) the primary risk to blanket bog appears to be from increased summer temperatures and decreased rainfall in summer, resulting in drought and corresponding negative impacts to the habitat. This is concerning, as the climate change scenarios indicate that with increased warming, there may be increased summer temperatures and reduced rainfall, particularly in the south of England, as detailed in stage 3.

Stage 4 is a broad review of each habitat, with a more detailed assessment for the top 10 ‘high-nature, high-carbon’ habitats.

Stage 4 Outputs:

A series of tables and narrative highlighting the different climate change scenarios and how the high carbon habitats may be influenced by them.

5. Climate change exposure and risk to habitats

Climate Change Scenarios and Climate Variables

Climate variables and how they may change with a changing climate are given in Appendix 1. These maps highlight the spatial variability in climate change projections across England for 3 Representative Concentration Pathways (RCP) scenarios: RCP2.6 (+1.6°C by 2081-2100), RCP6.0 (+2.8°C by 2081-2100), and RCP8.5 (+4.3°C by 2081-2100) (Met Office, 2018).

These exposures suggest broad trends where summer weather is expected to be hotter and drier, whereas winter weather is expected to be warmer and wetter. As the warming projection increases, so does the intensity of the effect of climate change.

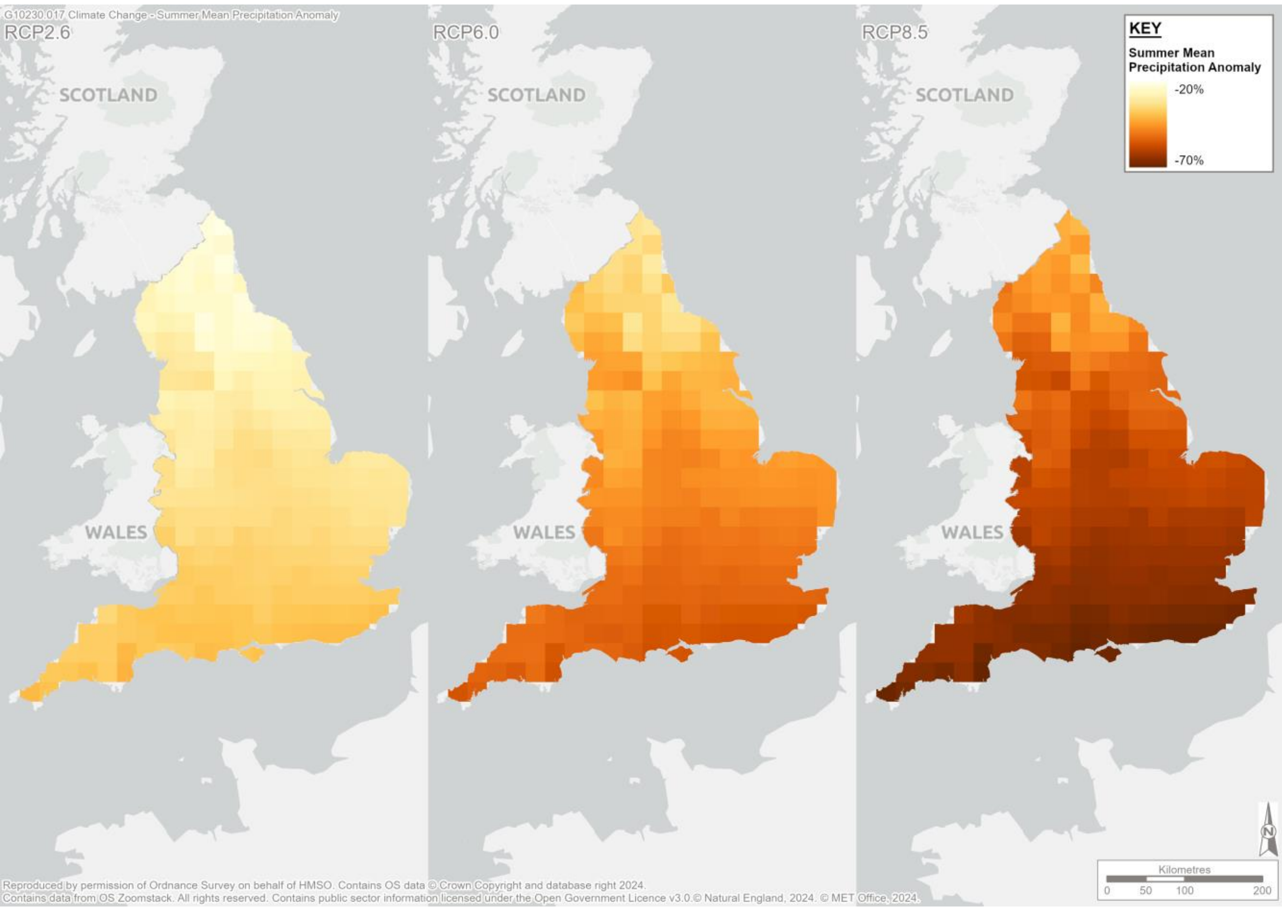

Figure 4. Summer mean precipitation anomaly for RCP 2.6 (+1.6°C by 2081-2100), RCP6.0 (+2.8°C by 2081-2100), and RCP8.5 (+4.3°C by 2081-2100) across England. Deeper orange tones represent decreasing precipitation. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

This is shown in Figure 4 above, which highlights the decreasing rainfall expected across England during the summer for the three scenarios. Darker orange tones represent decreasing summer rainfall.

It is also apparent that the climate projections get less certain as the warming projection increases, highlighted by the increases in standard deviation shown in Tables 3 to 8 below.

Summer Temperature Anomalies

Summer maximum temperature anomaly refers to the deviation from the average maximum temperatures during the summer season over a specified period. This is the average of the highest temperatures experienced during summer. Positive anomalies suggest increasing maximum temperatures during summer i.e. the hottest day in summer in the future may be hotter than the hottest day in summer now. The baseline period taken is 1961-1990 and the projected average is for 2070-2098.

Results are given in Table 3 and Appendix 1 and suggest increasing summer maximum temperature anomalies. This has a mean increase of 3.89°C for RCP2.6. This indicates that, in the future, the hottest day of summer may be average of 3.89°C hotter than for the baseline period. This rises to 8.84°C for RCP8.5.

Similarly, the summer mean temperature anomaly refers to the difference between the average temperature during the summer months and the long-term average for the same period. It differs, however, in that it represents the mean summer temperature, rather than the maximum. So positive anomalies indicate temperatures higher than the historical average, while negative anomalies indicate temperatures lower than average over the course of the season. Increasing anomalies are often associated with heatwaves, droughts, and other extreme weather events over the course of the season, posing risks to ecosystems, agriculture, human health, and infrastructure.

The results are given in Table 4 and Appendix 1 and suggest increasing mean summer temperatures as the climate change projection goes up. This starts at 3.31°C higher than the baseline period for the RCP2.6 scenario, rising to 7.76°C for the RCP8.5 scenario.

Increased summer temperatures may profoundly impact habitats, leading to changes in their structure, composition, and ecological functioning. Heat stress may lead to physiological changes in plants, such as reduced growth rates or increased susceptibility to pests and diseases. Additionally, warmer temperatures can accelerate the rate of evapotranspiration, leading to drier conditions and potentially affecting soil moisture levels. This can alter habitat suitability for various plant species, potentially leading to shifts in plant communities and changes in habitat structure.

This may be particularly pertinent for riparian habitats with implications for the decreased availability of water resources, particularly in habitats such as wetlands, rivers, and lakes. Warmer temperatures can lead to increased rates of evaporation, potentially reducing water levels and altering hydrological regimes further. This can impact the abundance and distribution of aquatic species, as well as the overall functioning of freshwater ecosystems.

Drought conditions and warmer average temperatures may also increase pressures from wildfire, with subsequent changes to habitats and the potential to release large quantities of carbon dioxide into the atmosphere.

Table 3. Climate change exposure value for the summer maximum temperature anomaly, for 3 climate change scenarios (RCP2.6, 6.0 and 8.5).

Representative Concentration Pathway (RCP)	Mean Value (°C)	Highest Value (°C)	Lowest Value (°C)	Standard Deviation
2.6	3.89	4.44	3.11	0.34
6	6.57	7.58	5.37	0.54
8.5	8.84	10.14	7.10	0.78

Table 4. Climate change exposure value for the summer mean temperature anomaly, for 3 climate change scenarios (RCP2.6, 6.0 and 8.5).

Representative Concentration Pathway (RCP)	Mean Value (°C)	Highest Value (°C)	Lowest Value (°C)	Standard Deviation
2.6	3.31	3.73	2.77	0.24
6	5.69	6.56	4.82	0.43
8.5	7.67	8.76	6.47	0.59

Winter Temperature Anomalies

The winter maximum temperature anomaly refers to the variation from the average or expected maximum temperatures during the winter season over a specified period. Positive anomalies indicate maximum temperatures may be higher than average, meaning the warmest day in winter is warmer, while negative anomalies indicate temperatures lower than average temperatures.

The results are given in Table 5 and Appendix 1 and show a general trend towards higher maximum temperature anomalies, rising as the climate change scenario goes up.

The winter mean temperature anomaly represents the difference between the average temperature during the winter months and the long-term average for the same period. Increasing anomalies are often associated with milder winters, alterations in precipitation patterns, and impacts on ecosystems, agriculture, and infrastructure.

The results are given in Table 6 and Appendix 1 and show a shift towards warmer mean temperatures in the winter months. Increased winter temperatures can have significant effects on habitats, reshaping their ecological dynamics and processes. One impact noted by the Climate Change Adaptation Manual (NE751) is the alteration of phenological events, such as flowering and leaf emergence, which may occur earlier due to warmer temperatures. This can disrupt the synchrony between species interactions, potentially affecting pollination, seed dispersal, and predator-prey relationships.

Warmer winters may lead to changes in species distribution patterns as organisms shift their ranges in response to changing temperature regimes. This can result in the establishment of novel species assemblages and the displacement of native species adapted to cooler conditions.

Alterations in temperature regimes may also affect snowfall patterns and influence water availability in mountainous regions, affecting the timing and duration of snowmelt. This may impact the hydrological cycle, soil moisture levels, and vegetation dynamics, with influences on habitat suitability for plant and animal species.

Warmer winters may facilitate the survival of species such as grey squirrel and deer. For woodlands, this may be of particular importance, with increasing populations of deer and squirrels resulting in increased browsing pressure, alongside increased disease prevalence.

Table 5. Climate change exposure value for the winter maximum temperature anomaly, for 3 climate change scenarios (RCP2.6, 6.0 and 8.5).

Representative Concentration Pathway (RCP)	Mean Value (°C)	Highest Value (°C)	Lowest Value (°C)	Standard Deviation
2.6	2.36	2.48	2.21	0.04
6	3.78	3.92	3.52	0.08
8.5	5.13	5.32	4.74	0.12

Table 6. Climate change exposure value for the winter mean temperature anomaly, for 3 climate change scenarios (RCP2.6, 6.0 and 8.5).

Representative Concentration Pathway (RCP)	Mean Value (°C)	Highest Value (°C)	Lowest Value (°C)	Standard Deviation
2.6	2.47	2.59	2.34	0.05
6	3.94	4.18	3.68	0.11
8.5	5.34	5.69	4.98	0.18

Summer Mean Precipitation Anomaly

The summer mean precipitation anomaly refers to the deviation from the average or expected amount of precipitation during the summer months over a specified period. Positive anomalies indicate higher precipitation than the historical average, while negative anomalies indicate lower precipitation. The baseline period is 1961-1990 and the projected average is for 2070-2098.

The results are given in Table 7 and Appendix 1. There is a general trend in decreasing summer mean precipitation values. Reduced precipitation during summer months may have wide impacts on habitats. One of the most immediate consequences is diminished water availability, particularly in habitats reliant on seasonal rainfall.

Grasslands, wetlands, and seasonal rivers may experience water scarcity, leading to depleted soil moisture and drying of water bodies. This may disrupt plant growth, reduce habitat suitability for aquatic species, and intensify competition for limited water resources among organisms. Additionally, prolonged dry spells may exacerbate drought conditions, subjecting habitats to increased water stress.

The structural composition of habitats may also undergo significant changes in response to reduced summer precipitation. Wetlands and marshes, which rely on consistent water inputs, may shrink, or completely dry up, resulting in habitat loss for dependent species and influencing habitat function. Forested areas, particularly those susceptible to wildfires, may become more vulnerable as dry conditions persist. This can alter habitat structure and disrupt ecological processes, impacting the overall resilience of ecosystems.

Species adapted to drier conditions may thrive, while those dependent on specific water sources may decline or disappear from affected areas. These shifts can lead to disruptions in ecological communities and alter species interactions, potentially impacting ecosystem functioning and stability.

Table 7. Climate change exposure value for the summer mean precipitation anomaly, for 3 climate change scenarios (RCP2.6, 6.0 and 8.5).

Representative Concentration Pathway (RCP)	Mean Value (% change)	Highest Value (% change)	Lowest Value (% change)	Standard Deviation
2.6	-33.95	-22.08	-42.46	4.80
6	-47.48	-32.00	-57.32	6.31
8.5	-59.14	-41.16	-69.97	7.15

Winter Mean Precipitation Anomaly

The winter mean precipitation anomaly refers to the deviation from the average or expected amount of precipitation during the winter months over a specified period. Positive anomalies indicate higher precipitation than the historical average, while negative anomalies indicate lower precipitation. Increasing winter mean precipitation anomalies can have various impacts, including changes in snowfall patterns, alterations in water availability for ecosystems and agriculture, and impacts on winter flooding and water resource management.

The results are shown in Table 8 and Appendix 1 and highlight a shift towards increasing winter precipitation. This increased precipitation may lead to soil erosion, waterlogging, and habitat loss. These changes in soil moisture levels and vegetation composition may affect the distribution and abundance of plant and animal species, disrupting ecosystem dynamics and altering biodiversity patterns. Furthermore, heavy rainfall events can result in increased sediment runoff and nutrient pollution in waterways, impacting water quality and aquatic ecosystems.

Table 8. Climate change exposure value for the winter mean precipitation anomaly, for 3 climate change scenarios (RCP2.6, 6.0 and 8.5).

Representative Concentration Pathway (RCP)	Mean Value (% change)	Highest Value (% change)	Lowest Value (% change)	Standard Deviation
2.6	23.14	38.59	9.47	4.96
6	36.02	58.37	17.11	7.35
8.5	48.20	77.48	24.19	9.96

Climate Change Risks to High Carbon Habitats

Climate change poses a number of risks to high carbon habitats. In some cases, climate change may degrade the condition of habitats and make them less able to sequester carbon into the future. In some scenarios, this degradation is already severe enough that peatland carbon sinks are already emitting carbon back into the atmosphere, a phenomenon that is well documented in habitats such as blanket bog where oxidation of peat releases carbon dioxide.

As described above, modelling suggests that summers will be hotter and drier, and winters warmer and wetter (Met Office, 2018). This suggests an increased risk of summer drought, and an increased risk of flooding in winter months.

Each habitat type will experience specific pressures resulting from climate change. Pressures may also vary depending on the location – for example blanket bog in the Pennines will differ from blanket bog found in the southwest of England. This is due to different climatic variables, with the south of England predicted to experience more extreme increased temperatures and reduced rainfall in summer compared to the north, both key risk factors for blanket bog.

The condition of each habitat also greatly influences its adaptive capacity against climate change. Where a habitat exists in a highly degraded condition currently, it may not be able to adapt to climate change as well as a habitat in good condition.

This means that a clear understanding of a particular site is needed to provide the best management approach that helps mitigate against climate change and promote healthy functioning ecosystems.

For wetland environments, prolonged periods of lower water tables in the summer may lead to substantial changes in hydrological regime, and result in significant changes to species composition and overall function. These include:

- blanket bog
- lowland raised bog
- coastal floodplain and grazing marsh
- lowland fens
- upland fens, swamps, and flushes

In the case of coastal habitats, there exists additional influence from sea level rise and 'coastal squeeze' where the area between the sea and the shore gets smaller as the sea rises. Saline intrusion and increased inundation by sea water puts coastal and associated river valley habitat at particular risk, where sometimes it may not be possible to adapt the habitats to prevent habitat loss, especially in locations where there is no room for adaption or expansion such as where hard sea defences protect settlements.

Lowland and upland heathland present unique challenges. Typically found on peaty and mineral soils, they hold large quantities of carbon. Drought and an increased risk of wildfire however put the habitats at risk, with the possibility of wildfires burning underlying peat and causing subsequent release of carbon dioxide back into the atmosphere in a positive feedback loop for climate change.

Similarly, woodland habitats such as deciduous woodland and wood pasture and parkland also may experience challenges. Increased summer temperatures and drought may put pressure on certain tree species and lead to changes in growth rates and species assemblage across the habitat types. Whereas warmer and wetter winters may cause a proliferation in the number of mammal and insect pests such as deer and squirrels, resulting in increased disease and limiting natural regeneration of woodland where trees have died due to summer drought.

For all high carbon habitat types, management strategies will have to be employed to ensure that habitats are able to adapt to climate change pressures where possible, and appropriate measures taken where it is clear that a habitat type may not be able to adapt (in the case of squeeze on coastal habitats for example).

The risks to the 'top ten' high nature/high carbon habitats are considered below. Tabulated summaries for each habitat in terms of each climate change risk are found at Appendix 2.

Blanket Bog

Blanket bog is an upland habitat forming in flat or gently sloping areas with high rainfall and low evapotranspiration. It is characterised by mire species, especially the principal "bog-builder" sphagnum mosses. Much of the UKs blanket bog is in a degraded condition due to burning, drainage, overgrazing and atmospheric pollution. It is a large carbon store, but is particularly sensitive to climate change, especially when in degraded condition. This is reflected in the work of Staddon and others (2023), showing a sensitivity of 5 in degraded condition, which can be pushed down to 3 when the habitat is in good condition (see Table 2 earlier).

As per findings in Part 1 of the Nature Net Zero report, England has about 236,000 hectares of blanket bog in the PHI, with an estimated total carbon store of about 114 million tonnes which is about 22% of the carbon stored in England's priority habitats. Upland Deep peat is much greater and has substantial potential to be restored back to Blanket Bog. Unfortunately, due to its generally degraded condition, the oxidation process means it is a net carbon emitter, with an estimated annual flux to the atmosphere of about 806,000 tonnes CO_2 equivalent.

As a primarily rain-fed habitat, reduced rainfall in summer months and prolonged drought may change species assemblage and lead to degradation of habitat and peat the condition. Climate change can bring hotter summers, drier summers, wetter winters, and intensified storm events, impacting blanket bogs. Warmer temperatures and reduced water tables may alter plant species, while increased evapotranspiration and droughts can affect vegetation composition and increase wildfire risk. Wetter winters and storms can lead to erosion and peat instability.

This is illustrated in **Error! Reference source not found.** and **Error! Reference source no t found.**. These highlight spatial aspects of climate change across England, with wetland habitats in southwestern areas experiencing more extreme anomalous effects than their northern counterparts in terms of reduced summer rainfall and increased summer temperatures.

Error! Reference source not found. and **Error! Reference source not found.** relate to Fi gures 5 and 6. They indicate the proportion of blanket bog that is present in each banding for the summer climate variable.

In respect of hotter summer temperatures the majority of blanket bog falls in the second lowest banding (a predicted rise of 5.3°C to 5.5°C, using RCP6.0. In respect of summer rainfall, the majority of blanket bog is found in the lowest banding where a -32% to -39% decrease in summer rainfall is expected.

Bodmin Moor, Dartmoor and Exmoor, in England's southwest, represent about 9% of England's blanket bogs. They are in the upper quintiles of extreme anomalous summer temperature and drought projections, with >50% reduction in summer precipitation expected by the 2080's – see Figure 6.

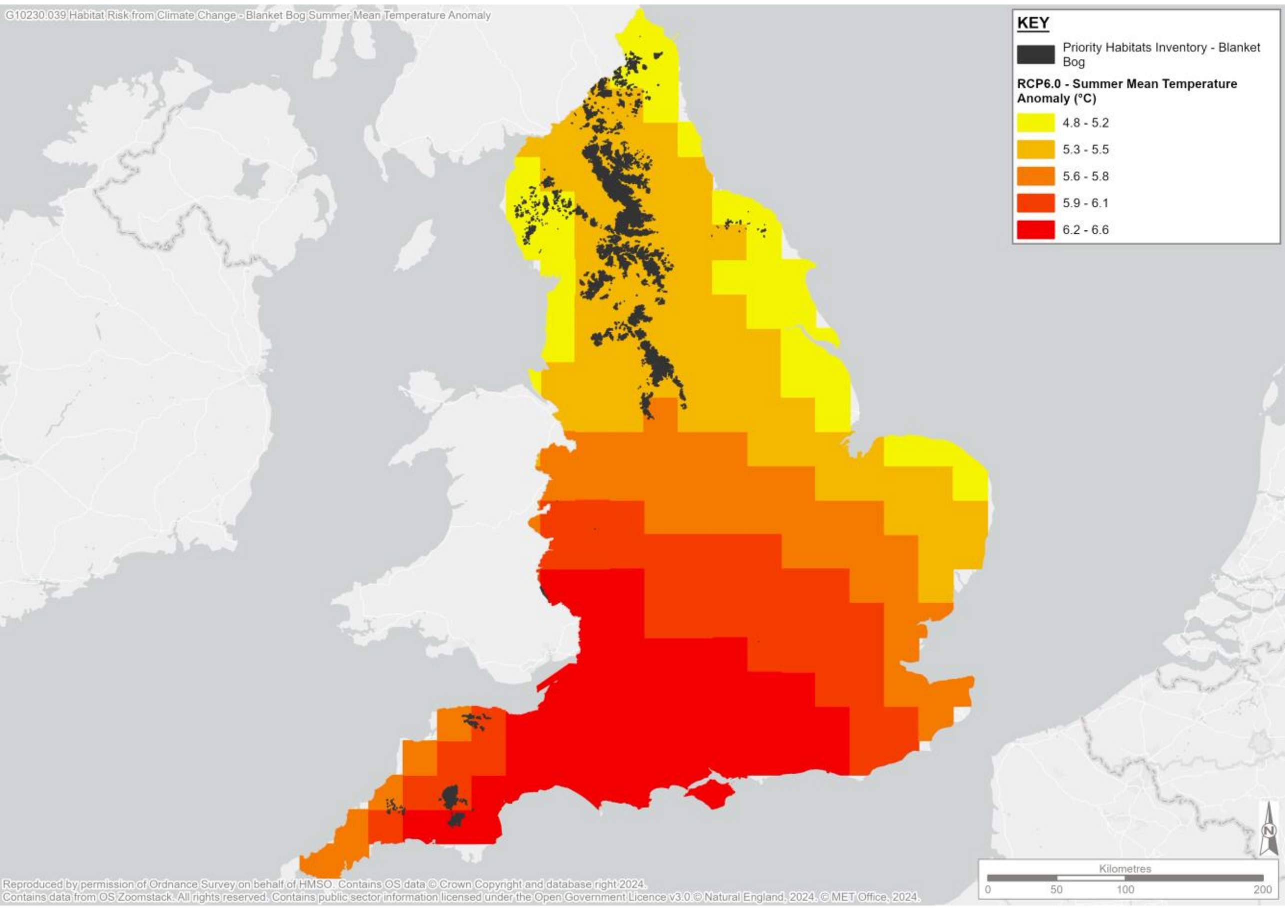

Figure 5. Location of blanket bog, showing the projected summer mean temperature anomaly (°C) highlighting areas in southwest England which may be impacted more by increased summer temperatures. Based on RCP6.0 projection. *Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under* the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.

Table 9. The proportion of blanket bog within each banding of summer mean temperature anomaly (%) as highlighted in Figure 5.

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
No climate data available	0.0
4.8 - 5.2	5.8
5.3 - 5.5	85.0
5.6 - 5.8	1.6
5.9 - 6.1	5.2
6.2 - 6.6	2.5

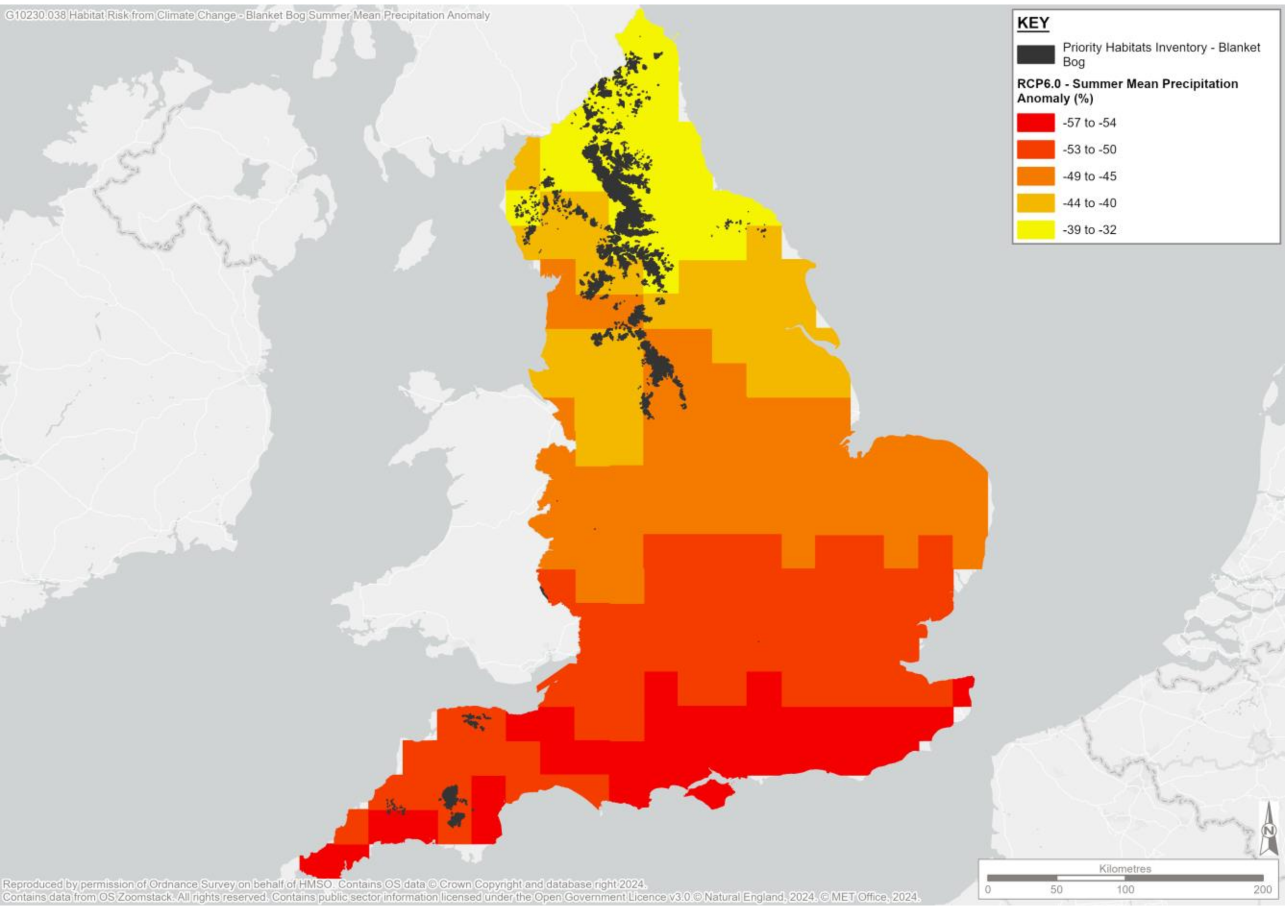

Figure 6. Location of blanket bog, showing the projected summer mean precipitation anomaly (%), highlighting areas in southwest England which may be impacted more by reduced summer rainfall. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Table 10. The proportion of blanket bog within each banding of summer mean precipitation anomaly (%) as highlighted in Figure 6.

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
No climate data available	0.0
-32 to -39	60.4
-40 to -44	15.9
-45 to -49	15.4
-50 to -53	8.2
-54 to -57	0.1

The degradation of blanket bogs due to draining, burning, overgrazing, and pollution has left many of them dry and unable to properly function. Given the dependence of bogs on a reliable high water table, actions to improve water quantity and quality on sites will become increasingly important as climate change progresses.

Adaptation options for blanket bogs include adjusting land management regimes to prevent further degradation from trampling, burning and overgrazing, re-vegetating bare peat, and restoring natural hydrological regimes through drain and gully blocking.

Additionally, identifying areas likely to retain the necessary hydrological regime for bog development and protecting them under optimal management is crucial to ensure they continue to store carbon and function as an ecosystem. On a positive note, higher winter precipitation could enable hydrological recharge of peat vulnerable to summer drought, provided water is retained within the bog and erosion control measures are installed.

Given the extended periods of time required to restore blanket bog, and the logistical difficulties of co-ordinating a landscape recovery programme, a 'resist change' approach of active blanket bog restoration would need to be prioritised in the southwestern moors, which, as shown at Figures 5 and 6, are most exposed to extreme and anomalous climatic changes which directly threaten the habitat and its carbon.

Deciduous Woodland

Woodland covers 10 per cent of England's area, of which 77 per cent is broadleaved (Forest Research, 2023). Deciduous woodland is a grouping of six priority woodland habitat types. England has about 760,000 hectares of deciduous woodland PHI, with an estimated total carbon store of about 231 million tonnes which is about 45% of the carbon stored in England's priority habitats. It is important for sequestration, with an estimated annual absorption from the atmosphere of about 8,165,000 tonnes CO_2 equivalent as noted in Part 1 of this report. It may experience pressure from climate change due to prolonged drought and the influence of pests and diseases. The work of Staddon and others (2023) gives the habitat a sensitivity rating of 3 in degraded condition, and 2 when in good condition (see Table 2).

Threats from climate change include the increased frequency and severity of summer droughts. This poses a risk to drought-sensitive tree species, particularly on certain soil types, mainly in southern and eastern England. Stressed trees may become more vulnerable to insect pests and diseases, which are expected to proliferate due to increased activity and reduced winter mortality under climate change. Deer and grey squirrel populations may also rise, posing further challenges to woodlands and hindering natural regeneration efforts. This may lead to changes in species assemblage, with corresponding changes to habitat function and ability to sequester carbon.

Deciduous woodland covers broad regions across England, experiencing different climates across the country. As such, it will also be influenced differently to climate change across the country, and

management practices and species mixes should adapt depending on these regional changes (Figure 7, Figure 8,
Table 11 and Table 12.

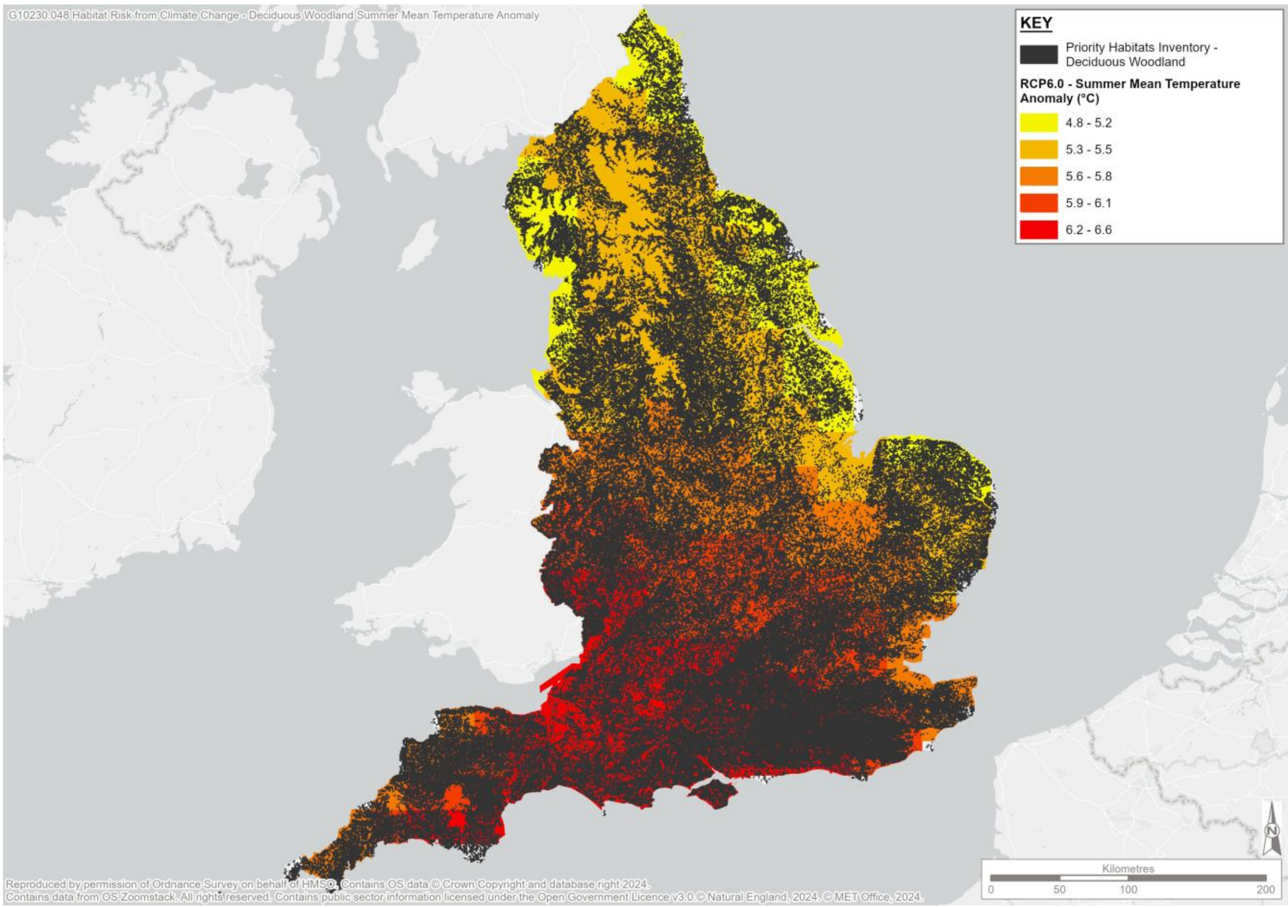

Figure 7. Location of deciduous woodland, showing the projected summer mean temperature anomaly (°C) highlighting the broad habitat coverage across England. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Table 11. The proportion of deciduous woodland within each banding of summer mean temperature anomaly (%) as highlighted in Figure 7.

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
No climate data available	1.2
4.8 - 5.2	7.9
5.3 - 5.5	20.4
5.6 - 5.8	14.8

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
5.9 - 6.1	23.0
6.2 - 6.6	32.7

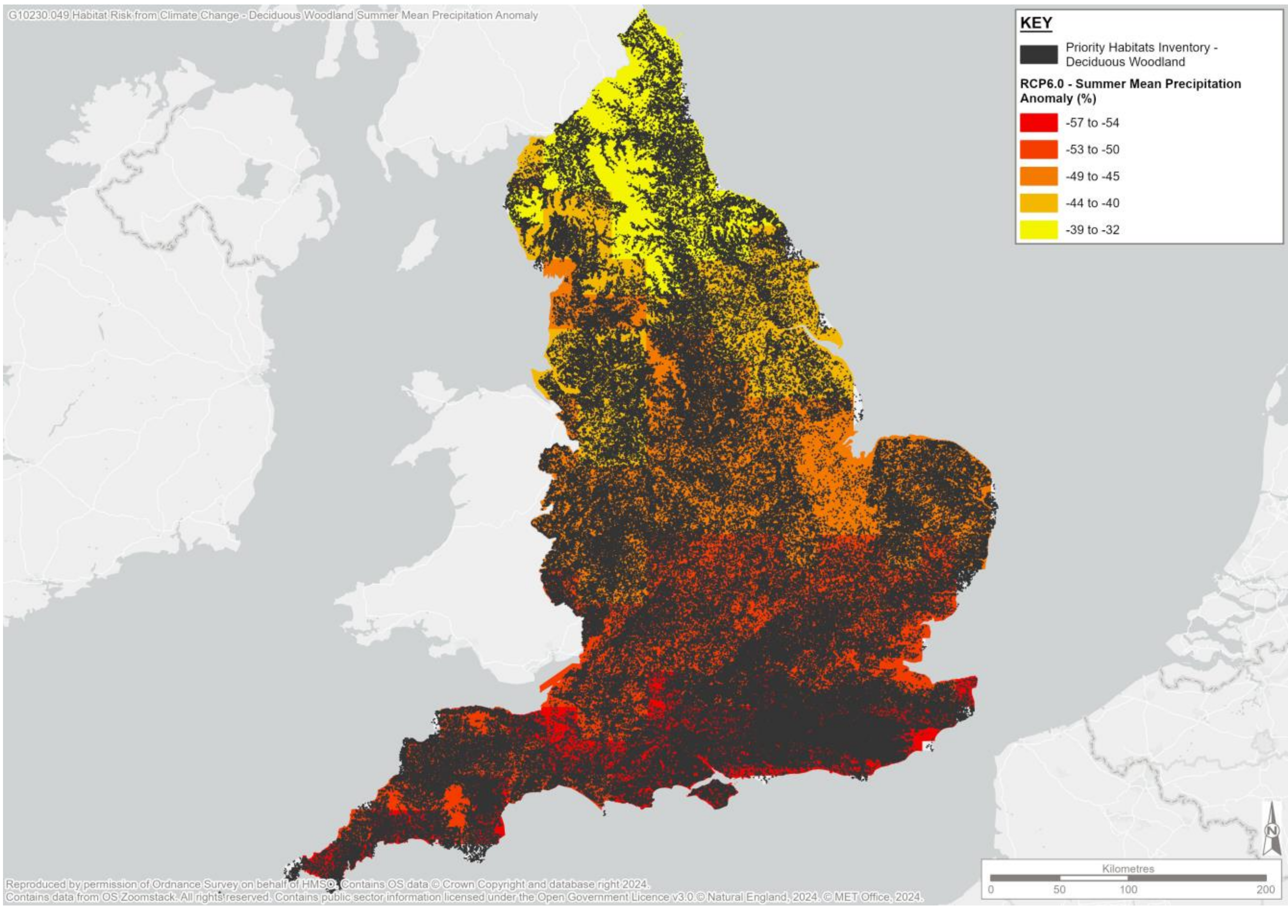

Figure 8. Location of deciduous woodland, showing the projected summer mean precipitation anomaly (%),) highlighting the broad habitat coverage across England. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Table 12. The proportion of deciduous woodland within each banding of summer mean precipitation anomaly (%) as highlighted in Figure 8.

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
No climate data available	1.2
-32 to -39	6.7
-40 to -44	11.3

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
-45 to -49	22.6
-50 to -53	32.9
-54 to -57	25.4

Upland Heathland

Upland heathland is characterised by the presence of dwarf shrubs (such as gorse and heather) growing on acidic mineral and peat soils. There are extensive areas in upland environments of England, 79% of the priority habitat being located on deep and shallow peat. With climate change, it may experience changes in species composition, and it may encroach into current areas of blanket bog as these degrade.

Its sensitivity to climate change is influenced by whether it is dry or wet. Dry upland heath has a sensitivity of 3 when in degraded condition and 2 in good condition. Wet upland heath has sensitivities of 4 in degraded condition and 3 in good condition (see Table 2).

England has about 230,000 hectares of upland heathland, with an estimated total carbon store of about 50 million tonnes which is just under 10% of the carbon stored in England's priority habitats. Unfortunately, it is a net carbon emitter, with an estimated annual flux to the atmosphere of about 12,400 tonnes CO_2 equivalent as referenced in part 1 of this report. Projected temperature changes are expected to influence community structure and species composition, potentially causing upland heaths to resemble current lowland heaths more closely. However, the increased winter moisture in upland areas, particularly in northwestern England, may moderate this effect. Nonetheless, wet upland heaths could be vulnerable to shifts in precipitation patterns, especially during summer. Some sites may also face vulnerability to potential increases in visitor numbers with issues of habitat trampling or wildfire, mainly in popular and accessible areas.

The considerable size of upland heath patches, along with the diverse topography and habitat mosaic, may confer some resilience to climate change. While fragmentation and isolation are less problematic compared to lowland heaths, less mobile species could still face limitations within their original sites, particularly those at lower altitudes and in southern regions.

Different aspects of climate change will interact with heathland systems, necessitating flexible management strategies. Beyond climate change, heathlands face threats like habitat loss, fragmentation, and overgrazing. Enhancing upland heath resilience involves reducing these pressures and restoring habitats.

Adaptation requires targeted restoration and creation of heathland habitats. Proposed adaptation measures include reinstating wet heath areas, developing fire contingency plans, minimizing erosion, and allowing increased scrub and woodland cover. Identifying potential climate change refugia and maintaining habitat structural diversity are also crucial. Conservation objectives should reflect climatic gradients, acknowledging that species conservation actions may need to shift locations under a changing climate.

The spatial distribution of upland heathland across the country is similar to blanket bog, with large quantities in the north and the south west as highlighted in Figure 9 and Figure 10. Over 60% of it will experience increases in mean summer temperature of 5.3°C as forecast by RCP6.0, as well as corresponding reductions in summer rainfall, as highlighted in
Table 13 and Table 14.

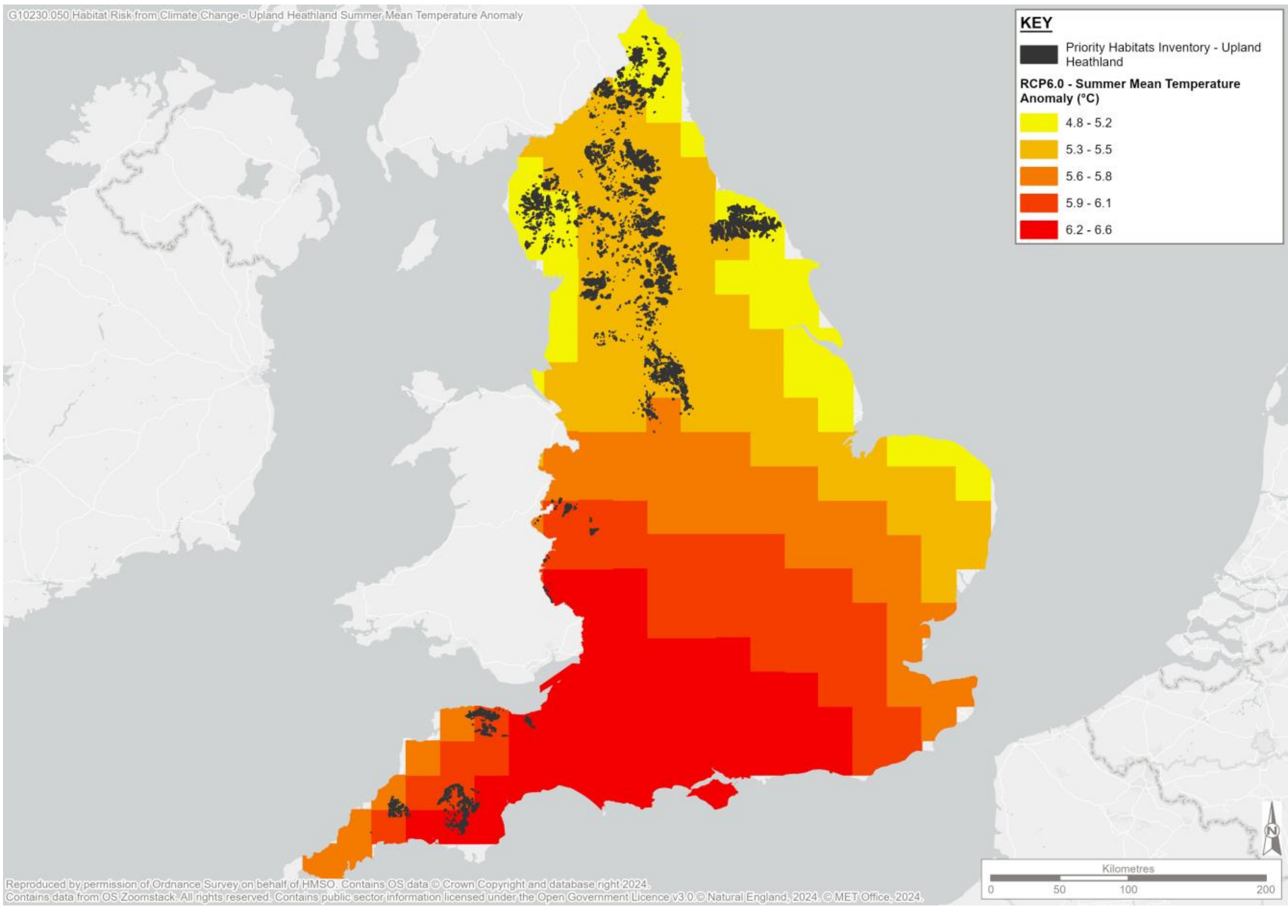

Figure 9. Location of upland heathland, showing the projected summer mean temperature anomaly (°C) highlighting areas in southwest England which may be more exposed to high summer temperatures. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Table 13. The proportion of upland heathland within each banding of summer mean temperature anomaly (%) as highlighted in Figure 9.

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
No climate data available	0.0
4.8 - 5.2	26.3
5.3 - 5.5	60.4

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
5.6 - 5.8	1.8
5.9 - 6.1	8.6
6.2 - 6.6	2.9

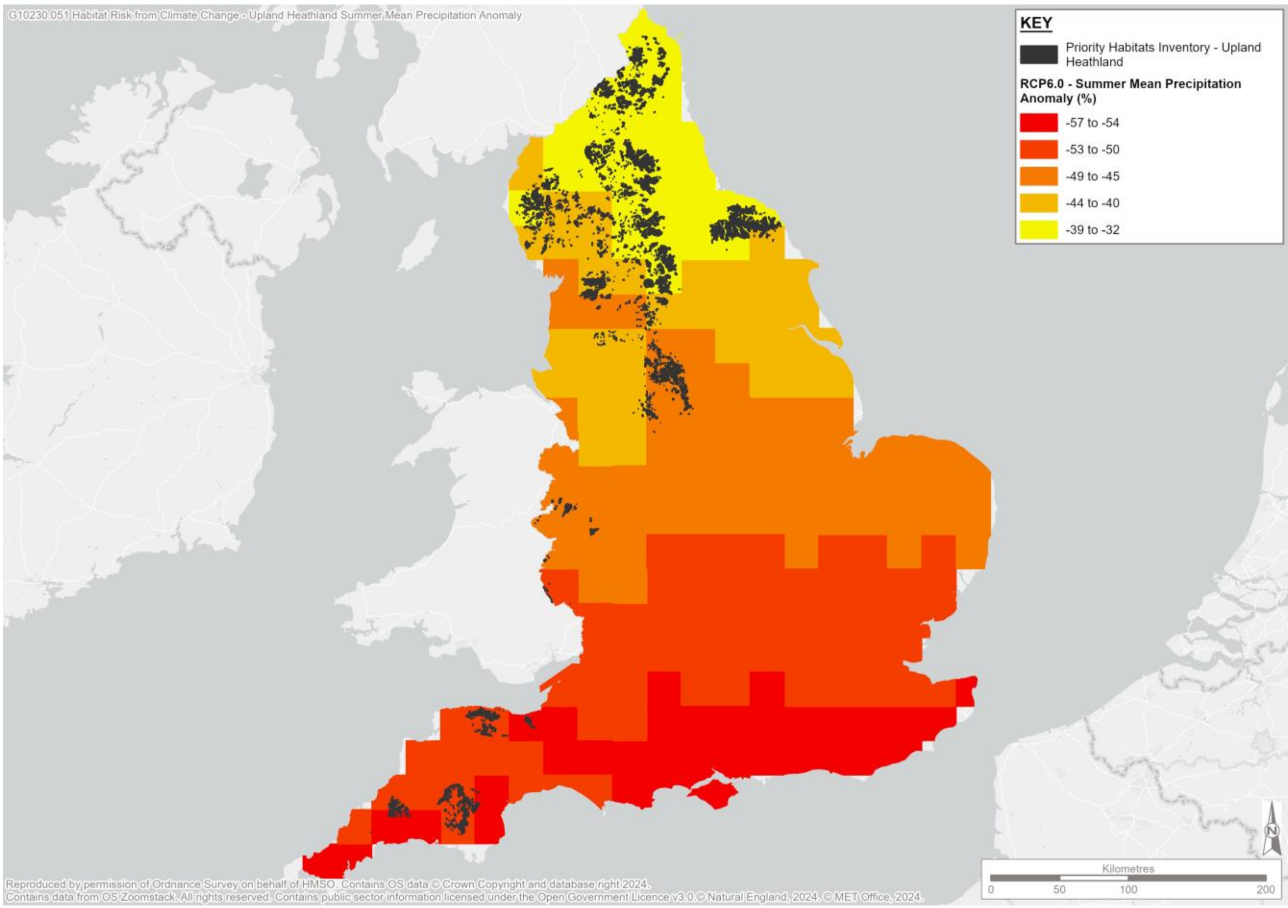

Figure 10. Location of upland heathland, showing the projected summer mean precipitation anomaly (%),) highlighting areas in southwest England which may be more exposed to decreased rainfall in summer. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Table 14. The proportion of upland heathland within each banding of summer mean precipitation anomaly (%) as highlighted in Figure 10.

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
No climate data available	11.2
-32 to -39	6.4

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
-40 to -44	4.0
-45 to -49	14.6
-50 to -53	12.5
-54 to -57	51.3

Coastal and Floodplain Grazing Marsh (CFGM)

Coastal and floodplain grazing marsh (CFGM) is dependent on periodic inundation and high-water levels, which makes it sensitive to the projected changes in patterns of rainfall and extreme events such as drought and flooding. Coastal occurrences of CFGM are at risk from sea level rise, with pressures from ‘coastal squeeze’ as a result of existing flood defences and urbanisation. Sea level rise can lead to risk of increased inundation and potential coastal erosion, with freshwater sites adjacent to the coast sensitive to saline intrusion.

It is particularly sensitive to climate change for these combined reasons and is given a sensitivity of 5 when in degraded condition and 4 when in good condition (see Table 2 earlier). The literature also highlights the difficulty for CFGM in adapting to climate change due to the impact of coastal squeeze and that it is an artificial habitat often created by draining other habitat such as coastal and floodplain wetlands, while still retain high wildlife assemblage.

England has about 231,000 hectares of CFGM, with an estimated total carbon store of about 14 million tonnes, which is about 4.6% of the carbon stored in England’s priority habitats. They sit on 40,000ha of deep peaty soils, 120ha of shallow peaty soils and 15,000ha of soils with peaty pockets, as detailed in part 1 of this report.

Hotter summers may alter plant phenology, affecting the timing of flowering and seed setting; while drier summers could favour stress-tolerant species and reduce food availability for ground-nesting birds. The resultant changes to the water table may also influence the habitat’s ability to function and sequester carbon. Conversely, wetter winters may change inundation patterns, impacting floodplain wetland plant communities and breeding success of water birds.

In combination with sea level rise, there may be a loss of habitat with increased susceptibility to invasive species and erosion, especially where these issues are already prevalent. The areas which may be affected by increasing summer temperatures and reduced summer rainfall are shown in Figure 11, Figure 12,
Table 15 and Table 16.

Table 16Coastal grazing marshes require site-specific management of flood defences and drainage systems to become more naturally functioning systems and reduce the pressures from climate change, working alongside strategies to reduce pollution, adjusting grazing regimes, expanding marshes, and monitoring invasive species.

In terms of carbon, a transition from CFGM to coastal saltmarsh may represent an opportunity for increased storage because saltmarsh has a typical store of 393 tonnes Cha^{-1}, compared to CFGM which has a typical store of 109 $tCha^{-1}$.

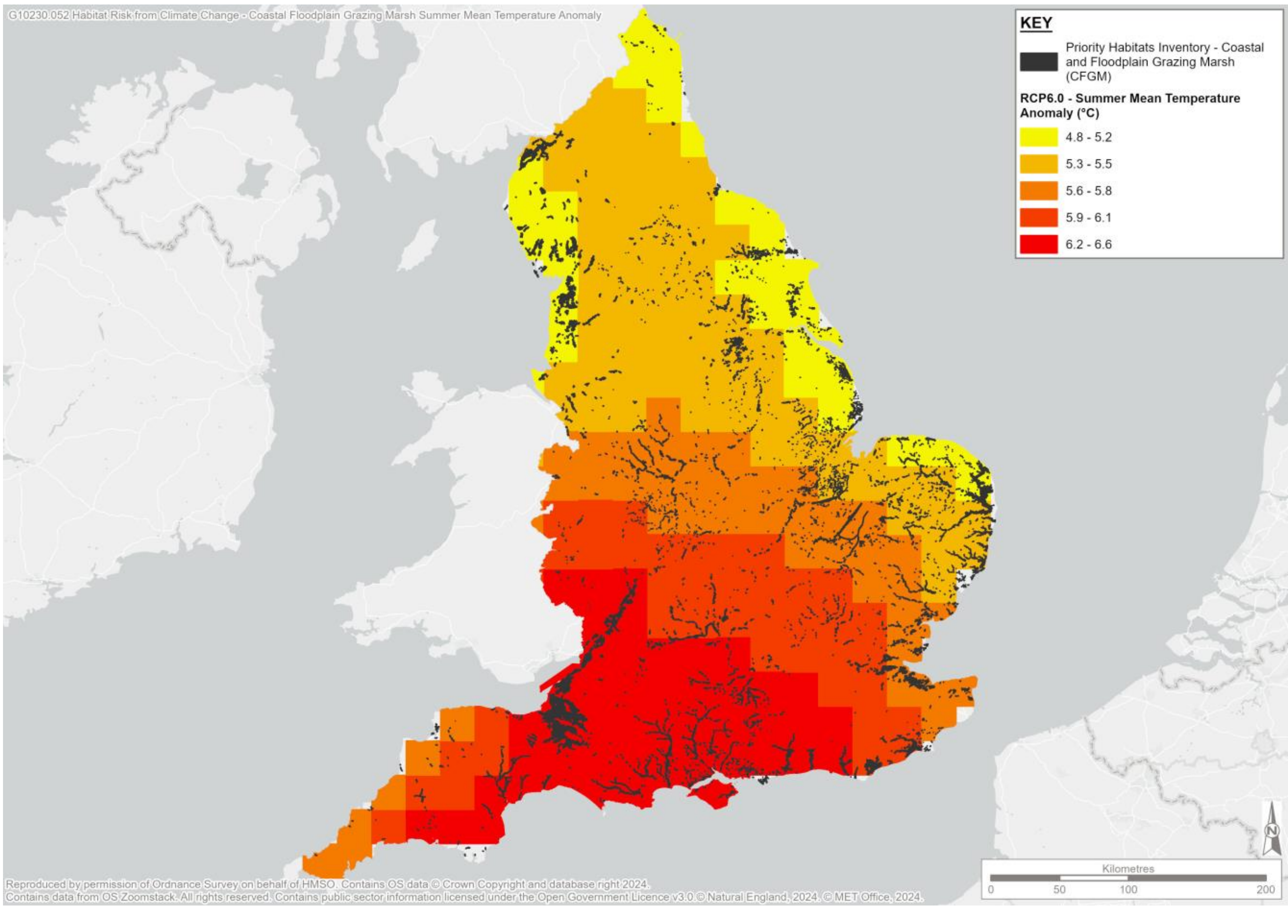

Figure 11: Location of Coastal and Floodplain Grazing Marsh, showing the projected summer mean temperature anomaly (°C) highlighting the coastal distribution. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Table 15. The proportion of coastal and floodplain grazing marsh within each banding of summer mean temperature anomaly (%) as highlighted in Figure 11.

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
No climate data available	2.8
4.8 - 5.2	18.6
5.3 - 5.5	17.7
5.6 - 5.8	13.7

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
5.9 - 6.1	9.9
6.2 - 6.6	37.4

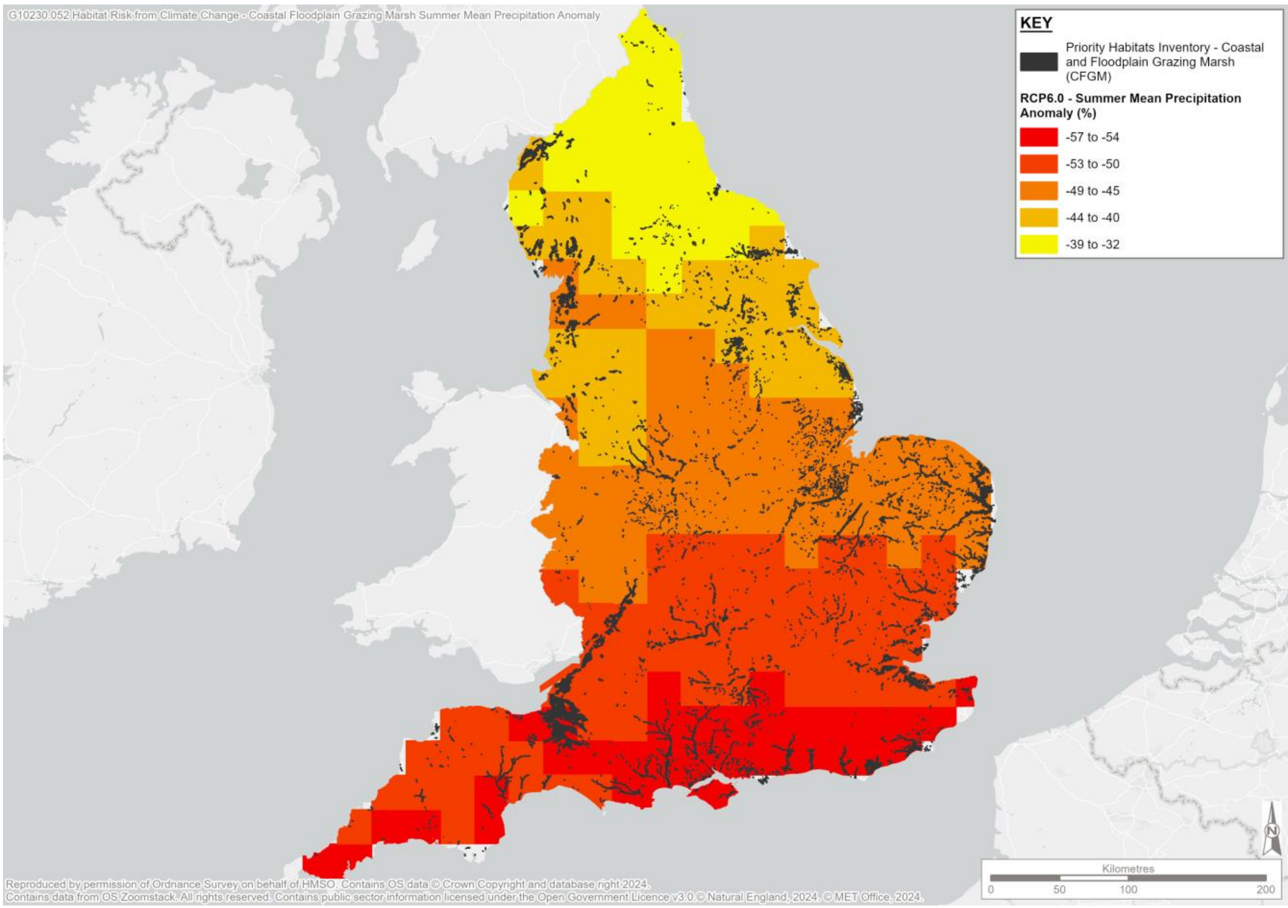

Figure 12. Location of Coastal and Floodplain Grazing Marsh, showing the projected summer mean precipitation anomaly (%),) highlighting the coastal distribution. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Table 16. The proportion of coastal and floodplain grazing marsh within each banding of summer mean precipitation anomaly (%) as highlighted in Figure 12.

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
No climate data available	2.8
-32 to -39	3.0
-40 to -44	15.7

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
-45 to -49	25.2
-50 to -53	38.1
-54 to -57	15.1

Lowland Raised Bog

Lowland raised bogs develop within lowland areas such as in river floodplains, the heads of estuaries and within topographic depressions and are the deepest peatland ecosystems capable of storing large quantities of carbon within them. When in good condition, they are expected to exhibit relatively high climate change resilience and are referred to as active raised bog (peat forming), but for the most part are in a degraded state in England, due to peat cutting, drainage and historic land management especially around the edges of remaining habitat and are referred to as degraded raised bog (no longer peat forming.

Similarly to blanket bog, lowland raised bog is highly sensitive to climate change, having a sensitivity of 5 when in degraded condition which can be reduced to 3 when in active condition (see Table 2).

England has about 35,000 hectares of lowland raised bog habitat, with an estimated total carbon store of about 20 million tonnes which is about 3.9% of the carbon stored in England's priority habitats - the most carbon dense of any habitat by area. Unfortunately, due to the extent of habitat not in active bog-building status, the oxidation process means it is a net carbon emitter, with an estimated annual flux to the atmosphere of about 42,500 tonnes CO_2 equivalent as referenced in part 1 of this report.

Increased temperatures and longer growing seasons may reduce the dominance of bog vegetation, influenced by site-specific hydrological conditions and rainfall patterns. Hotter summers could lead to a lowered water table, disrupting the natural hydrological balance. Drought conditions may also exacerbate water table drawdown, alter vegetation composition, increase erosion, and raise the risk of wildfires, especially in degraded bogs. Where this is the case, lowland raised bog becomes a net source of carbon dioxide rather than a sink, as peat is oxidised and releases carbon into the atmosphere.

**This is shown in Figure 13 and Figure 14, which highlight the possible risk to lowland raised bog in south western parts of the country which may face more severe increases in summer temperature and decreases in rainfall. The majority of lowland raised bog, over 80%, is likely to experience mean summer temperature rises of more than 5.3°C (
Table 17, Table 18).**

Meanwhile, increased surface water runoff in wetter winters may heighten erosion and water quality issues. Lowland raised bogs are particularly vulnerable to degradation and erosion, especially when hydrology is compromised by historic drainage surrounding the bog area, as many are.

To mitigate the effects of climate change, habitat restoration should be prioritised to improve the condition of current lowland raised bogs and improve resilience into the future. This may include restoring natural hydrological regime, removing invasive species and excess trees, and re-vegetating bare peat. It may also be possible to reinstate much larger areas of lowland raised bogs in the surrounding peat body and fen habitat restoration, based on a thorough understanding of the hydrology and extent of peatland to ensure a reduction of carbon being lost.

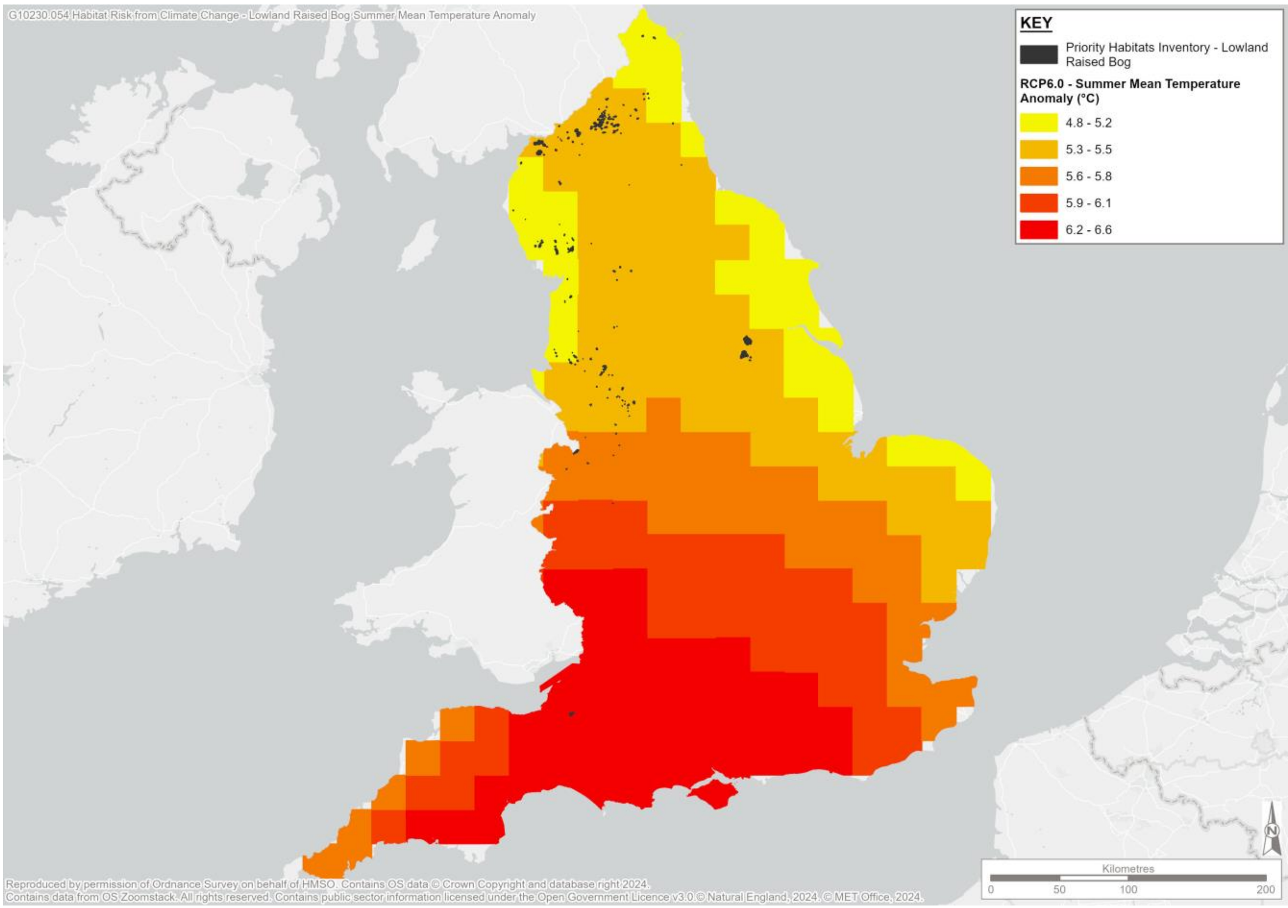

Figure 13. Location of lowland raised bog, showing the projected summer mean temperature anomaly (°C) highlighting regions in southwest england which may be more exposed to increased summer temperatures. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Table 17. The proportion of lowland raised within each banding of summer mean temperature anomaly (%) as highlighted in Figure 13.

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
No climate data available	0.0
4.8 - 5.2	14.5

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
5.3 - 5.5	79.9
5.6 - 5.8	2.8
5.9 - 6.1	0.1
6.2 - 6.6	2.7

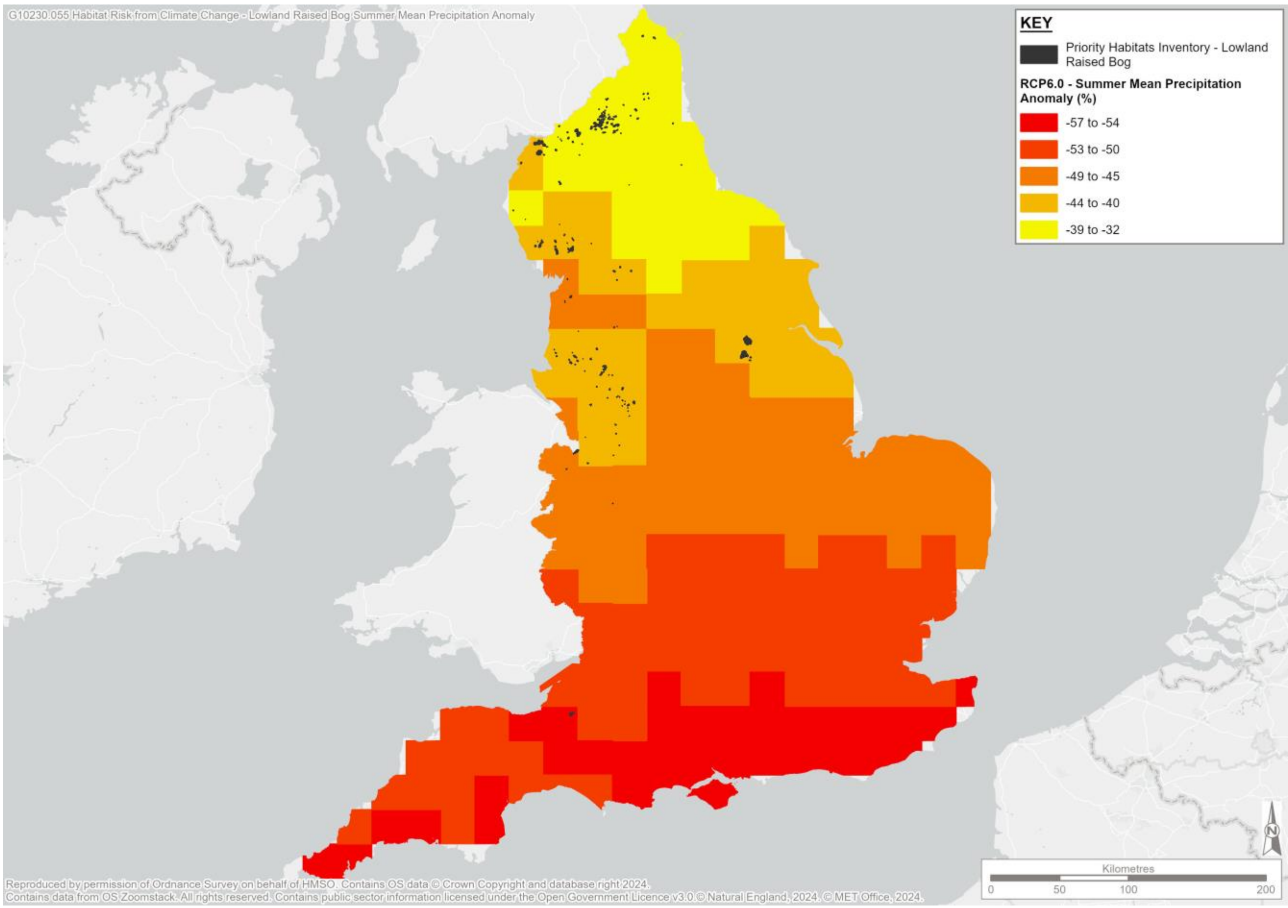

Figure 14. Location of lowland raised bog, showing the projected summer mean precipitation anomaly (%),) highlighting regions in southwest England which may be more exposed to reduced summer rainfall. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Table 18. The proportion of lowland raised bog within each banding of summer mean precipitation anomaly (%) as highlighted in Figure 14.

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
No climate data available	0.0

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
-32 to -39	31.3
-40 to -44	62.6
-45 to -49	3.3
-50 to -53	2.7

Lowland Fens

Lowland fens are habitats occurring on wet and mineral soils and are fed by groundwater. They are a diverse group of habitat types and store large quantities of carbon but are highly sensitive to climate change. This is due to their reliance on groundwater quality and quantity, which are forecast to change dramatically with climate change. Sea level rise and associated saline intrusion will pose an increasing threat to fens near to the coast.

Lowland fens are markedly sensitive to climate change. The work of Staddon and others (2023) give them a sensitivity of 5 when in degraded condition, and 4 in good condition, highlighting difficulties fens will may experience in adapting to climate change (Table 2).

England has about 19,900 hectares of remaining lowland fen, with an estimated total carbon store of about 14 million tonnes which is about 2.8% of the carbon stored in England's priority habitats. Unfortunately, the oxidation process means it is a net carbon emitter, with an estimated annual flux to the atmosphere of about 66,000 tonnes CO_2 equivalent as referenced in part 1 of this report.

Climate change impacts may result in increased mean temperatures and subsequent longer growing seasons. As such, there may be changes to plant growing seasons, with corresponding effects on management practices like cutting regimes and stocking density. Hotter summers may result in higher nitrogen concentrations due to reduced water volume and increased mineralization, potentially leading to eutrophication of ditch networks and dominance of invasive species, while altered seasonal rainfall patterns may cause increased seasonal variation in water table levels, impacting wetland specialists and potentially leading to changes in community composition.

These drier summers could increase soil moisture deficit, leading to habitat loss, changes in community composition, and intensified grazing or conversion to arable cropping, with subsequent changes in the habitat's ability to sequester and store carbon (Figure 15, Figure 16, Table 19, Table 20).

Wetter winters, however, may increase the risk of polluted runoff and flooding, altering species composition and complicating management further, while increasing the risk of erosion.

In coastal areas, sea level rise may cause saline intrusion with subsequent changes to hydrological properties and species composition, all of which may change the ability of the habitat to function properly, especially when the habitat may already be in a degraded condition.

Adaptation options may include characterizing water regimes, flexible management practices, restoring floodplains, evaluating, and modifying drainage systems, addressing nutrient enrichment, managing invasive species, and identifying and protecting sites with assured water quality and quantity. As the fens represent an important economic resource, this must also be balanced alongside financial returns, with corresponding considerations on how best to manage carbon resources within the habitat.

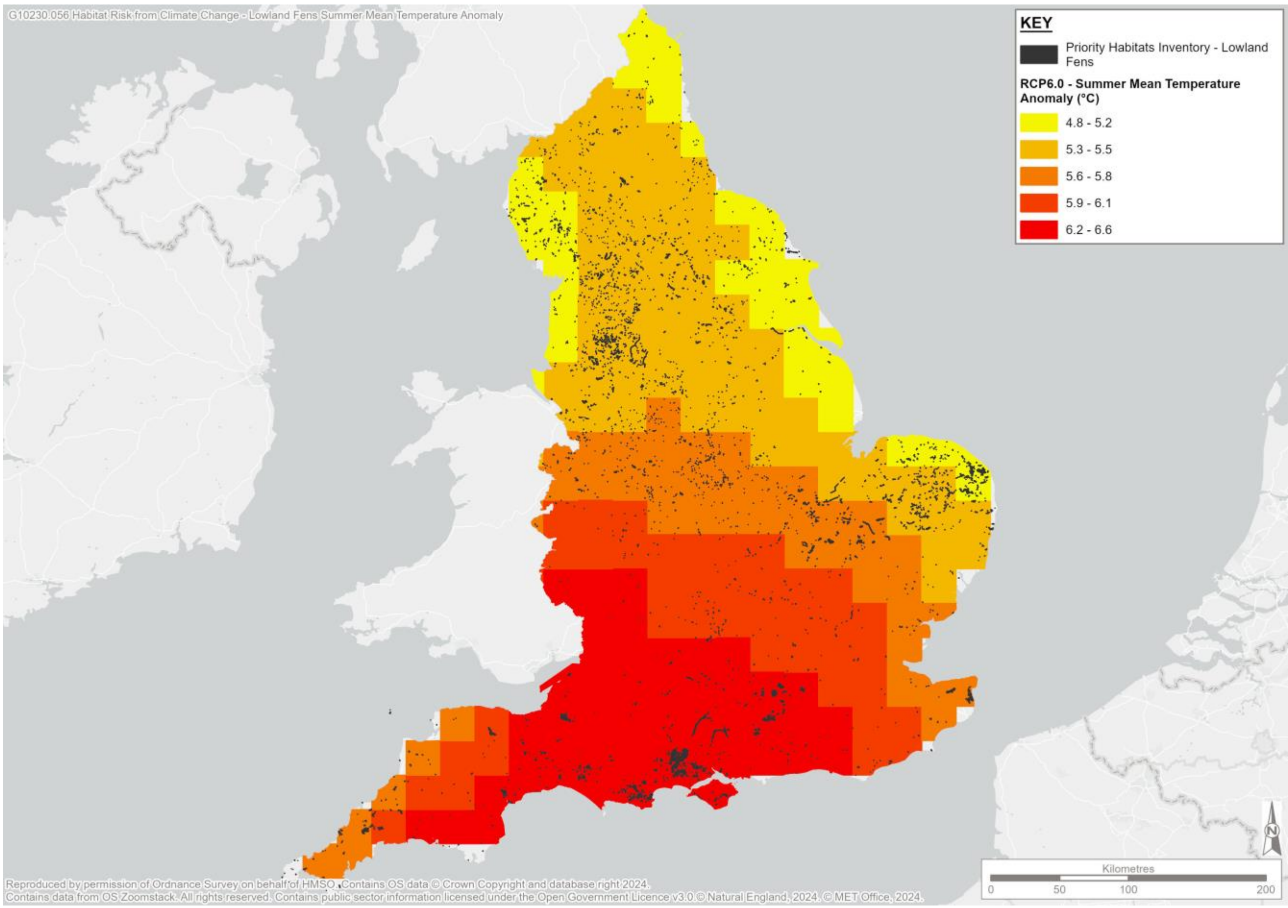

Figure 15. Location of lowland fens, showing the projected summer mean temperature anomaly (°C) highlighting regions in southwest England which may be more exposed to increased summer temperatures. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Table 19. The proportion of lowland fens within each banding of summer mean temperature anomaly (%) as highlighted in Figure 15.

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
No climate data available	1.4

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
4.8 - 5.2	13.8
5.3 - 5.5	33.7
5.6 - 5.8	17.8
5.9 - 6.1	4.2
6.2 - 6.6	29.2

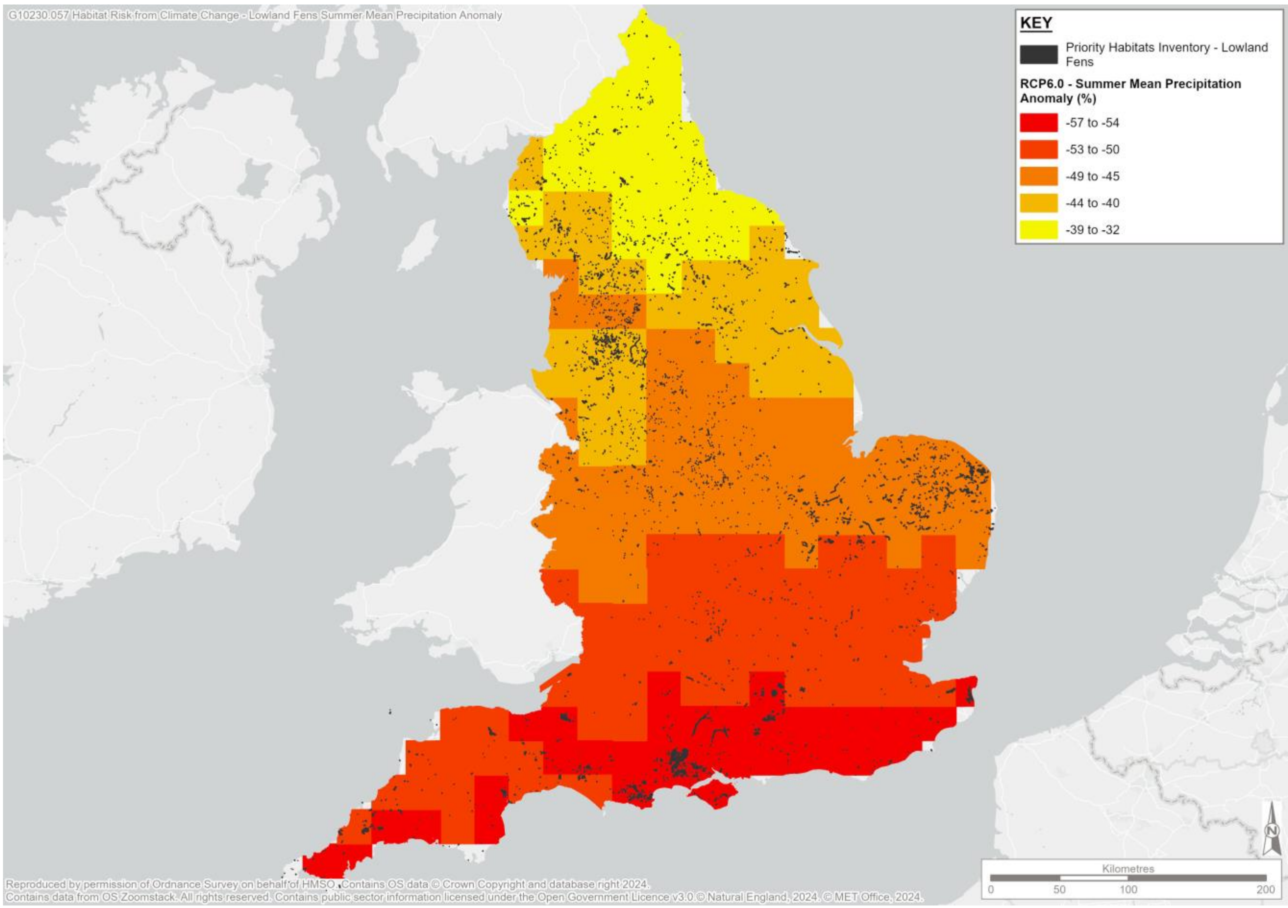

Figure 16. Location of lowland fens, showing the projected summer mean precipitation anomaly (%),) highlighting regions in southwest England which may be more exposed to reduced summer rainfall. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack.***

Table 20. The proportion of lowland fens within each banding of summer mean precipitation anomaly (%) as highlighted in Figure 16.

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
No climate data available	1.4
-32 to -39	10.3
-40 to -44	19.2
-45 to -49	27.9
-50 to -53	16.4
-54 to -57	24.7

Wood pasture and parkland

Wood pasture and parkland (WPP) is an open habitat type often consisting of large forest trees within a matrix of grazed grassland, woodland flora and/or heathland. It is a product of historic management and sits within a designed landscape, oftentimes supporting veteran trees with old-growth and deadwood, supporting numerous species. They are relatively resilient against climate change, but seasonal drought and storms may threaten veteran trees. It is given sensitivity values of 3 when in degraded condition and 2 when in good condition, noting the relative resilience of this habitat to climate change (see Table 2 earlier).

England has about 161,000 hectares of wood pasture and parkland (excluding priority habitats within the wider WPP boundary which are classified as individual habitats). This WPP has an estimated total carbon store of about 15.3 million tonnes which is about 3% of the carbon stored in England's priority habitats. Accurate estimates of sequestration and also the extent of degradation are not available for WPP.

**Hotter summers can lead to sun-scorch damage on trees, and drought conditions corresponding with reduced rainfall may increase the risk of fire and tree loss, especially for shallow-rooted species such as beech. This may be more prevalent in southern parts of England, and over 60% of wood pasture and parkland may experience 5.9°C hotter mean summer temperatures as predicted by RCP6.0 (
Table 21). Additionally, almost 60% is expected to have 50% less rainfall in summer (Table 22), largely influencing southern regions (Figure 17 and Figure 18).**

Warmer winters with fewer frost events may, however, increase survival rates of pests like grey squirrels and deer, impacting tree regeneration. Increased precipitation may also raise water tables, increasing the likelihood of wind throw and exacerbating tree loss and stress. In combination, these factors contribute to the expansion of pests and pathogens, potentially leading to significant losses in key tree species.

As this habitat is already heavily reliant on human management input, its resilience against climate change will also depend on adaptation of management regimes and these decisions must consider landscape and cultural values, especially for historic parklands. Potential adaptation options include reducing non-climatic pressures, protecting mature trees, ensuring tree regeneration, and developing fire management and pest outbreak plans. Careful consideration of species selection, soil type, and planting location may be important for future tree planting.

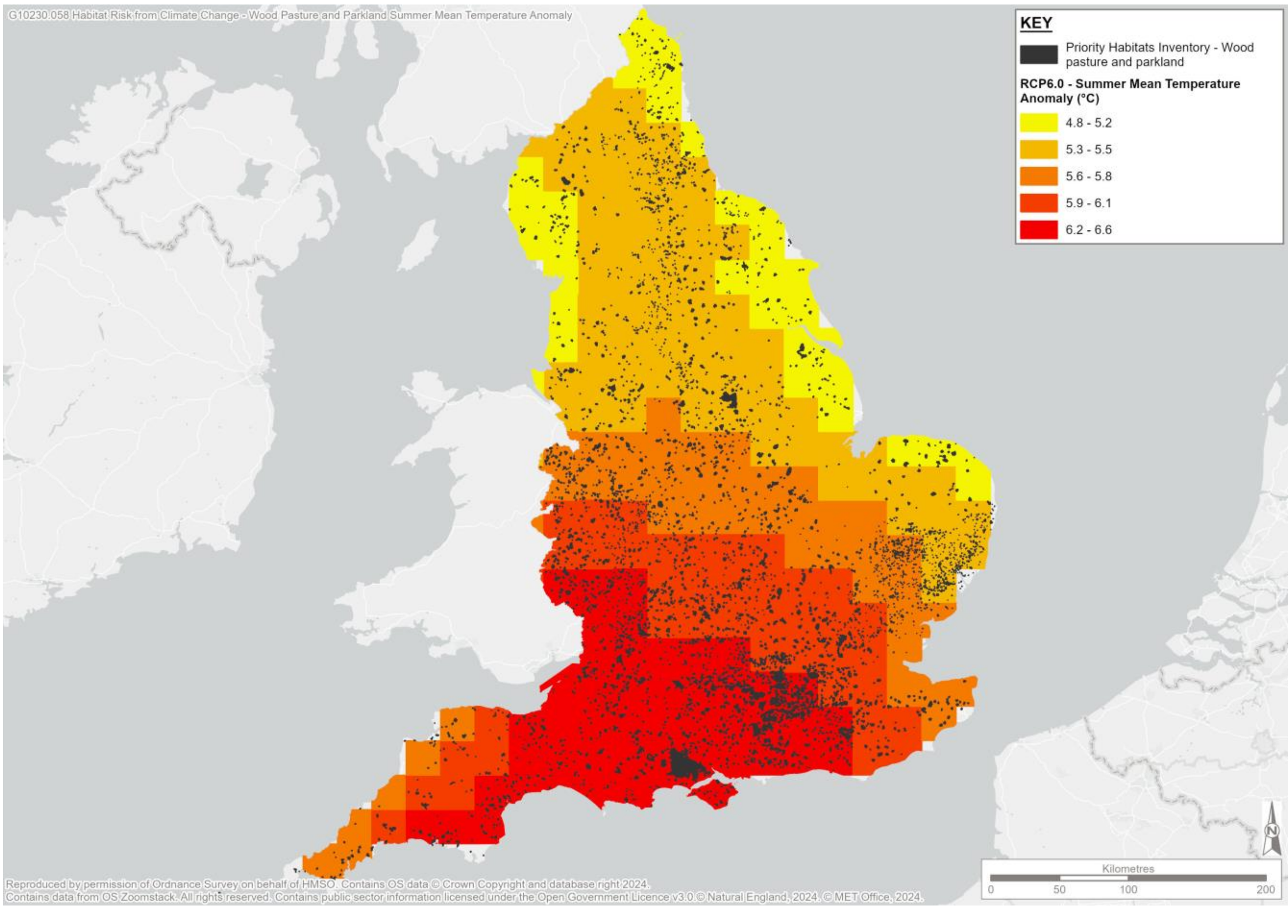

Figure 17. Location of wood pasture and parkland, showing the projected summer mean temperature anomaly (°C) highlighting regions in southwest England which may be more exposed to increased summer temperatures. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data***

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Table 21. The proportion of wood pasture and parkland within each banding of summer mean temperature anomaly (%) as highlighted in Figure 17.

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
No climate data available	0.4
4.8 - 5.2	5.9
5.3 - 5.5	18.9
5.6 - 5.8	15.1
5.9 - 6.1	24.3
6.2 - 6.6	35.3

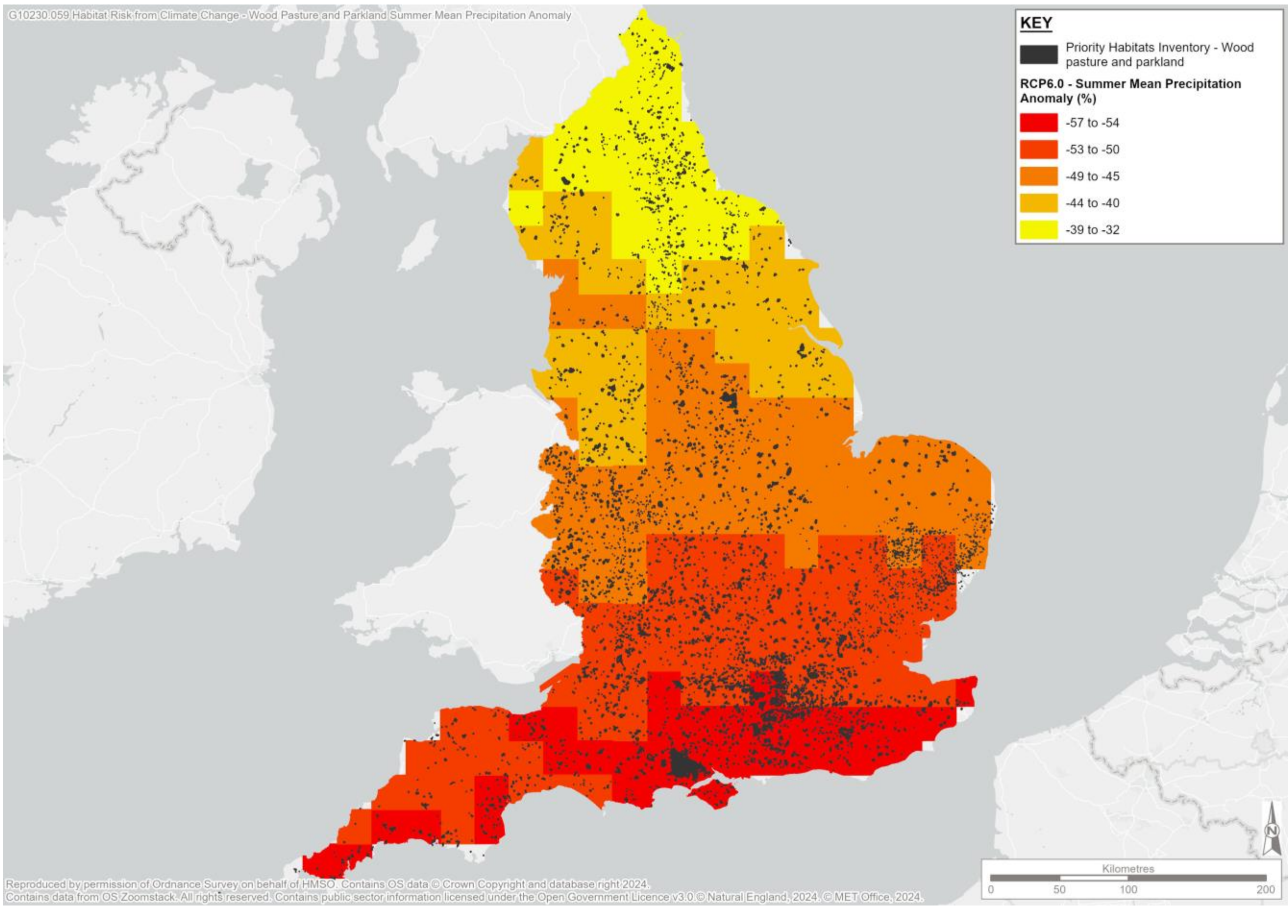

Figure 18. Location of wood pasture and parkland showing the projected summer mean precipitation anomaly (%),) highlighting regions in southwest England which may be more exposed to reduced summer rainfall. Based on RCP6.0 projection. *Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from*

Table 22. The proportion of wood pasture and parkland within each banding of summer mean precipitation anomaly (%) as highlighted in Figure 18.

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
No climate data available	0.4
-32 to -39	6.6
-40 to -44	8.9
-45 to -49	25.4
-50 to -53	36.3
-54 to -57	22.3

Lowland heathland

Lowland heathland is often found on acidic mineral and shallow peat soils, and is a broadly open landscape typified by heather and gorse cover. It exists as a result of prehistoric woodland clearance on these naturally less densely wooded areas and is kept open by burning, cutting and grazing, and represents a reasonably large carbon store. Most of the remaining patches of the habitat are small. It is sensitive to climate change and in particular changes in hydrological conditions and droughts. Lowland heathland had a value of 4 for sensitivity, for both degraded and good condition habitats (see Table 2 earlier).

England has about 54,500 hectares of lowland heathland, with an estimated total carbon store of about 6 million tonnes which is about 1.2% of the carbon stored in England's priority habitats. Unfortunately due to the oxidation process it is a slight net carbon emitter, with an estimated annual flux to the atmosphere of about 3,000 tonnes CO_2 equivalent as referenced in part 1 of this report.

The influence of increased temperatures and longer growing seasons on heathland ecosystems is multifaceted. These changes may disrupt the dominance of certain plant species, potentially favouring more competitive plants over dwarf shrubs. Moreover, alterations in nutrient cycling and insect herbivory could shift the balance towards grass dominance, while the reduced window for winter management, such as controlled burning and cutting, may pose challenges for habitat maintenance. Hotter summers pose additional risks, including heightened wildfire susceptibility and habitat structural changes, which could lead to local-scale species extinctions and irreversible vegetation damage with corresponding changes to carbon sequestration. This may be more prevalent in south regions (Figure 19 and Figure 20), and over 50% of lowland heathland is expected

**to have mean summer temperatures at least 6.2°C warmer than currently as forecast in the RCP6.0 scenario, which may have major implications (
Table 23 and Table 24).**

Conversely, warmer winters may offer some benefits to certain species, yet they could also promote grass dominance and threaten remaining wet heathlands as these have been largely drained, particularly if nutrient deposition increases. Wetter winters might result in increased runoff and nitrogen deposition, altering nutrient availability and favouring competitive grasses over specialist species. Collectively, these changes present a complex challenge for heathland ecosystems, threatening typical landscapes while potentially benefiting other species.

To enhance resilience, it's crucial to address these pressures. Flexibility in site management is essential to adapt to changing climate conditions, requiring adjustments in grazing, cutting, and burning regimes. Additionally, targeted habitat restoration and creation efforts can bolster heathland networks and increase habitat connectivity.

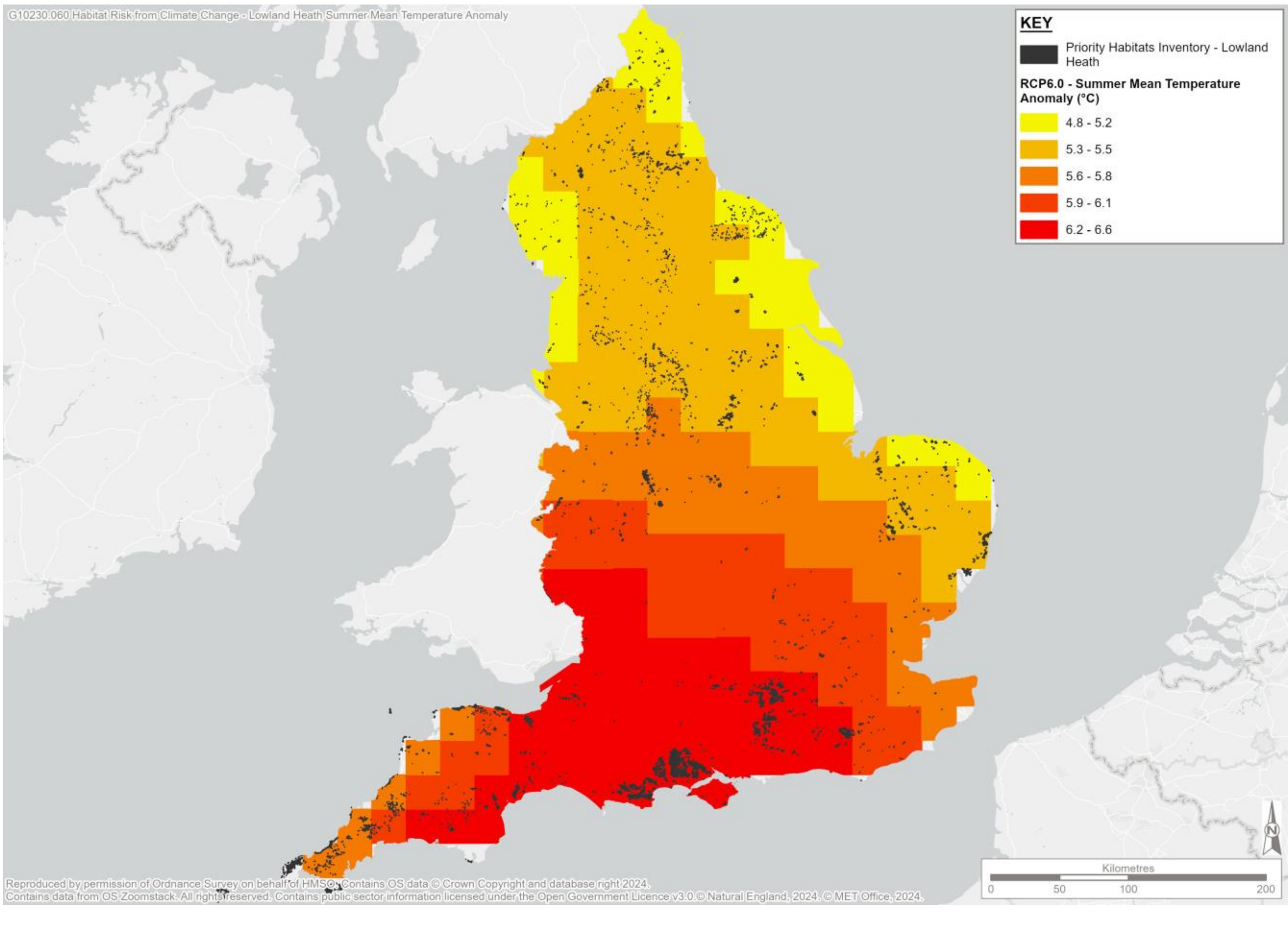

Figure 19. Location of lowland heathland, showing the projected summer mean temperature anomaly (°C) highlighting regions in southwest england which may be more exposed to increased summer temperatures. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from***

Table 23. The proportion of lowland heathland within each banding of summer mean temperature anomaly (%) as highlighted in Figure 19.

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
No climate data available	11.2
4.8 - 5.2	3.9
5.3 - 5.5	15.4
5.6 - 5.8	10.6
5.9 - 6.1	4.5
6.2 - 6.6	54.5

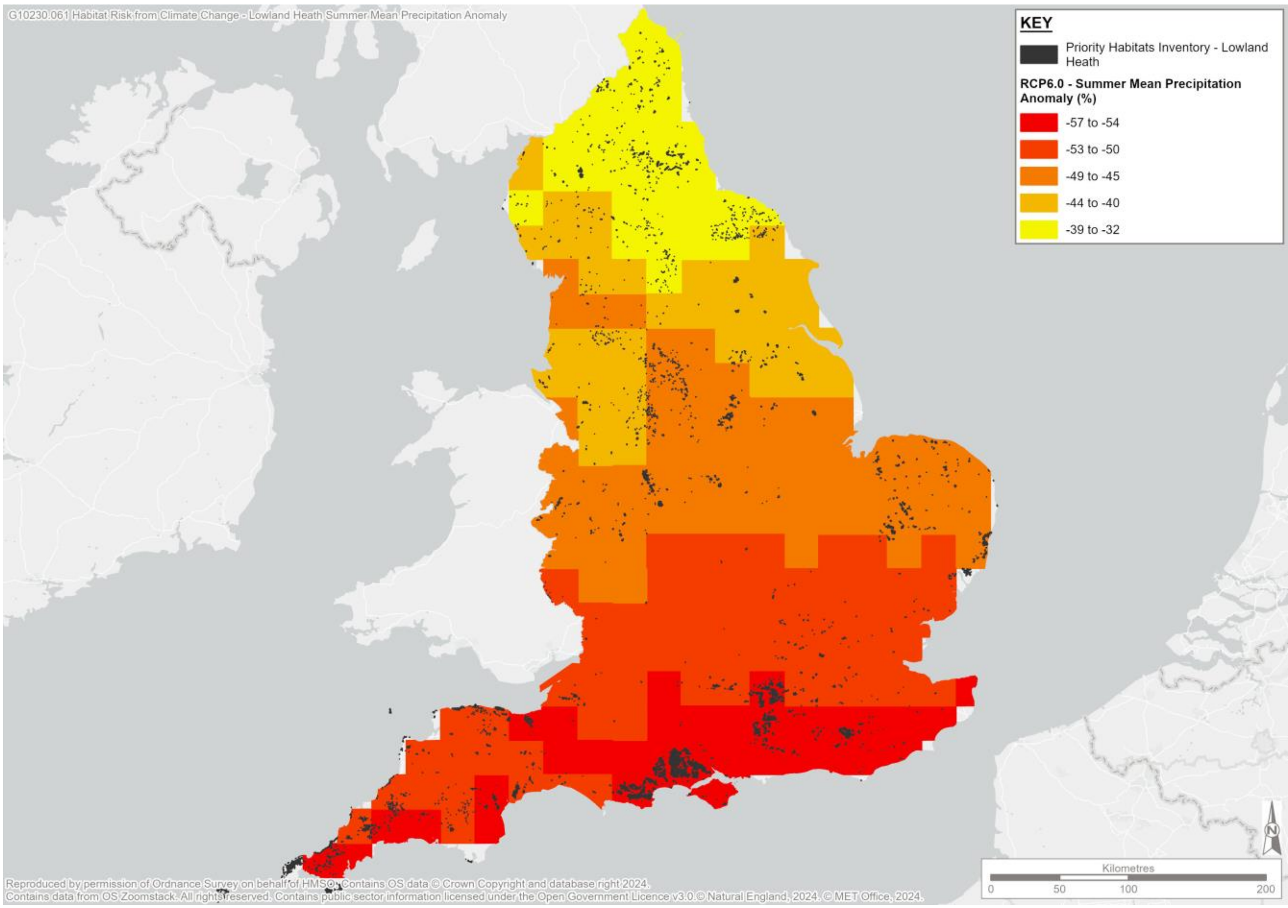

Figure 20. Location of lowland heathland, showing the projected summer mean precipitation anomaly (%),) highlighting regions in southwest England which may be more exposed to reduced summer rainfall. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from***

Table 24. The proportion of lowland heathland within each banding of summer mean precipitation anomaly (%) as highlighted in Figure 20.

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
No climate data available	11.2
-32 to -39	6.4
-40 to -44	4.0
-45 to -49	14.6
-50 to -53	12.5
-54 to -57	51.3

Coastal saltmarsh

Coastal saltmarshes lie in the upper vegetated portions of intertidal mudflats. They have diverse vegetation communities with regional variations, reflecting the age and management types that have occurred historically. Grazing may have occurred in the past, and land claim has reduced the extent such that coastal saltmarsh often lies beside arable land now. It is highly sensitive to climate change, particularly from se level rise and increased storm events, exacerbated by flood defences. As with other coastal habitats sensitive to sea level rise, coastal saltmarsh is very sensitive to climate change, with values of 5 for degraded condition and 4 for habitats in good condition (see Table 2 earlier).

England has about 36,300 hectares of coastal saltmarsh, with an estimated total carbon store of about 14 million tonnes which is about 2.8% of the carbon stored in England's priority habitats. Saltmarsh also sequesters carbon, with an estimated annual absorption from the atmosphere of about 23,000 tonnes CO_2 equivalent as referenced in part 1 of this report.

Saltmarshes face threats from rising sea levels, intensified storm events, and isostatic changes, compounded by hard sea defences hindering habitat replacement and rollback. Increased inundation and waterlogging from this sea level rise, or from increased rainfall in the winter months, may foster invasive plants and erosion, altering soil processes and community composition. This erosion may exacerbate seaward margin loss, steepening marsh profiles, and fragmenting creeks, henceforth altering habitat functionality and the ability to sequester carbon.

Hotter and drier summers, however, may increase evaporation during this season, potentially raising upper marsh salinity and causing vegetative dieback and changes to species assemblage (Figure 21, Figure 22,
Table 25,
Table 26). These combined pressures underscore the need for adaptive management and restoration efforts to safeguard saltmarsh ecosystems.

Adaptation strategies may focus on maintaining natural coastal processes that support saltmarshes, including managing sediment supply and allowing for inland migration. This may involve managed realignment projects and restoring coastal floodplains by removing artificial structures, managing recreational pressure, and minimizing surface erosion through flexible grazing management.

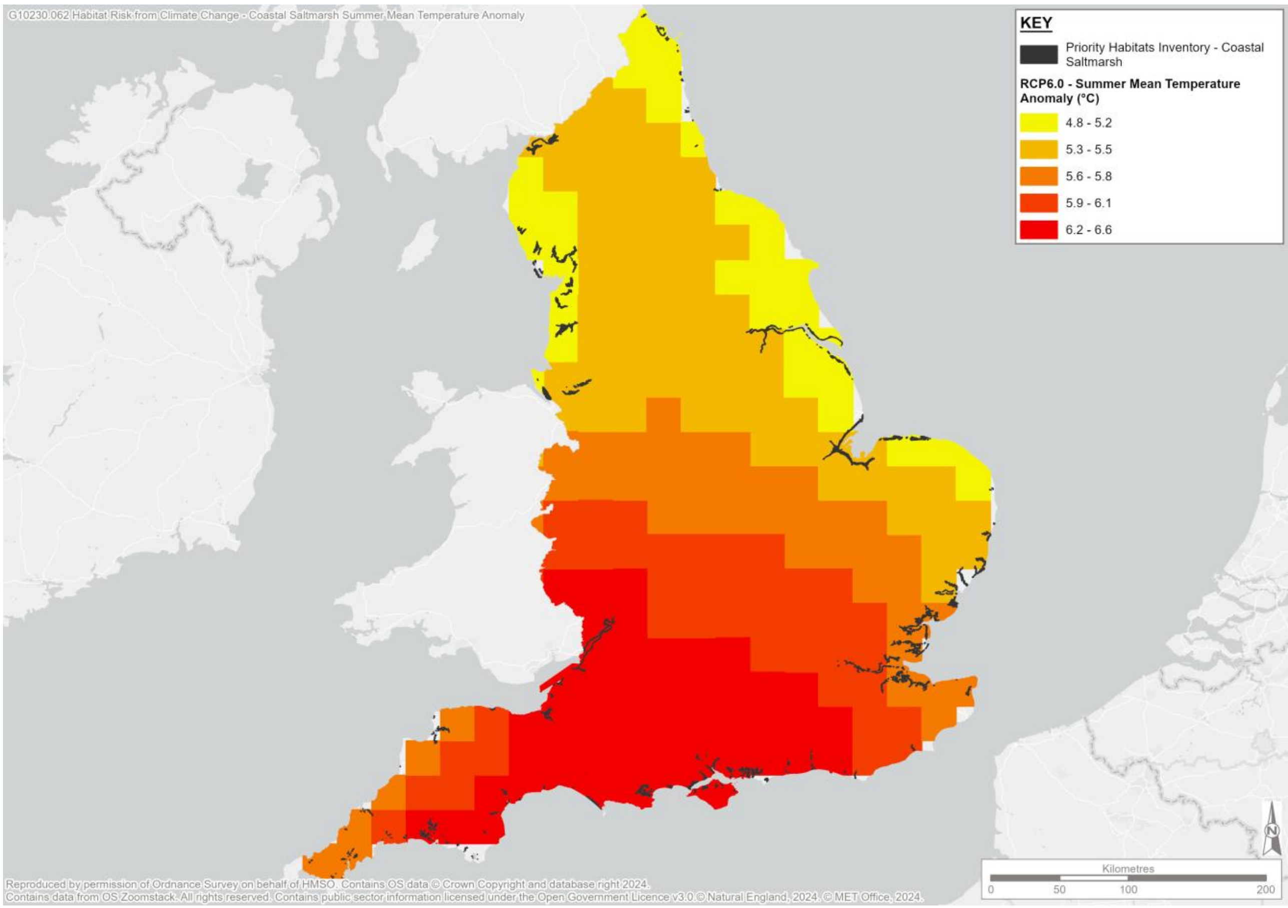

Figure 21. Location of coastal saltmarsh, showing the projected summer mean temperature anomaly (°C) highlighting the coastal spatial distribution. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector information licenced under*** **the Open Government Licence v3.0 © Natural England, 2024. © MET office, 2024.**

Table 25. The proportion of coastal saltmarsh within each banding of summer mean temperature anomaly (%) as highlighted in Figure 21.

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
No climate data available	6.1

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
4.8 - 5.2	31.9
5.3 - 5.5	35.7
5.6 - 5.8	14.6
5.9 - 6.1	1.3
6.2 - 6.6	10.5

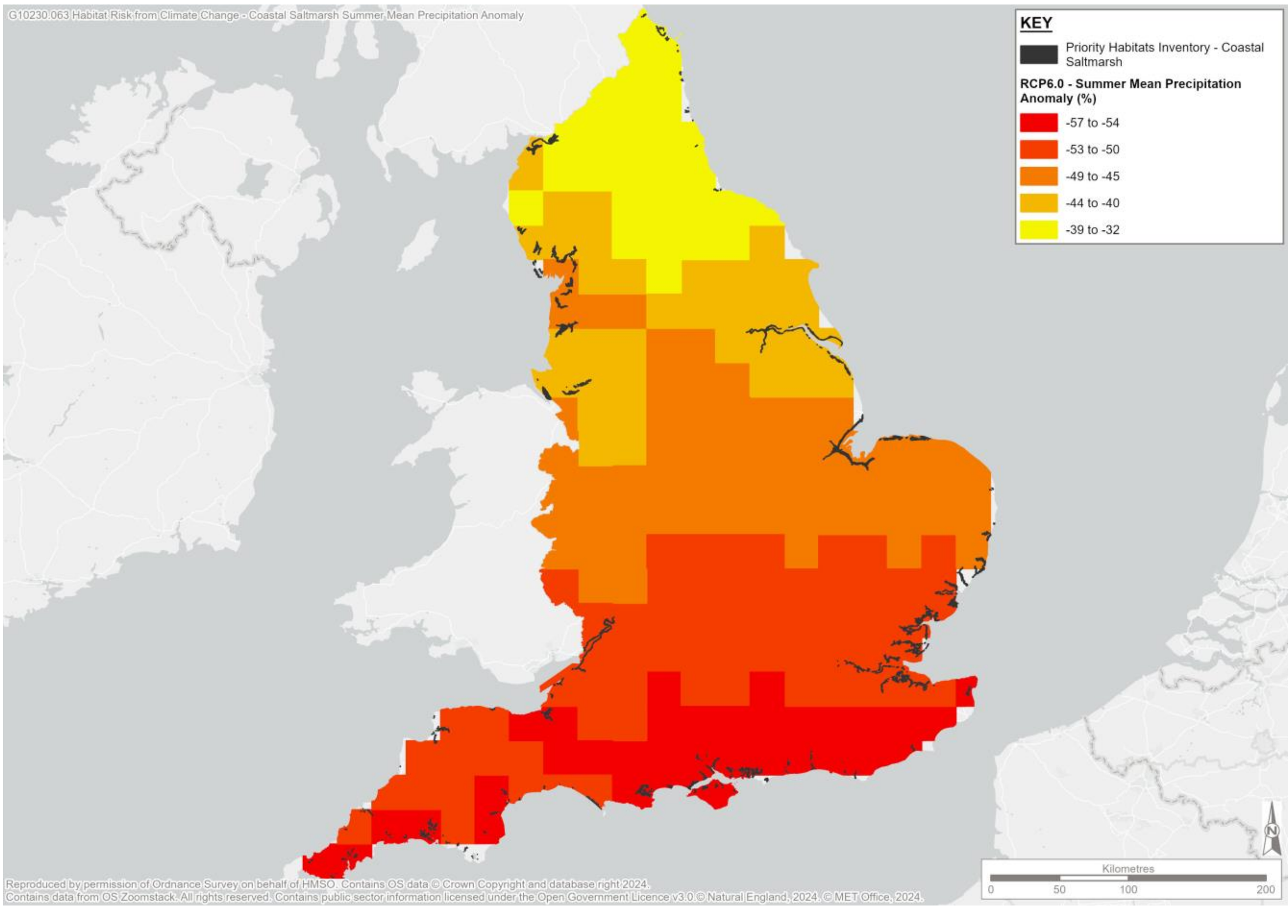

Figure 22. Location of coastal saltmarsh, showing the projected summer mean precipitation anomaly (%),) highlighting the coastal spatial distribution. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains data from OS Zoomstack. All rights reserved. Contains public sector***

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Table 26. The proportion of coastal saltmarsh within each banding of summer mean precipitation anomaly (%) as highlighted in Figure 22.

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
No climate data available	6.1
-32 to -39	5.5
-40 to -44	25.6
-45 to -49	34.9
-50 to -53	20.4
-54 to -57	7.5

Upland flushes, fens and swamps

Upland flushes, fens and swamps are found in upland areas (above the moorland enclosure line) which receive rainfall from precipitation and groundwater and are characterised by peaty or mineral waterlogged soil, with a high-water table. While small, they contribute to carbon storage and biodiversity, and are often found within a mosaic of other upland habitats. They are particularly sensitive to changes in precipitation through climate change, namely summer drought. Due to this, they are given sensitivity values of 5 for habitats in degraded condition, and 4 for those in good condition (see Table 2). Flushes may be more at risk due to water table draw down.

England has about 13,000 hectares of upland flushes, fens and swamps, with an estimated total carbon store of about 3.9 million tonnes which is 0.76% of the carbon stored in England’s priority habitats. Unfortunately, it is a net carbon emitter, with an estimated annual flux to the atmosphere of about 44,000 tonnes CO_2 equivalent as referenced in part 1 of this report.

Reduced rainfall and higher temperatures in the summer months may lead to a reduced water table and corresponding changes to water quality, influencing species assemblage the function of the habitat. These changes may also lead to oxidation of underlying peat if it is able to dry out, with corresponding release of carbon into the atmosphere. This may be more prevalent in southern regions where temperatures are expected to rise more in summer alongside decreased rainfall (Figure 23 and Figure 24), but the majority of upland flushes, fens and swamps are found in northern

regions. The majority of the habitat is expected to experience less than 5.5°C increases in summer mean temperature (
Table 27 and
Table 28) but this still may be enough to incur negative consequences for this habitat.

In winter, increased rainfall events, and storm events in particular, may also lead to landslips and erosion within the vicinity of upland flushes, fens and swamps, with possible loss of certain areas.

Where adaptation is concerned, the locality of the habitats must be considered. Sitting within wider habitats, their management is contingent on adjacent land use and as such should be considered within a part of the wider landscape. Management adaptation may include the restoration of hydrological function, management of livestock pressures and the minimisation of scrub encroachment where soils have dried out.

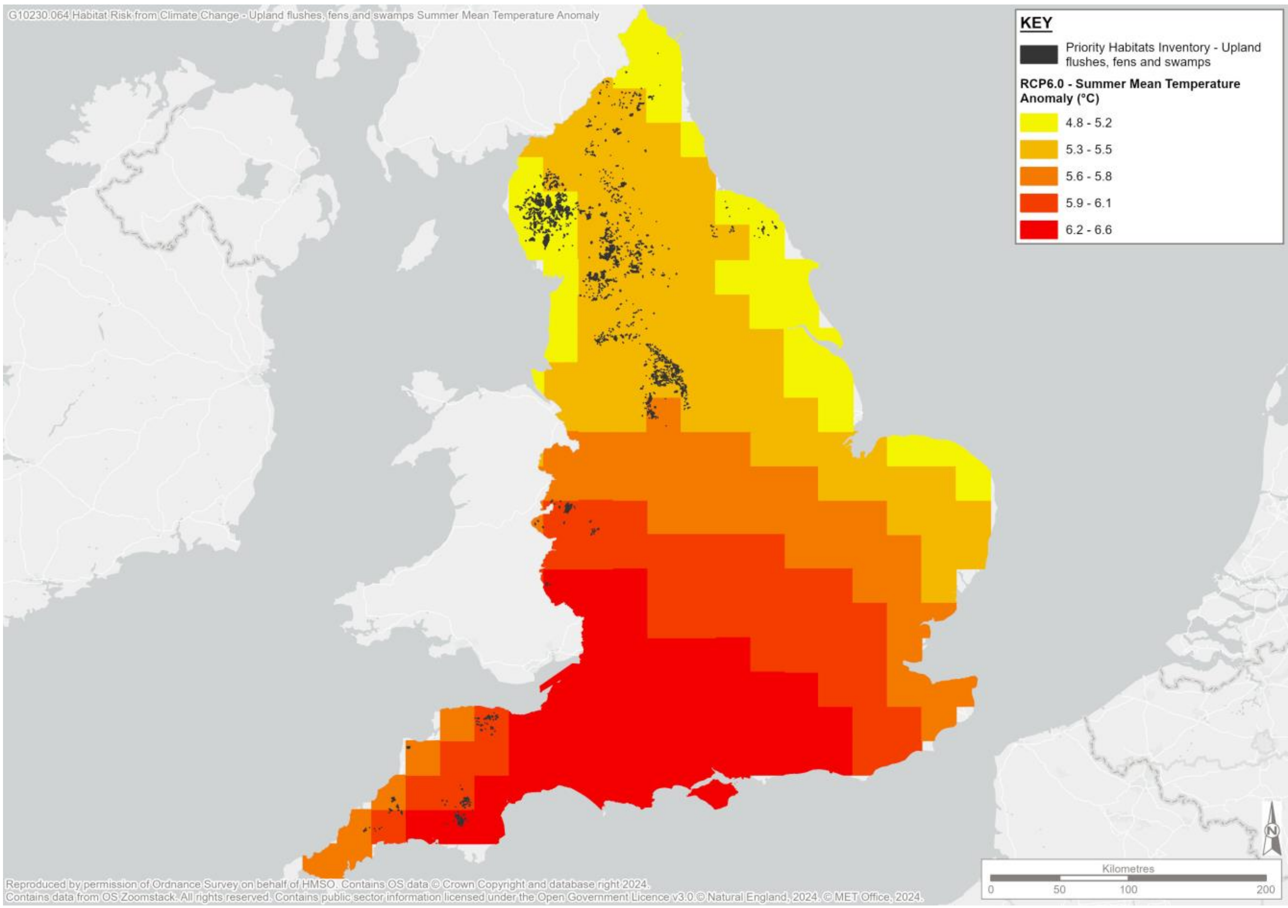

Figure 23. Location of upland flushes, fens and swamps, showing the projected summer mean temperature anomaly (°C) highlighting regions in southwest England which may be more exposed to increased summer temperatures. Based on RCP6.0 projection. ***Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024.***

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Table 27. The proportion of upland flushes. Fens and swamps within each banding of summer mean temperature anomaly (%) as highlighted in Figure 23.

RCP6.0 - Summer Mean Temperature Anomaly (°C)	%Area
No climate data available	0.0
4.8 - 5.2	46.3
5.3 - 5.5	39.6
5.6 - 5.8	3.3
5.9 - 6.1	5.2
6.2 - 6.6	5.6

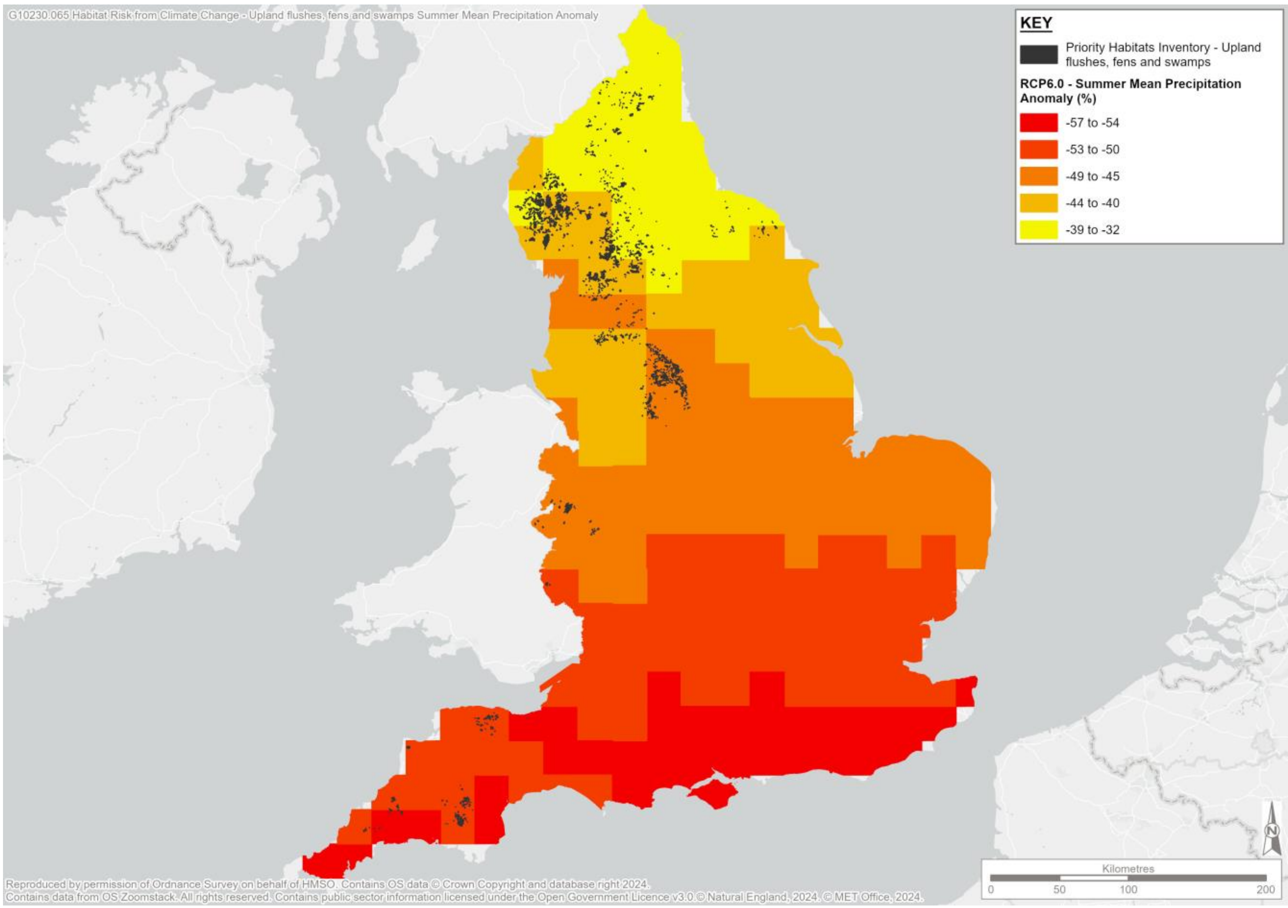

Figure 24. Location of upland flushes, fens and swamps, showing the projected summer mean precipitation anomaly (%),) highlighting regions in southwest England which may be more exposed to reduced summer rainfall. Based on RCP6.0 projection. *Reproduced by permission of Ordnance Survey on behalf of HMSO. Contains OS data © Crown Copyright and database right 2024. Contains*

Table 28. The proportion of upland flushes, fens and swamps within each banding of summer mean precipitation anomaly (%) as highlighted in Figure 24.

Summer Mean Precipitation Anomaly (%) for RCP6.0	%Area
No climate data available	0.0
-32 to -39	23.3
-40 to -44	55.6
-45 to -49	10.5
-50 to -53	9.6
-54 to -57	0.9

6. Reducing vulnerability of habitats

Habitats may be able to absorb or adapt to climate change. In terms of carbon, this 'adaptive capacity' may reduce the adverse effect of climate change on a habitat's capacity to sequester and store carbon. Adaptive capacity is highly habitat and location dependent. Consequently, each habitat needs bespoke consideration and review of management practices to improve its resilience and its adaptive capacity.

Potential adaptation options for individual habitats are provided in the Climate Change Adaptation Manual (Natural England and RSPB, 2020).

A number of widely-applicable measures are listed, which will improve the adaptive capacity of habitats at a landscape scale. Whilst these measures are primarily targeted at biodiversity, the same approaches will often safeguard carbon stores and/or reduce emissions from high-carbon habitats.

- Increasing habitat quality and condition: habitat condition is a major factor when considering the adaptive capacity of a habitat. Habitats in degraded condition are much less likely to be able to adapt to the pressures of climate change and cope with more extreme events. Table 2 summarises the climate sensitivity of habitats in good and degraded condition. In many cases, improvements to habitat condition and ecosystem processes will improve resilience, for example blocking artificial drainage features helps retain high water tables in blanket bogs, and restore ecosystem functioning.

- Increasing patch size: habitat fragmentation lowers the resilience of a habitat. By increasing the patch size of habitats and increasing connectivity, a network of habitats can be built to improve resilience to climate change.

The concept of nature (recovery) networks is the idea that co-ordinating these approaches at a landscape scale and enabling land and habitat managers to work across ownership boundaries will bring strategic gains for nature – “the whole being greater than the sum of the parts”.

Nature Networks are thus also a key part of reducing the vulnerability of wildlife and habitats to the impacts of climate change (Crick et al, 2020). Working at this larger ecosystem or landscape scale help to facilitate restoration of wider ecological processes as well as buffering sites from human pressures and nutrient enrichment.

Habitat expansion to provide climate change mitigation and adaptation

Adaptation is about tackling the vulnerabilities and risks climate change brings and making the most of any opportunities. (Natural England and RSPB, 2020).

Increasing the area of the semi-natural habitats in England, particularly of carbon-rich habitats such as peatland and woodland, can provide climate change adaptation benefits alongside biodiversity and social benefits.

The potential climate change mitigation and adaptation roles for a range of habitats are provided in Table 29 In this context mitigation means reducing the sources of, or enhancing the sinks of carbon, and adaptation describes ways of dealing with the effects.

Other less extensive habitats such as hedgerows, scrub and use of agro-forestry can provide similar climate change adaptation benefits.

Many of the England’s habitats however are small and fragmented (Lawton et al., 2010), particularly in the lowlands, and are not functionally connected. Filling in the gaps in between these habitats through habitat expansion will connect ecosystem processes across a larger area and provide carbon storage and sequestration benefits. Significant areas of land for habitat expansion in England are identified in Part 3 of this project.

To achieve good habitat restoration, there is incentive to undo much of the damage to the ecosystem pathways in order to allow the biological aspects the opportunity to recover once again. Carbon is a good marker for the ecosystem boundaries that used to exist historically and need restoration.

Allowing the space for more natural processes increases dynamism and heterogeneity of habitats across an area or zone which will give species more niches to adapt to a warming world.

On peatland habitats, restoration work should be undertaken at the peat body scale. Often the habitat is just a remnant patch in the centre of a larger body of degraded peatland. Restoration and expansion of this surrounding area will help the peat body function much more effectively. It allows complete hydrological restoration by raising the water table without impacting on the surrounding (farm) land making the peatland much more robust and resilient to future climate impacts.

Part 3 of this Nature Net Zero project examines the potential for enhancement and functional restoration of peatland habitats. For example, the geographical scope for expansion and restoration of blanket bog is quantified and mapped.

Table 29. Potential climate change mitigation and adaption roles of habitats (from Stafford and others 2021)

Habitat	Climate change mitigation role	Climate change adaptation role
Peatland	Healthy peatlands have a net cooling effect on the climate, contributing to the Net Zero by 2050 target. Degrading peatlands release carbon into the atmosphere. Peatlands in England emit approximately 10 million tonnes carbon dioxide equivalent per year (BEIS, 2021).	Peatland in good condition can help slow water flow during storm events. Restoration reduces peatland vulnerability to climate change.
Woodlands	Woodland covers 10 per cent of England's area, and 77% is broadleaved. Deciduous woodlands store 231mt C. There is scope to increase this with planting the 'right tree in the right place'.	Woodlands can provide adaptation through reducing flood risk and provide shade and cooling. Expansion of native woodland around existing woodland will increase robustness to climate change.
Grassland	Grassland soils can absorb and filter water, cycle nutrients and store carbon (particularly in the uplands).	Extensive management of grassland can increase water filtration rates and reduce flood risk.
Heathland	Soil conservation and minimal disturbance is the best mitigation tool as most of the carbon in heathlands is within the soil.	Appropriate management of heathland can assist with conserving soil, reducing the impact of flooding and wildfires
Saltmarsh	Expansion of saltmarsh habitats can provide sequestration and burial of carbon in saltmarsh sediment.	Saltmarsh provides a natural form of coastal protection from sea-level rise and storms.
Wetlands	The limited data available indicates large mitigation potential but there is uncertainty. When functioning naturally, freshwater habitats and floodplains mostly function as carbon sinks.	Re-naturalisation of watercourses and wetland restoration can provide natural flood management. Planting trees to shade and cool rivers helps protect biodiversity, and the extension of riparian forests into headwater streams can create thermal refuges and moderate temperature changes.

Many floodplain habitats are small and isolated from the river system. The hydrological processes that were once present have been interrupted and many of the floodplain topography has been homogenised through drainage and ploughing. This means microclimates and natural variation is much reduced, which are the conditions that lead to for more resilient conditions in a changing climate. It allows far more ecotones and hydrological gradients to be present allowing species the ability to move over very short distances as the habitat dries out or gets wetter in the changing conditions our altering seasons will inflect upon them.

Biotic aspects of wetlands are also very controlled by the ecosystem processes that underpin them. Therefore, the type of groundwater or amount of through flow will influence the types of plants that can gain a competitive advantage by being able to thrive in the conditions created.

At one time floodplains would have been much richer in different and varied vegetation communities from wet woodland to reedbeds, tall and short fen types, ponds and scrapes along with flushes and seepage lines all responding to the much greater natural variation in topographical heterogeneity. These variation in the biological responses by plant species leads to much greater variation in microclimate and conditions that many more insects and animals can exploit and use to aid their life cycle and would allow greater possibility for variation to climate responses in different conditions that they experience at different times of the year.

Landscape types for climate change adaptation

High-quality and distinctive resilient landscapes are required to enable habitats to adapt to climate change. Resilience can be addressed at different spatial scales, which may allow for increased climatic vulnerability in particular places, provided suitable habitats are available elsewhere within a larger, functionally connected, surrounding area forming part of wider ecological networks or nature networks.

Raised bog habitat are often the central remnant of a larger peat body ecosystem. Restoration of a functioning whole peat body with associated wetland lagg fen habitats will help to give back the control to nature, to adjust to future climate and grow and adjust to changing drier summers and wetter winters. Often we also need to buffer these sites and the input slopes to allow a zone of lower nutrients to protect biodiversity that requires low nutrient environments.

The majority of rivers in England have been straightened, through bank modification to allow water to speed up down the catchment. This has also led to a major disconnect from the river to the floodplain which would have been much more integrated working jointly in tandem to adjust and support changing conditions. Making space for natural river systems will allow both society to gain through greater retention of water in dryer summers and alleviation of the greater flood events by slowing the flow of water downstream by allowing the floodplain to once again flood in more locations. Less intensive management can also increase the potential for carbon to be stored in floodplains in their deep alluvial soils.

Blanket bogs have been drying out through the addition of drainage over centuries. Many upland water courses have been deepened over time. Much peat cutting for fuel has also occurred effecting hydrology and drying out areas above. Grip blocking in the 2nd part of the 20th century has drained large areas of our upland landscapes. Burning of these areas converted blanket bog vegetation in to an artificial and much dryer heathland vegetation, reducing their ability to hold water and naturally breath in higher rainfall periods in winter and retain water for longer through dryer summer periods.

Many woodlands are fragmented in the landscape and the woodland microclimates become very effected by an edge effect which can have an influence well over 100m into a woodland landscape. Fragmentation of deciduous woodland areas can be reduced and remain more resilient by creating larger sites and buffer ancient woodland sites with new native planting or natural regeneration.

Saltmarsh and coastal wetlands providing relief against coastal flooding and storm surges but are also at threat from rising sea levels and are not being able to rollback inland as this happens due to the presence of hard defences. Adaptive approaches will need to adopted including a reduction in the extent of hard defences to allow a more natural coastline to be restored and support biodiversity through this change.

Approaches to habitat restoration to deliver climate change adaptation

Resist, Approach or Direct – the RAD Framework

The RAD Framework (resist, accept, direct) offers a structured approach for decision-making regarding management objectives amidst ecological shifts caused by climate change. Given the uncertainties inherent in climate change, the framework presents three main approaches—resist, accept, and direct—to effectively manage climate-related risk and deliver climate change adaptation for high-carbon habitats. The framework is articulated by Schuurman and others (2020).

In the ‘resist’ approach, efforts are made to uphold or restore ecosystem processes, function, structure, or composition based on historical or acceptable current conditions. Strategies may include controlling the spread of both native and non-native invasive species and managing vegetation height and growth through techniques such as cutting or grazing combined with scrub management.

Alternatively, the ‘accept’ approach acknowledges the inevitability of change within ecosystems due to climate shifts, refraining from intervening to alter their natural trajectory. Actions under this approach may involve redesignating sites based on the arrival of new species or habitat changes and potentially relocating species to more suitable climatic locations.

The ‘direct’ approach actively guides ecosystem processes, allowing better function, structure, or composition toward desired new conditions. This may include measures like expanding the size, number, and connectivity of habitat patches, allowing a wider zone for natural process, extending monitored features beyond existing boundaries, and adjusting water levels on-site to foster new habitat and species assemblages.

Nature-Based Solutions (NbS)

Working alongside the RAD framework, nature based solutions (NbS) are increasingly recognised as an approach to mitigating against, and adapting to climate change, and also delivering nature recovery.

The IUCN define NbS as “actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits” (Cohen-Shacham et. al., 2016).

Climate change adaptation can be achieved via NbS through improving the management and condition of existing priority habitats, and habitat restoration such as those outlined in Table 29 above. These may be combined as a nature network, a collection of high-quality and well-connected areas that allow wildlife to thrive and cope with climate change, as well as enhancing natural beauty and delivering benefits for people such as flood alleviation (Natural England, 2020).

The development of nature networks is an important form of NbS to help nature and human society adapt to a changing climate (Crick et al. 2020). However climate change also needs to be taken into account in developing networks:

- Building resilience through creating better, bigger, more and joined up areas for wildlife and through restoring natural processes is an essential starting point for reducing the risks from climate change. Targeted habitat creation and restoration can also be used to reduce specific climate change threats, for example through the reduction of the susceptibility of wildlife areas to drought.
- Enhancing a more natural hydrological regime in a landscape promotes resilience to both droughts and floods, by increasing water storage as a buffer against drought and allowing water courses and habitats to adapt naturally to fluctuating water levels.
- Maintaining coastal habitats despite rising sea levels depends on allowing the shoreline to shift and new habitat to form inland to compensate for areas which are lost to the sea. Ensuring that coastal habitats have the space to migrate inland naturally or through managed realignment is vital for the resilience of coastal networks.
- Locations with topographic heterogeneity and structural complexity provide a range of microclimates so species will be able to persist and adapt to changes, both through the variation in seasonal events and longer term changes to the microclimate.
- Some areas support the persistence of species that would otherwise be lost as a result of climate change. These are often areas which are locally cool as a result of

their altitude, aspect or location close to the coast. Recognising and protecting these climate 'refugia' areas within nature networks increases the chances of maintaining species in a landscape.

- Larger and less fragmented wildlife sites can improve the resilience to fluctuating weather conditions and extreme events.
- Increasing connectivity will allow some species to spread across the landscape and colonise new areas that may be more suitable for them in a changing climate. This is most likely to benefit species of intermediate dispersal capacity. However, it should be noted that this may, in some cases, increase risks from invasive non-native species, pests and diseases.
- Some change is inevitable even with resilient ecosystems and nature networks and it is important to ensure that conservation planning takes account of inevitable change and manages for best outcomes in changed and potentially unpredictable circumstances. This includes adjusting conservation objectives for sites to reflect changing environmental suitability.

7. Recommendations & Conclusions

Semi-natural habitats in England have the potential to store and sequester large amounts of carbon, helping to mitigate climate change and contribute to goals to achieve net-zero emissions. The 10 habitats with the highest quantity of stored carbon are listed below:

- Blanket Bog
- Deciduous Woodland
- Upland Heathland
- Coastal and Floodplain Grazing Marsh
- Lowland Raised Bog
- Lowland Fens
- Wood pasture and parkland
- Lowland heathland
- Coastal saltmarsh
- Upland flushes, fens and swamps

These habitats all provide the opportunity to continue storing carbon from the atmosphere, with the possibility of expanding and improving their condition to store more carbon into the future.

However, while these habitats are able to store carbon now, climate change is putting pressure on them and influences their ability to sequester and store more carbon. Most of the habitats listed above are recognised as being very or highly sensitive to adverse effects of climate change, particularly when in degraded condition. Deciduous woodland and wood pasture and parkland are less sensitive, and particularly when in good condition, are significant in carbon sequestration.

Hotter and drier summers may increase the chances of summer drought, resulting in habitat degradation and loss, with possible release of carbon through peat oxidation and tree death. The extreme summer heat and drought anomalies are most pronounced for habitats in south-central England. For example upland blanket bogs, upland heathland and upland flushes, fens and swamps on Bodmin Moor, Dartmoor and Exmoor are projected to experience a 50% reduction in summer rainfall by the 2080s (based on the RCP6.0 projection). This is likely to cause hazards such as wild fire and erosion resulting in loss of carbon in store. Their counterpart upland habitats in northern England, which represent over 90% of the English extent of blanket bog, will experience less change in this period.

Additionally, warmer and wetter winters may cause flooding and change species assemblage, as well as increasing the prevalence of pests and again putting pressures on habitats.

Thus each habitat and each site should be considered on a site-specific basis; considering their ability not only to mitigate climate change through carbon sequestration and storage, but also through their adaptive capacity and the pressures that climate change may put on them which may compromise their ability to function in the future.

Where there are plans to manage habitats to sequester carbon, there should also be consideration of the location of the habitat and the possible risks it may face in order to future-proof any habitat restoration. Higher risk areas may need intervention sooner and through a more directed bold approach to restoration away from the present management system.

The Resist, Accept, Direct Framework offers a way for policy-makers and site managers to consider particular courses of action and prioritisation of funding. For example, in the case of the southwestern blanket bogs most vulnerable to loss of carbon store, a ‘resist’ approach would prioritise rapid landscape-scale action to bring the habitats into good condition and manage hydrology so that winter rainfall was retained in the bogs for as long as possible to mitigate the effect of summer droughts.

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Glossary

Term	Definition
Adaptation	A change in natural or human systems in response to the impacts of climate change. These changes moderate harm or exploit beneficial opportunities and can be in response to actual or expected impacts.
Adaptive capacity	The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, take advantage of opportunities, or cope with the consequences. Adaptive capacity can be an inherent property of the system, i.e., it can be a spontaneous or autonomous response. Alternatively, adaptive capacity may depend upon policy, planning and design decisions carried out in response to, or in anticipation of, changes in climatic conditions.
Climate change scenario	A plausible description of the change in climate by a certain time in the future. These scenarios are developed using models of the Earth's climate, which are based upon scientific understanding of the way that the land, ocean and atmosphere interact and their responses to factors that can influence climate in the future, such as greenhouse gas emissions.
Climate variable	Surface variables such as temperature, precipitation, and wind.
Climate Hazard	The potential occurrence of a climatic or weather event or climatic trend that may cause impacts to exposed features such as damage, death or changes in condition.
Climate Risk	The potential for adverse consequences where something of value is at stake and

Term	Definition
	where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard. Risk results from the interaction of vulnerability (of the affected feature), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence.
Climate Impact	In the context of climate change, an effect of climate change on the environment. This may be detrimental or beneficial and may be either as a direct consequence of climate change, or as a result of a human response to climate change.
Exposure	The presence of a feature in places and settings that could be adversely affected by a climate hazard.
High-carbon habitat	A habitat with the potential to sequester and store large amounts of carbon.
Mitigation (of climate change)	A human intervention to reduce emissions (such as those resulting from burning fossil fuels) or enhance the sinks (such as forests and soil) of greenhouse gases.
Priority Habitat	Priority habitats cover a wide range of semi-natural habitat types, and were those that were identified as being the most threatened and requiring conservation action under the UK Biodiversity Action Plan (UK BAP).
Projection	A plausible description of the future and the pathway that leads to it. Projections are not predictions. Projections include assumptions, for example, on future socio-economic and technological developments,

Term	Definition
	which might or might not happen. They therefore come with some uncertainties.
Representative concentration pathway (RCP)	Representative Concentration Pathways (RCPs) outline four distinct trajectories for greenhouse gas (GHG) emissions, atmospheric concentrations, air pollutant emissions, and land-use throughout the 21st century. These pathways encompass a stringent mitigation plan (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0), and one scenario characterized by very high GHG emissions (RCP8.5). Baseline scenarios, which do not involve additional efforts to limit emissions, fall within the range of pathways between RCP6.0 and RCP8.5. RCP2.6 represents a scenario where global warming is limited to below 2°C above pre-industrial levels.
Resilience	The ability of a social or ecological system to absorb disturbances while retaining the same basic ways of functioning, and a capacity to adapt to stress and change.
Sensitivity	The degree to which a system is affected, either adversely or beneficially, by climate variability or change.
Vulnerability	In this context, the degree to which an individual, environmental feature or a system is susceptible to the adverse effects of climate change. Vulnerability is influenced by the system's sensitivity and its adaptive capacity, as well as the magnitude of the change.

Appendices 1 & 2

See separate document for Part 2- Climate Risk to Carbon in Habitats - Appendices 1 & 2

Appendix 1: Climate Change Exposure Scenarios

Maps of Spatial distribution over 3 climate change scenarios. It uses three Representative Concentration Pathways (RCP) scenarios: RCP 2.6 (+1.6°C), RCP 6.0 (+2.8°C), and RCP 8.5 (+4.3°C).

1. Summer mean temperature anomaly for England for three climate change scenarios (RCP2.6, RCP6.0 & RCP8.5)
2. Summer maximum temperature anomaly for England for three climate change scenarios (RCP2.6, RCP6.0 & RCP8.5)
3. Summer mean precipitation anomaly for England for three climate change scenarios (RCP2.6, RCP6.0 & RCP8.5)
4. Winter mean temperature anomaly for England for three climate change scenarios (RCP2.6, RCP6.0 & RCP8.5)
5. Winter maximum temperature anomaly for England for three climate change scenarios (RCP2.6, RCP6.0 & RCP8.5)
6. Winter mean precipitation anomaly for England for three climate change scenarios (RCP2.6, RCP6.0 & RCP8.5)

Appendix 2: Influence of Climate Change on High Carbon Habitats

Tables on Top 10 Carbon Habitats list the likely climate impact (RCP variable expected), the effect this will have on the individual habitat and some adaptation responses that will help reduce the risk to these habitats.

1. Influence of climate change on blanket bog
2. Influence of climate change on deciduous woodland
3. Influence of climate change on upland heathland
4. Influence of climate change on coastal floodplain and grazing marsh
5. Influence of climate change on lowland raised bogs
6. Influence of climate change on lowland fens
7. Influence of climate change on wood pasture and parkland
8. Influence of climate change on lowland heathland
9. Influence of climate change on coastal saltmarsh
10. Influence of climate change on upland flushes, fens and swamps

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