Committee on Climate Change

UK 2017 Climate Change Risk Assessment

UK Climate Change Risk Assessment 2017 Evidence Report

Summary for Wales

UK Climate Change Risk Assessment 2017 Evidence Report – Summary for Wales

Contents

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1. Introduction

1.1 Context

The population of Wales was 3.1 million in 2015, accounting for 5% of the total UK population. Average population density is around half that of England (excluding London), at 149 people per km^2. Density is highest in the conurbations in the south of the country, with the Cardiff metropolitan area making up over one-third of the total population (1.1 million). The centre and north-west of the country is relatively sparsely populated, with the density of some local authority areas averaging less than 50 people per km^2.

Wales has an aggregate area of 20,779 km^2 and 2,700 km of coastline. A complex geological history has made Wales a largely mountainous country. Snowdonia in the northwest has the highest mountains, with the Cambrian Mountains occupying most of the central part of the country. In the south are the Brecon Beacons and the Black Mountains. The coastal plain is narrow in the north and west of the country but wider in the south, where the Vale of Glamorgan has some of the best agricultural land. The main rivers are the River Dee, part of which forms the boundary between Wales and England, the Rivers Clwyd and Conwy, which flow northwards into Liverpool Bay and the Irish Sea. Parts of the River Severn also form the boundary between Wales and England.

Wales has a maritime climate, the predominant winds being southwesterlies and westerlies blowing in from the Atlantic Ocean. This means that the weather in Wales is in general mild, cloudy, wet and windy. The country's wide geographic variations cause localised differences in amounts of sunshine, rainfall and temperature. Rainfall in Wales varies widely, with the highest average annual totals in Snowdonia and the Brecon Beacons, and the lowest near the coast and in the east, close to the English border. Throughout Wales, the winter months are significantly wetter than the summer ones.

Wales is divided into 22 unitary authorities, which are responsible for the provision of all local government services, including education, social work, environmental and road services. Below these in some areas there are community councils. Travel routes within Wales are influenced by the topography and the mountainous nature of the country: the main rail and road routes between South and North Wales loop to the east and pass largely through England. The only motorway in Wales is the M4 from London to South Wales, entering the country over the Severn Crossing, passing close to Newport, Cardiff and Swansea. The South Wales Main Line links London Paddington with Swansea, entering Wales through the Severn Tunnel. Other main line services from the Midlands and the North of England join at Newport.

This document summarises the Wales-specific evidence included in the UK Climate Change Risk Assessment (CCRA2) Evidence Report.[1] The CCRA Evidence Report was developed at UK-wide scale involving scientists, government departments and other stakeholders from across the United Kingdom. In some areas the country-specific information is limited and readers should refer to the full Evidence Report for a more detailed analysis of each of the risks and opportunities described here. This document only includes references to sources of information that were not included in the full Evidence Report.

[1] www.theccc.org.uk/uk-climate-change-risk-assessment-2017

1.2 The CCRA method

In compiling CCRA2 the UK Government asked the ASC to consider the following question:

"Based on the latest understanding of current, and future, climate risks/opportunities, vulnerability and adaptation, what should the priorities be for the next UK National Adaptation Programme and adaptation programmes of the devolved administrations?"

To answer this question, each of the risks and opportunities identified has been assessed in a three-step urgency scoring process (see Figure WS.1 below and Chapter 2 of the Evidence Report):

1. What is the current scale of climate-related risk or opportunity, and how much action is already underway?
2. What is the potential scale of future risks and opportunities, and to what extent will planned actions or autonomous adaptation address these?
3. Would there be benefit from further action being taken in the next five years within each of the four countries of the United Kingdom?

Each assessment is based on the evidence available to the team of authors that worked on each chapter, collated through a call for evidence in early 2014, two rounds of academic peer review, and numerous stakeholder discussions that took place during the process. The available evidence has been supplemented by four research projects commissioned specifically for CCRA2, funded by the Natural Environment Research Council, the Adaptation Sub-Committee, and the Environment Agency:

- Future projections of UK flood risk (Sayers et al, 2015).
- Updated projections of water availability in the UK (HR Wallingford et al, 2015).
- An aggregate assessment of climate change impacts on the goods and services provided by the UK's natural assets (AECOM et al, 2015).
- Developing high-end (High++) climate change scenarios (Met Office et al, 2015).

The Evidence Report uses the concept of urgency to summarise the findings of the analysis and reach conclusions that meet the study's aim. One of four 'urgency categories' has been assigned to each risk or opportunity, to summarise the ASC's advice for the next round of national adaptation programmes. The urgency categories are designed to be mutually exclusive, so that each risk or opportunity falls in to a single urgency category.

Note, the 'research priority' category is reserved for those areas where in the ASC's opinion, the risks could be significant but further evidence is needed to determine the best course of action. Significant research gaps will also exist elsewhere, and these gaps have been identified within the individual chapters of the Evidence Report. But where other urgency categories have been assigned, it means the existing evidence base is judged to be sufficiently robust to recommend either more action being taken, current levels of action being sustained, or things being kept under review for now (watching brief).

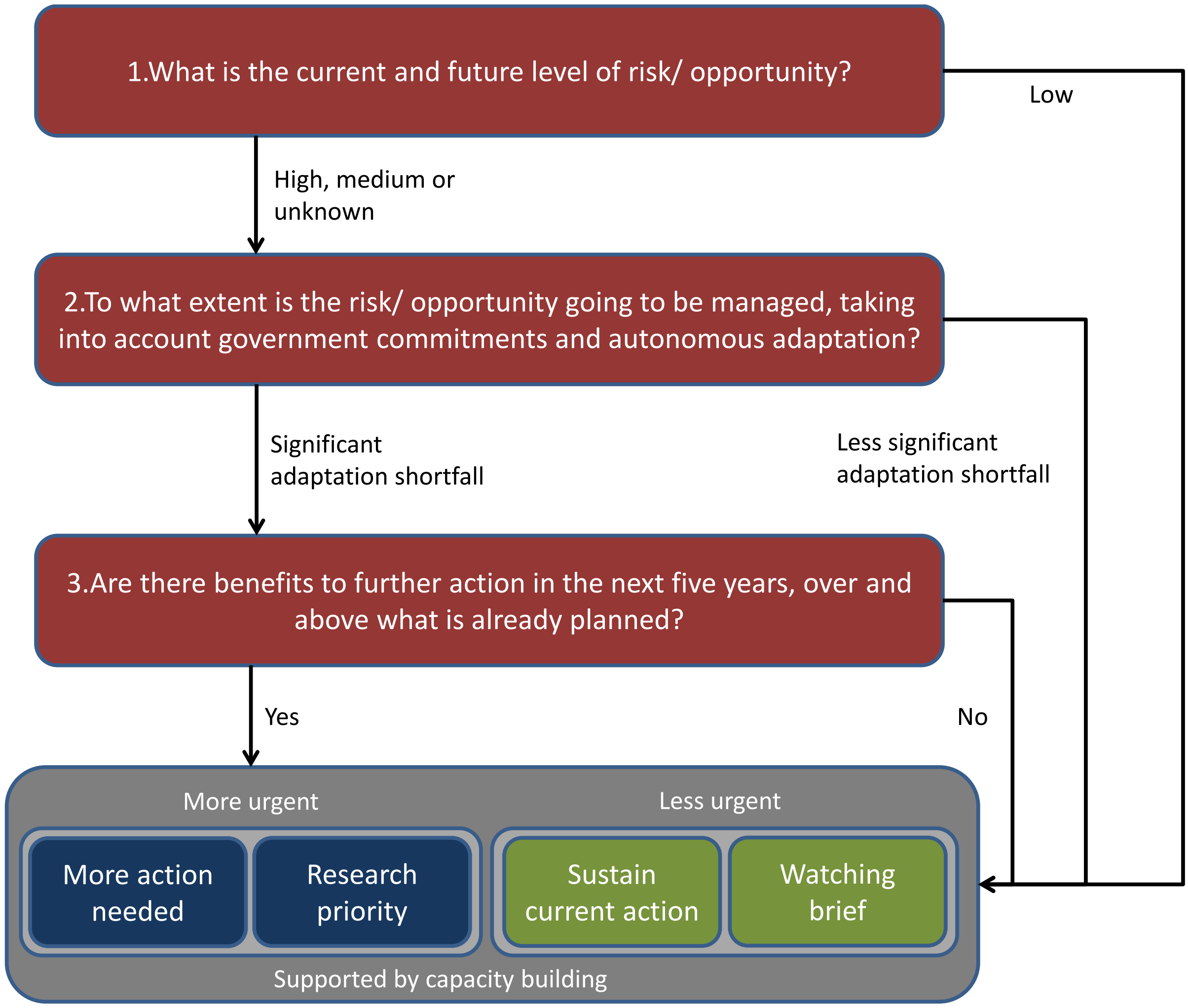
- **More action needed.** New, stronger or different Government policies or implementation activity – over and above that already planned – are needed in the next five years to reduce long-term vulnerability to climate change.

- **Research priority.** Research is needed in the next five years to fill significant evidence gaps or reduce the uncertainty in the current level of understanding in order to assess the need for additional action.
- **Sustain current action**. Current and planned levels of future activity are appropriate, but continued implementation of these policies or plans is needed to ensure that the risk is managed in the future. This includes any existing plans to increase or change the current level of activity.
- **Watching brief.** The evidence in these areas should be kept under review, with long-term monitoring of risk levels and adaptation activity so that further action can be taken if necessary.

Across all of the risks and opportunities identified, **capacity building** will be important to equip decision makers and practitioners to make timely, well-evidenced and well-resourced decisions.

When evidence on the magnitude of risk and level of adaptation being undertaken allows distinction between UK nations, separate urgency scores are presented for Wales. However, in most cases the urgency score for Wales was the same as for all UK nations or there was insufficient evidence to distinguish among countries. In these cases the urgency score for the UK is presented.

Figure WS.1. Overview of approach for urgency scoring



Source: CCRA Evidence Report, Chapter 2.

1.3 Impact of the vote to leave the European Union

The process of compiling the CCRA Evidence report was complete before the results of the EU Referendum in June 2016 were known. Leaving the European Union is unlikely to change the overall scale of current and future risks from climate change, but in some areas it may affect individual policies and programmes important to address climate-related vulnerabilities.

If such policies and programmes are changed, it will be necessary for UK measures to achieve the same or improved outcomes to avoid an increase in risk. The Adaptation Sub-Committee will consider the impact of the EU Referendum and the Government's response in its next statutory progress report on the UK National Adaptation Programme, to be published in June 2017.

2. Climate change in Wales

2.1 Observed changes

Annual average temperatures in Wales are similar to the UK average. Average temperatures over land have warmed in recent decades with the 2005 - 2014 decade 0.9°C warmer than the 1961-1990 average (Chapter 1). However, there are no significant recorded changes in number of days of air frost in Wales since 1960 (Met Office, State of UK Climate 2014). Average annual rainfall over Wales has not changed significantly since 1910.

At the UK level daily maximum and minimum temperature extremes have increased by just over 1°C since the 1950s (Brown et al., 2008), and there is some evidence that heavy seasonal and annual rainfall events have also increased (Jones et al., 2013). There has been a significant decrease in the number of heating degree days, from 2609 per year in 1961-1990 to 2387 per year in 2005 - 2014. The number of cooling degree days has not changed over this period.

Sea level trends are difficult to break down for Wales. A UK sea level index, computed using data from five stations (Aberdeen, North Shields, Sheerness, Newlyn and Liverpool), provides a UK-scale best estimate of 1.4 ± 0.2 mm/yr for sea level rise since 1901 (Woodworth et al., 2009), corrected for vertical land movement.

2.2 Projected changes

The latest set of projected changes in climate for Wales comes from the 2009 UK Climate Projections. Under a medium emissions (A1B) scenario, regional summer mean temperatures are projected to increase by between 0.9 – 4.5°C by the 2050s compared to a 1961-1990 baseline.[2]

Regional winter precipitation totals are projected to vary between -2 - to +31% for the same scenario.[3] Table WS.1 shows how extreme summer temperatures and winter rainfall are projected to change for Cardiff, compared to the other UK capital cities.

[2] http://ukclimateprojections.metoffice.gov.uk/23673?emission=medium
[3] http://ukclimateprojections.metoffice.gov.uk/23674?emission=medium

Table WS.1. Values of 20-year return period events for daily maximum surface temperature in summer (June-August), and accumulated rainfall over five consecutive days in winter (December-February)

City	Daily summer max temperature (°C)				5-day winter rainfall accumulation (mm)			
	1961-1990 Observed	2041-2060 Low	2041-2060 Central	2041-2060 High	1961-1990 Observed	2041-2060 Low	2041-2060 Central	2041-2060 High
Cardiff	31.7	31.9	34.7	38.1	73.6	76.6	79.8	83.6
Belfast	25.9	26.5	28.5	30.9	70.3	70.6	76.9	84.6
London	34.4	34.1	37.2	40.6	56.1	57.8	62.5	68.3
Edinburgh	23.5	24.8	26.2	27.9	63.4	63.5	70.0	78.4

Source: from Brown et al. (2014), CCRA2 Evidence Report, Chapter 2.
Note: For each national capital, estimated observed values for 1961-1990 are compared with values for the 10th (low), 50th (central) and 90th (high) percentiles of probabilistic projections for 2041-2060 under the A1B emissions scenario. Projections are obtained by applying the UKCP09 methodology to predict future changes in parameters controlling the properties of statistical EVD. The examples provided show cases where the results are robust to plausible variations in the methodology, based on sensitivity tests assessing the degree of consistency between the global and regional modelling components of UKCP09.

The average sea level for Cardiff is expected to increase by between 22.8 cm and 37.6 cm by 2090 compared to a 1990 baseline. Higher rates of sea level rise for the UK of up to 1.9 metres by 2100 have been modelled in a plausible high++ scenario, though this is considered highly unlikely to occur this century. However, sea levels are projected to continue to rise beyond 2100 even in lower emission scenarios and several meters of sea level rise within centuries is possible.

2.3 Climate change adaptation in Wales

The UK Government is required under the Climate Change Act (2008) to publish a UK-wide climate change risk assessment (CCRA) every five years. The Act stipulates that the Government must assess 'the risks for the United Kingdom from the current and predicted impacts of climate change'. Reports must be prepared and be submitted to the UK Parliament by the UK Government and the devolved administrations of Northern Ireland, Scotland and Wales.

Under the Climate Change Act, the Welsh Government is required to report on the objectives, actions and priorities taken to manage climate change impacts. The Welsh Government published a Climate Change Strategy in 2010 with accompanying Delivery Plan. The Welsh Government has submitted annual reports on the progress against the Strategy and Plan.

Climate change is integral to the Wellbeing of Future Generations Act (2015). The Act aims to improve the social, economic, environmental and cultural wellbeing of Wales. The Act puts in place seven wellbeing goals providing a shared vision for the public bodies listed in the Act to work towards. Climate change is at the heart of the Act and integral to all of the Wellbeing Goals. The Resilience Goal specifically highlights the need to adapt to climate change. The Act aims to make public bodies think more about the long-term, work better with people and communities and each other, look to prevent problems and take a more joined-up approach. Welsh Ministers are required to publish a Future Trends report which contains predictions of likely future trends in the economic, social, environmental and cultural wellbeing of Wales, in addition to any related analytical data and information that the Welsh Ministers consider appropriate. The evidence from this CCRA will inform the assessment. To ensure Wales is thinking about the long term and building resilience at the local level, the Act requires Public Service Boards to work together and publish a plan setting out objectives and steps to be taken to meet them, taking into account the risks identified from the Climate Change Risk Assessment.

The Environment (Wales) Act 2016 provides the legislative framework for the sustainable management of natural resources. Central to this is building resilience into natural systems and communities, in order to tackle the challenges faced now and into the future. The Act includes a provision for Natural Resources Wales (NRW) to report on the current state of natural resources, ecosystems and the benefits they provide through the publication of a State of Natural Resources Report (SoNaRR). The SoNaRR highlights the condition and extent of Wales' natural resources, their ability to respond to pressures including climate change, and their ability to provide benefits for society.

The Act also requires Welsh Ministers to prepare a National Natural Resource Policy (NNRP) which will draw on the evidence from SoNaRR to set out the priorities for the sustainable management of natural resources at a national level. It will outline how the sustainable management of Wales' natural resources will provide benefits to society and the economy as well as the environment, supporting the goals outlined in the Wellbeing of Future Generations (Wales) Act.

The priorities identified in the NNRP will be delivered at a local level through Area Statements produced by NRW. These will identify collaborative opportunities for different bodies to work together to proactively manage natural resources in a more joined up and integrated way. The Climate Change Risk Assessment National Summary for Wales will provide an important source of evidence for SoNaRR and will feed into the development of the NNRP.

3. Natural environment and natural assets

Climate change poses risks in Wales to soils, freshwater resources, natural carbon stores, marine ecosystems, farming, forestry, wildlife and habitats. More action is needed to manage these risks. More evidence is also needed to fully characterise other climate change risks that are likely to be important for the natural environment in Wales, including changes in agricultural and forestry productivity and land suitability, as well as the impacts to freshwater and marine species.

The Natural Environment and Natural Assets chapter in the CCRA Evidence Report is structured through the use of a natural capital framework. The risks and opportunities from climate change to key 'natural assets' are assessed and these are summarised, along with the urgency scores, in Table WS.2.

Table WS.2. Urgency scores for natural environment and natural assets

Risk/opportunity (reference to relevant section(s) of CCRA Evidence Report)	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
Ne1: Risks to species and habitats due to inability to respond to changing climatic conditions (3.2)	UK				More action needed to reduce existing pressures, improve condition of habitats, restore degraded ecosystems, and deliver coherent ecological networks. More action to factor climate change into conservation planning and site management
Ne2: Opportunities from new species colonisations (3.2)	UK				More action needed to deliver coherent ecological networks and to factor changes in species composition into site management.
Ne3: Risks and opportunities from changes in agricultural and forestry productivity and land suitability (3.3)		UK			More research needed on the nature and scale of changing land suitability and its impacts. More research needed into resilient trees and crop varieties or species, and cropping regimes.
Ne4: Risks to soils from increased seasonal aridity and wetness (3.3)	UK				More action needed to reduce existing pressures on soils, increase uptake of soil conservation measures and restore degraded soils.
Ne5: Risks to natural carbon stores and carbon sequestration (3.3)	UK				More action needed to restore degraded carbon stores, particularly peatlands. Ensure climate change impacts on carbon stores are accounted for in the UK GHG inventory.
Ne6: Risks to agriculture and wildlife from water scarcity and flooding s (3.4)	UK				More action needed to reduce pollution and over-abstraction and improve the ecological condition of water bodies Ensure decisions on use of water allow for necessary environmental flows and take account of climate change.

Table WS.2. Urgency scores for natural environment and natural assets

Risk/opportunity (reference to relevant section(s) of CCRA Evidence Report)	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
Ne7: Risks to freshwater species from higher water temperatures (3.4)		UK			More evidence needed on scale of risk and effectiveness of adaptation measures.
Ne8: Risks of land management practices exacerbating flood risk (3.3, 3.4)	UK				Deliver wider uptake of natural flood management in high-risk catchments especially where there are likely to be carbon storage, water quality and biodiversity benefits. Review potential for adverse flood risk outcomes from land subsidies.
Ne9: Risks to agriculture, forestry, landscapes and wildlife from pests, pathogens and invasive species (3.7)			UK		Continue to implement surveillance and bio-security measures. Continue current research efforts into the impact of climate change on long-term risks.
Ne10: Risks to agriculture, forestry, wildlife and heritage from change in frequency and/or magnitude of extreme weather and wildfire events (3.3)			UK		Continue to build resilience of ecosystems to drought, flood and fire Continue current efforts to manage and respond to wildfires. Monitor heat stress impacts on livestock. Continue current efforts to manage impacts of high winds on forestry.
Ne11: Risks to aquifers, agricultural land and habitats from saltwater intrusion (3.5)			England, Wales	Northern Ireland, Scotland	Continue actions to manage salinity risks to freshwater habitats. Monitor impacts on aquifers to assess whether risks are increasing.
Ne12: Risks to habitats and heritage in the coastal zone from sea-level rise; and loss of natural flood protection (3.5)	UK				More action needed to deliver managed realignment of coastlines and create compensatory habitat.
Ne13: Risks to and opportunities for marine species, fisheries and marine heritage from ocean acidification and higher water temperatures (3.6)		UK			More research needed to better understand magnitude of risk to marine ecosystems and heritage.
Ne14: Risks and opportunities from changes in landscape character (3.7)				UK	Monitor impacts and ensure climate change is accounted for in future landscape character assessments.

Ne1: Risks to species and habitats due to inability to respond to changing climatic condition, and Ne2: Opportunities from new species colonisations

Current and future risks/ opportunities

Throughout the UK terrestrial species appear to be shifting distributions as the climate warms. In Wales, there is evidence of species moving northwards and uphill, with new colonisations from the south. There is also strong evidence that migratory bird species are responding to changing climatic conditions as they migrate shorter distances in the non-breeding season and many have shifted north-eastwards to new feeding grounds. The observed increase in average temperatures has had generally positive effects upon terrestrial invertebrates during spring and summer. However, warmer and wetter winters have also had negative effects on moth and butterfly populations.

Shifts in the spatial range of species and changes in phenology will have implications for the ecological composition of communities and habitats, with both winners and losers. Some areas will experience local species extinctions (i.e. species that are lost from a particular geographical area but may remain present in other areas across the UK). Species at their southern range margin are at significant risk of being lost from current parts of their range, particularly those associated with cold montane habitats that are likely to see continued contraction of their range to the most northern and high-altitude locations. The scale of actual local extinctions in response to changes in climate space will be heavily dependent on the ability of individual species to physically disperse. The rates of colonisation differ markedly between species and fundamentally depend on whether there is suitable habitat conditions present for a species to spread. Species will not able to autonomously adapt if there is insufficient suitable habitat in good condition available for them to do so.

Adaptation

The Welsh Government published a Nature Recovery Plan for Wales in December 2015.[4] This sets out the commitments to biodiversity in Wales, and identifies the issues to be addressed to reverse the loss of biodiversity. It includes objectives to tackle the key pressures including climate change, particularly by increasing the resilience of the natural environment, to improve the ability of species and habitats to adapt. The Nature Recovery Plan also sets out how Wales will deliver the commitments of the UN Convention on Biological Diversity and the EU Biodiversity Strategy.

The Sustainable Management of Natural Resources and the new Biodiversity and Resilient Ecosystems Duty introduced by the Environment (Wales) Act 2016 will require taking into account the resilience of ecosystems and in particular their diversity, condition, connectivity, extent and adaptability. This has been put in place specifically to strengthen the ability of ecosystems to continue to deliver the range of services required by society now and in the future in the face of climate change and will include enhancing ecological networks. This approach will underpin the development of the National Natural Resources Policy for Wales and the delivery through Area Statements.

There has not been an assessment of the extent to which Wales's network of habitats and protected sites have the ecological coherence to be resilient to future climate change, as has

[4] http://gov.wales/topics/environmentcountryside/consmanagement/conservationbiodiversity/?lang=en

been done in England though the Lawton Review. However, there has been an assessment of the vulnerability of all protected sites and their features to climate change that in part provides a similar assessment. Furthermore, the findings of the Lawton Review have informed the objective and principles of the Sustainable Management of Natural Resources that underpin NRW's purpose and take forward the ecosystem approach in Wales, a central aspect of which is building the resilience of ecosystems.

There is currently no national strategy for identifying and safeguarding coherent ecological networks at the landscape-scale, (the need for which was highlighted by Lawton), although a variety of local initiatives are doing this and a number of these are explicitly taking account of climate change.

While the EU Nature Directives do not explicitly account for changing species distribution and migratory patterns driven by climate change, Article 4 of the Birds Directive obliges Member States to keep their network of Special Protection Areas under review to ensure they are the 'most suitable territories' in number and size. The current UK review of the SPA network (terrestrial and coastal) will take such species distribution changes into account. The European Commission has also provided Member States with guidance on climate change and the Natura 2000 sites.

Urgency score

More action needed - Further action is needed now and into the future to:

- Increase current efforts to reduce existing pressures, improve the ecological condition of protected wildlife sites, and restore degraded ecosystems, such as peatlands, wetlands and native woodlands. Ecological restoration can take many decades for some habitats, meaning that there are long lead-in times for adaptation action.
- Take more flexible and integrated approaches to managing natural capital, including further realignment of the coast, catchment-scale management strategies, and landscape- scale initiatives to increase habitat extent and improve habitat condition and connectivity.
- Bring climate and environmental change more explicitly into conservation planning at site level and at wider scales, including modifying objectives, especially towards maintaining ecosystem functions, and planning for and anticipating necessary changes in spatial distribution, for example by identifying and securing refugia. Site level conservation objectives and plans will need to be reviewed to assess whether management is appropriate for new or potential colonists. It is important that planning begins in time for action to be effective.

Ne3: Risks and opportunities from changes in agricultural and forestry productivity and land suitability

Current and future risks/ opportunities

There is good evidence that the biophysical capability of the land to support agricultural production has changed over recent decades as the climate has changed. The average length of the growing season has increased by around 60 degree-days over the 87-year period between 1914 and 2000 for Wales and England, with a substantial increase in the last decade of the 20th century. There is evidence that the trend to longer growing seasons and milder winters have provided opportunities for a shift to autumn-sown crops.

A high proportion of land in Wales is constrained in terms of its use due to climatic conditions, primarily in the uplands. Increases in temperature and solar radiation at key times of the year can have benefits for yields of some crop varieties. Grass growth also benefits from warmer conditions, but if conditions are too hot and dry there can be negative implications for productivity. Maize is more tolerant of drier conditions than grass and requires a minimum temperature higher than grass to grow effectively.

A projected trend towards warmer drier summers would increase the risk of heat stress in sensitive crops (e.g. winter wheat) and cause problems for those crops with high water demands (e.g. potatoes). At the same time, warmer drier summers and increased mean winter temperatures may be beneficial for some crops (e.g. maize which is sensitive to frost). There may also be increased potential for energy crops (e.g. miscanthus) which are currently limited by temperature. Warmer temperatures will undoubtedly be of benefit for grassland productivity, particularly in marginal upland areas that currently experience low productivity during colder conditions. In winter, the extended growing season with climate change may provide opportunities for longer outdoor grazing, but this could be counteracted if increased precipitation increases the risk of damage to swards by poaching from livestock.

The warming climate allows for a potential expansion of land used for agriculture in Wales. Many areas that are currently marginal for cultivation due to climatic limitations could experience an improvement in land capability. However, there may also be limitations to future agricultural productivity due to increased soil aridity in some locations. Overall, the area of Best and Most Versatile (Grades 1 to 3a) agricultural land in Wales and England is projected to decline from 37% currently to 7% in the 2080s (high emissions scenario) due to increased aridity and doughtiness. Over the same time period, the area of Grade 4 land is projected to increase from 2% to nearly 66%.

Other things being equal, there are likely to be increases in tree growth rates in the future, particularly in cooler and wetter areas, because of a lengthened and warmer growing season. For example, Sitka spruce growth rates may increase by up to 2.8 m^3 per hectare per year for each 1°C warming if other factors are not limiting. Models generally suggest positive changes to yield potential in western and northern areas (at least in the short to medium term). The productivity advantage of some conifer species over deciduous species may increase with warmer temperatures and higher CO_2 concentrations. However, the benefits of higher CO_2 concentrations for tree growth are not as significant on nutrient-limited soils, such as deep peat.

Adaptation

Farmers and foresters will be likely to take advantage of new opportunities autonomously, but this is likely to happen reactively and not through strategic planning.

Land use planning is mainly based upon a stationary climate and maintaining land resources in the same location (e.g. the use of BMV in the town and country planning system). There is minimal strategic planning or consideration of future land-use and the implications of changing suitability of land for agricultural production.

Autonomous adaptation is likely to occur in the selection of crop and grass varieties that are well-adapted to future environments through genetics and adaptive crop breeding. It will be necessary to ensure ready access to the necessary genetic variation through the continuing maintenance of germplasm collections. However, investment in genetics and crop breeding has a long lead time between research and large-scale field implementation.

Urgency score

More research needed - There is a need for a realistic assessment of the suitability of current agricultural and forestry systems in Wales the future given the projected changes in doughtiness and aridity. This could include reviewing the potential costs and benefits from more widespread production of 'novel' crops (e.g. grain maize, field-grown tomatoes, sunflowers, apricots, etc.). Such an assessment will provide the early steps to inform better decisions in the near future and reduce the risk of lock-in to unsustainable future pathways.

Further research to assess how changes in agricultural suitability can be better factored into land use planning decisions is also needed, so that future option values on the land are fully considered.

Ne4: Risks to soils from increased seasonal aridity and wetness

Current and future risks

Land management has to date been a more significant driver of risk to soil health than climate change. Land use is the dominant factor explaining trends in Soil Organic Carbon (SOC) losses in arable soils in England and Wales since the 1970s.

Data on soil loss by erosion in Wales are few, but estimates range from 0.02 to 1.27 t ha^{-1} yr^{-1} for mineral soils, and as much as 10 t ha^{-1} yr^{-1} in cultivated arable fields due to the exposure of bare soil. The risk of water-based soil erosion is expected to be higher with projected increases in the frequency and intensity of heavy rainfall events, but there are no Wales-only studies available. The use of waterlogged soils by heavy machinery or high livestock numbers can also increase erosion risk by causing long-term damage to soil structure. Erosion risk could be further exacerbated by changes in cropping types and cultivation practices, for example the further expansion of high-risk crops such as maize and increased cropping on marginal land, particularly slopes.

Soil erosion has implications for water quality, as sedimentation reduces levels of dissolved oxygen adversely affecting freshwater species. Increases in the frequency and intensity of heavy rainfall events will in turn increase the risk of water-based soil erosion. This risk could be further exacerbated by changes in cropping types and cultivation practices, for example the expansion of high-risk crops such as maize.

Wetland habitats, such as peat bogs and fens, are particularly sensitive to changes in the soil moisture regime. Climate change appears to be a more significant causal factor for the loss of SOC on peat soils in semi-natural habitats to date than on agricultural soils. Warmer and drier conditions could have adverse implications for the viability of already stressed peatland habitats and their species, particularly bryophytes (mosses and liverworts) (see Ne5 for further detail).

Changes in climate are also expected to affect the abundance and activity of soil microflora (e.g. bacteria, fungi and protozoans), with implications for decomposition of organic matter and hence carbon storage, nutrient cycling and fertility-related ecosystem services.

Adaptation

The 2006 Environment Strategy for Wales includes a high-level outcome that "soil is managed to safeguard its ability to support plants and animals, store carbon and provide other important ecosystem services." The Strategy proposes that changes in soil carbon will be monitored to assess progress with meeting this outcome. The Strategy is currently being reviewed in light of changes in policy since 2006, including the Environment (Wales) Act 2016 and the Welsh Government's Natural Resource Management programme.

There are a number of policy interventions that provide farmers with some incentives to conserve soils. These are primarily based on the EU Common Agricultural Policy (CAP), as farmers must provide minimum soil cover, take measures to prevent erosion, and maintain soil organic matter levels in order to qualify for the full single farm payment. However, in practice the low levels of inspection make it difficult for these requirements to be enforced. Voluntary agri-environment schemes funded under Pillar II of the CAP are also important mechanisms for encouraging soil conservation, although soil health is not a priority objective.

The on-going declines in soil carbon in croplands, increases in the area of some high erosion risk crops (e.g. maize) and the degraded condition of peatlands suggests that that the vulnerability of soils in Wales is increasing. Autonomous responses to the changing climate (e.g. cultivation of steeper slopes; expansion of maize cropping) may increase erosion risks further in the future. Current policy interventions are not sufficient to manage this risk.

Urgency score

More action needed - Further action is needed to improve the condition of degraded soils, restore peat habitats, better protect soils from damaging practices, limit soil sealing, ensure the safeguarding of BMV land and encourage the wider uptake of soil conservation. This will have a range of co- benefits for managing a wide range of climate and non-climate related risks and avoid lock-in to a pathway where Wales's most fertile and carbon-rich soils are lost at some point in the future. Many soil conservation actions are also cost-effective to implement now especially when accounting for non-market values, such as carbon and water quality. Ecological restoration can also take many decades for peat habitats, meaning that there are long lead-in times for action.

Ne5: Risks to natural carbon stores and carbon sequestration

Current and future risks/ opportunities

Carbon is naturally stored in soils and vegetation, as well as in marine and coastal habitats. Vegetation growth acts to sequester CO_2 from the atmosphere into plant tissues which can then be transferred to soil carbon through litter and humus. Soils can also be a source of CO_2 emissions through decomposition and respiration, which may be accompanied by losses of methane (mainly from wetlands) and nitrous oxide (mainly from artificial fertilisers), both powerful greenhouse gases. 'Blue carbon' is defined as the carbon stored in coastal and marine habitats and sediments. Typically, blue carbon is thought of as only being coastal, but recent studies suggest that offshore habitats around the UK are also important carbon stores. Rates of carbon sequestration are particularly high in saltmarsh and sand dunes.

The largest terrestrial carbon stocks occur in soils, particularly organic (carbon-rich) soils as exemplified by deep peat. Deep peat soils cover over 90,000 ha of Wales (4.3% of the total land area), of which 75% is in upland areas and 25% in lowland areas. Together, upland and lowland deep peat soils represent Wales' largest terrestrial store of carbon.[5] When in a pristine condition, peatlands are usually waterlogged and actively sequester carbon due to retarded

[5] Evans, C., Rawlins, B., Grebby, S., Scholefield, P., Jones, P. (2015) Glastir Monitoring & Evaluation Programme. Mapping the extent and condition of Welsh peat. Welsh Government. https://gmep.wales/resources

decomposition rates and colonisation by peat-forming species, notably *Sphagnum*. Across large parts of the UK, these conditions have been lost through human activities such as drainage for agriculture and forestry, intensive grazing, managed burning and peat extraction. Exposure of formerly waterlogged peats to the air as a result of drainage leads to peat oxidisation, converting carbon stored for millennia into CO_2, which is emitted to the atmosphere, a process directly analogous to the burning of fossil fuels.

Overall, at least three quarters of the Welsh peatland area is thought to have been impacted by one or more land-use activity, including drainage, overgrazing, management neglect, conversion to grassland and afforestation. As a result of these activities, Welsh peatlands are currently estimated to be a net source of GHG emissions, in the region of 0.4 million tonnes of CO_2-equivalent per year. This broadly equates to around 7% of annual Welsh transport-related CO_2 emissions. It is estimated that in 1990 (the baseline year for measuring GHG emissions) the majority (58%) of peatland GHG emissions derived from areas under agricultural grassland management, with a further 17% from conifer plantations, and 15% from drained or modified blanket bog in the uplands. Subsequent restoration activities and agri-environment measures since 1990 are believed to have substantially reduced emissions from upland blanket bog, but emissions from agricultural and forestry use of peatlands are thought to have remained fairly static.[6]

Woodland cover in Wales is currently 306,000 hectares (150,000 hectares of conifers and 156,000 hectares of broadleaves). In 2014, Welsh forests sequestered 1.2 $MtCO_2$. This amounts to 8% of the total CO_2 sequestered by UK forests in that year.

Climate change may have direct impacts on the ability of soils and vegetation to sequester and store carbon. A longer growing season and increased CO_2 concentrations in the atmosphere could increase sequestration rates by trees. There is some evidence of enhanced tree biomass growth in recent decades across Europe, but this may be attributable to non-climate factors (enhanced N deposition; recovery from S deposition; forest management changes).

However, higher temperatures and changes to soil moisture regimes could increase carbon losses due to enhanced soil respiration. There is some evidence that these factors could be contributing to the observed carbon losses from peatlands in Wales. In vulnerable areas (e.g. drained peatlands), higher temperatures and drier summers would be likely to substantially increase the loss of carbon, with implications for both CO_2 emissions and water quality (through higher DOC levels). Tree planting on deep peat soils would also have adverse implications for soil carbon stores, as peats have to be drained for trees to be established. Any significant expansion of intensive agricultural production to the northern and western areas of Wales in response to changing climatic conditions would also be likely to have negative implications for soil and forest carbon stocks.

Adaptation

The Wales Climate Change Strategy (2010) contains an aspiration to create 100,000 hectares of new woodland between 2010 and 2030 as a means to help Wales achieve significant levels of reduction in greenhouse gas emissions by long-term carbon sequestration. In 2014, the Welsh Government commissioned research to review the climate change target. This recommended a reduction in the target to 50,000ha of woodland creation to be delivered over 25 years up to 2040.

[6] *Ibid*.

Peatland restoration activities in Wales have focussed primarily on blanket bogs in the uplands. It has been estimated that as a result of restoration and agri-environment measures, GHG emissions from upland blanket bogs have reduced from 15% of all peatland emissions in 1990 to around 7% at the present time. Restoration has taken the form of drain-blocking as well as grazing reductions under agri-environment (the Tir Gofal scheme). A 'theoretical maximum' estimate of the climate change mitigation that could be achieved through fully re-wetting and restoring all Welsh peatlands to near-natural status has been estimated to be at 0.33 million tonnes CO_2-eq per year. The Welsh Government have committed to a significant programme of peatland restoration through the development of a national Peat Policy Statement, *Peatlands for the Future*. Forestry Commission Wales have also identified priority sites for restoration within the 18,000 ha of woodland located on deep peat soils.

At a UK level, the impacts of climate change are not accounted for in future projections of GHG emissions and sequestration from soils and forests (termed the Land Use, Land Use Change and Forestry sector). The UK GHG inventory also currently underestimates GHG emissions from peatlands, although this is in the process of being addressed by the Department of Energy and Climate Change. GHG emissions and sequestration from coastal and marine ecosystems are not accounted for at all in the inventory or in LULUCF projections.

Urgency score

More action needed - Further action is needed to restore degraded peat habitats and create new woodlands in appropriate locations. This will have co- benefits for managing a wide range of climate and non-climate related risks. Restoration can take many decades for peat habitats, meaning that there are long lead-in times for action. Action is also needed to improve the UK GHG Inventory so that all carbon stores are accounted for and to better account for the potential implications of climate change on carbon stores and emissions in LULUCF GHG emissions projections.

Ne6: Risks to agriculture and wildlife from water scarcity and flooding

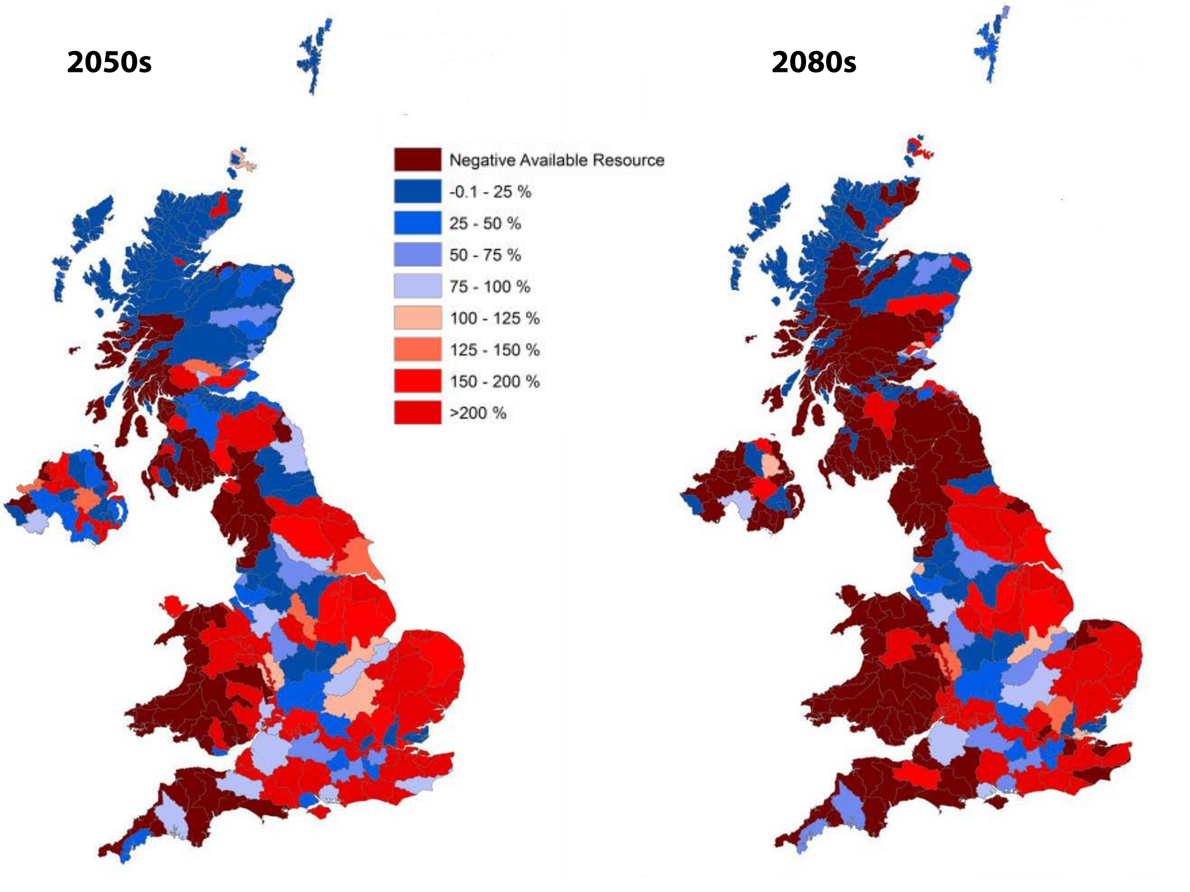
Current and future risks

Freshwater species are highly sensitive to low flows, as the quantity of water determines the level of dissolved oxygen available. Low flow conditions can also reduce dilution of pollutants. High flows and their associated sediment loads can cause significant ecological damage, e.g. to fish spawning beds. Water quality can also be adversely impacted during periods of heavy rainfall due to increased transport of diffuse pollutants from land to water and effluent discharge from point sources (e.g. storm overflows).

The amount of water abstracted for spray irrigation in Wales was 466 megalitres (Ml) in 2014, which amounted to less than 1% of total licensed abstraction. Pollution and the physical modification of water bodies are currently more significant adverse pressure on water bodies in Wales than abstraction, which only accounts for around 2% of reasons for failing to meet good ecological status.

Reduced water availability may become a more significant pressure on the ecological condition of water bodies in the future. Projections of future river flows imply changes across the seasons, with increases in average winter flows and reduced spring and summer flows. If current environment flow requirements are fixed into the future, then a high proportion of catchments in Wales in the 2050s are projected to not be able to meet environmental requirements during periods of low flows under a high climate scenario. By the 2080s no catchments in Wales are projected to have sufficient water resources available for both the natural environment and human uses in a dry year (Figure WS.2). This suggests an increased risk of water restrictions in all sectors, including for agricultural use and particularly those business specialising in crops that are dependent on supplementary irrigation. Calculating environmental flow rates as a proportion of future river flows would increase the available resource for abstraction. However, the ecological consequences of a long-term reduction in absolute environmental flows are likely to be significant.

Figure WS.2. Abstraction demand in 2050s and 2080s as a percentage of the available resource during low flow conditions under a high climate scenario; high population growth; no additional action adaptation; and fixed environmental flows.



Source: HR Wallingford (2015) for the ASC.

Note: The percentage of available demand is based on the average of Q95 and Q70 low flow conditions. The high climate scenario is UKCP09, High emissions, p 90. Negative Available Resource (shown in dark red) means that there is not enough natural resource to service the environmental flow requirement and therefore no resource available for human uses, assuming that the requirements of the natural environment must be met first.

Approximately 9,000 hectares of Best and Most Versatile (BMV) agricultural land in Wales (defined as Grades 1 to 3a) is at 1 in 75 year or greater risk from river flooding. A further 7,000 hectares is at a 1 in 75 year or greater risk of surface water flooding. Combined, this makes up around 10% of BMV land in Wales. [7]A relatively small area of BMV land (2,000 hectares) is currently at 1 in 75 year or greater risk of coastal flooding. However, inundation of agricultural land by salt water can cause significant damage to crops and over time result in soil salinization, with implications for the viability of the land for continued production. The area of BMV land at a 1 in 75 year risk from all sources of flooding is projected to increase by 35% by the 2050s if global mean temperatures are on a trajectory for a 4^{0}C rise by the end of the century.

Adaptation

The EU Water Framework Directive requires member states to prevent deterioration in all water bodies (rivers, lakes, estuaries, coastal and ground waters) and aim to achieve good ecological status by 2015. WFD objectives and measures are implemented through river basin management plans, which are developed and reviewed on a 6 year planning cycle. Any climate-driven changes in low or high flows could possibly challenge meeting the WFD timeline, and make it harder to ensure that water bodies remain in good ecological condition in the longer-term. Beyond the end of the third planning cycle in 2027 there is no clear mechanism for managing the consequences of changes in flow for meeting the WFD targets.

New and improved flood and coastal defences are being built to protect agricultural land as part of the wider national flood risk management programme overseen by Natural Resources Wales. NRW also spends money maintaining existing defences, including in agricultural areas, and channel conveyance such as dredging and vegetation management and techniques for natural flood risk management have been trialled. The way land is used and managed can either enhance or reduce high and low flows (see Ne8). Incentivising management practices that increase the natural capacity of soils and vegetation to store water or retard runoff rates requires policy intervention, as the recipients of the benefits tend to be located downstream. Some policies are in place to incentivise sympathetic management, mainly in the form of agri-environment schemes under Pillar II of the CAP along with some catchment-scale initiatives. However, management practices continue that are likely to be reducing the natural capacity of soils to manage flows, particularly in the uplands.

Urgency score

More action needed - Further action is needed to improve the condition of water bodies and to encourage the wider uptake of management practices that help to reduce the impacts of low and high flows. There is a need for more strategic planning for increased water scarcity in vulnerable locations, including re-evaluation of land use options and if necessary investment in storage infrastructure to maximise use of surplus winter rainfall. Further action to reduce demand in water-stressed areas will also need to be considered, including water pricing based upon the full value of the resource. Such action could have a range of co-benefits for managing climate and non-climate related risks and avoid lock-in to a pathway where the majority of Wales's water bodies are ecologically degraded in the future. Ecological restoration can also take many decades, meaning that there are long lead-in times for action. Consideration of the implications of relaxing environmental flow requirements for meeting WFD and biodiversity targets is also needed.

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[7] Based on there being around 157,000 ha of BMV in Wales. This figure is based on Welsh Government estimates that are currently being improved.

Ne7: Risks to freshwater species from higher water temperatures

Current and future risks

As waters warm, the thermal tolerance of species can be exceeded and warmer waters can have lower dissolved oxygen content. Water temperatures have increased in UK rivers and lakes at similar rates to regional air temperatures since the 1970s or 1980s with an average warming of 0.03C/yr reported between 1990-2006. This temperature change has modified the circulation of some lochs, particularly the process of stratification in which the thermal profile becomes more evident as a series of distinct layers, reducing circulation of water, oxygen and nutrients.

There is some evidence of a response to changes in water temperature, for example with reductions in fish species in some catchments. In one site, spring invertebrate abundances have declined by around 20% for every 1°C rise as species typical of cooler-water conditions have been lost. However, to date, increased temperatures have not directly caused any water bodies to fail to meet good ecological status under the Water Framework Directive. Temperature changes are often masked by other factors, notably changes in water quality.

Future projected temperature increases imply that this risk will increase with further adverse effects on sensitive species. Reductions in flow are also likely to lead to greater increases in river temperature in summer. Reduced circulation is likely to increase the risk from cyanobacterial blooms and deoxygenation in smaller, shallow lakes. Larger deeper lakes are likely to be more sensitive to longer periods of stratification reaching greater depths causing deoxygenation and loss of fish assemblages. Continued decline in species adapted to cold conditions (e.g. arctic charr) and those with complex life cycles (e.g. salmon) may be expected and with potential for invasive fish species such as Common Carp, European Catfish and Roach.

Projected future changes in water quality remain highly uncertain due to the complex interaction between climate change with land use change, which will vary by catchment. Few studies have been undertaken, but some projections show increased risk of algal blooms and suspended solids.

Adaptation

The primary legislative driver for managing the risk of higher water temperatures is the Water Framework Directive (WFD). WFD objectives and measures are implemented through river basin management plans, which are developed and reviewed on a 6 year planning cycle. Increasing water temperatures, combined with changes to flow, could possibly make meeting the WFD targets even more challenging Increasing water temperatures, combined with changes to flow, will make meeting the WFD targets even more challenging.

There have been some efforts to reduce the impacts of higher water temperatures through planting of riparian woodland, which provides localised shading and cooling. This has, however, been opportunistic rather than strategic, with efforts not necessarily targeted at the most sensitive locations. The amount of planting would have to be significantly increased to match the level of risk under medium or high future climate projections. There would be benefits for managing a wide range of climate and non-climate related risks from further riparian tree planting, as long as the right trees are planted in the right places. Widespread riparian planting would are also have long lead in times. For some species (e.g. Arctic fish such as vendace) translocation is being trialled as a last resort option. NRW have a programme in place to establish back-up populations of arctic charr. There is however a lack of evidence on the scale of possible translocation required, as well the potential wider ecological implications.

Urgency score

Research priority - Research is needed to inform the development of a strategic programme of riparian woodland creation targeted to provide cooling for sensitive water bodies of high biodiversity and/or cultural importance (e.g. salmon rivers). Further consideration is also needed into the costs and benefits of a possible cold-water species translocation programme. Such an assessment will provide the early steps to inform better decisions in the near future.

Ne8: Risks of land management practices exacerbating flood risk

Current and future risk

Degraded and compacted soils can exacerbate flood risk by increasing the speed of rainwater run-off and silting up rivers. Field studies have shown that some land management practices can cause soil compaction, due to the use of machinery or presence of livestock on waterlogged soils, resulting in damage to soil structure, reduced aeration and penetration of plant roots, and the potential for increased erosion due to reduced water infiltration and increased runoff from overland flow. While a number of small-scale studies have found locally occurring increases in soil compaction, there has been no systematic study of the national extent, or severity of this issue; as a result, it is not currently possible to provide a quantitative assessment of the current state or trend across the UK.

Agricultural land covers 88% of Wales's land area, which means that the way in which it is managed can have a profound effect on the wider impacts of flooding. Flood walls and embankments routinely protect what would be the natural floodplain from inundation, forcing water downstream into built-up areas where much more significant damage can be caused. Rivers over the course of centuries have been narrowed, deepened and straightened in order to maximise the available land for food production. This speeds the flow of water causing scour to riverside structures and potentially increases the size of flood peaks. Furthermore, there is evidence that some land management practices have a particularly adverse impact on downstream flood risk, including maize cultivation on slopes, over-stocking of livestock and the use of upland blanket bog habitats for grouse-shooting.

Warmer, wetter winters and drier summers in the future could affect increase rates of soil weathering and increase soil erosion (as noted in Ne.5 above). This could in turn increase peak flows and hence fluvial and groundwater flood risk. This risk will be exacerbated where soils are degraded and compacted due to land management practices.

Adaptation

As noted in NE.5, land managers are required to take measures to prevent erosion in order to qualify for the full single farm payment under Pillar 1 of the CAP. However, in practice the low levels of inspection make it difficult for these requirements to be enforced. There is currently no process in place that requires land managers to assess the extent to which their practices may be exacerbating flood risk.

Incentivising management practices that increase the natural capacity of soils and vegetation to store water or retard runoff rates can be challenging, as the recipients of the benefits tend to be located downstream. Voluntary agri-environment schemes funded under Pillar II of the CAP are important mechanisms for encouraging soil conservation. The Glastir Advanced scheme is currently trialling approaches to incentivise land management interventions that help reduce run-off with the aim of but rolling out measures across Wales. It is likely that the move in Wales to more integrated and ecosystem based natural resource management through the framework provided for in the Environment (Wales) Act 2016 will increase the development and uptake of NFM measures through Area Statements and new incentives.

There is increased interest in the adoption of Natural Flood Management (NFM) schemes, which maximise the use of natural fluvial and landscape features to reduce flood peaks. As most of these schemes are still in the early stages the benefits remain to be fully established and are usually specific to the sites in which they are located. Results from experiments, including in the Pontbren catchment (central Wales) suggested land use changes (reduced grazing pressure or afforestation) could reduce runoff rates by 50% or more. However, it remains difficult to determine the overall significance of measures that store flood waters and manage run-off at the catchment scale, or how they will influence the magnitude and severity of more extreme floods (for example, 1-in-50 or 1-in-100 year events).

A further challenge facing the wider uptake of NFM measures is that it is not possible to guarantee a specific standard of service for flood protection in the same way as with conventional flood defences. NFM schemes also generally require ongoing maintenance, which is typically not included in capital costs.

Urgency score

More action needed - There is a need to better understand the scale of land management practices that exacerbate downstream flood risk, in order to inform the specific policy interventions required. There is a need to review the potential for adverse flood risk outcomes due to the implementation of CAP policies, particularly under Pillar 1.

Further action is also needed to deliver wider uptake of NFM in catchments where the approach can make a significant contribution to reducing peak flow and subsequent flood risk. NFM approaches should also be designed to maximise benefits for carbon storage, water quality and biodiversity. The economic case for the wider use of NFM measures as part of the suite of Flood and Coastal Erosion Risk Management practices needs to be strengthened. This could be through undertaking cost benefit analysis comparing the costs of repairing flood damage with the costs and benefits of incentivising changes in land management practices. The non-market benefits from NFM, e.g. in terms of carbon storage or water quality, should also be included in any such assessment.

Ne9: Risks to agriculture, forestry, landscapes and wildlife from pests, pathogens and invasive species

Current and future risks

There has been a rise in recorded non-native species in terrestrial, freshwater and marine environments in Wales. Invasive species like rhododendron pose substantial problems for Welsh forestry, affecting ground and understorey flora, competing for water and nutrient resources and inhibiting natural tree regeneration. Species such as the American mink and the North American signal crayfish have rapidly increased in range in recent years with a significant impact on freshwater habitats and fauna.

The increase in this risk to date has primarily due to human agency and exacerbated by expansion in global trade with climate as a background factor. In addition, lack of natural competition may be an additional factor especially in landscapes of reduced biodiversity. However, each pest and pathogen has its own distinctive characteristics.

A warmer climate provides an increased likelihood of pests and diseases that were previously limited by climate (notably cold winters) to persist and disperse. There is an increased risk from expansion of vectors for bluetongue and of airborne spread of Foot and Mouth. Small changes in climatic conditions around critical thresholds may result in dramatic changes in parasitic nematodes in livestock. Insect pests are generally expected to become more abundant due to range expansions and phenological changes, including higher overwinter survival rates. Wetter winters may increase the risk of liver fluke, which is vectored by water-sensitive lymneid snails.

The colonisation and expansion of non-native species is much harder to predict than range changes in native species. Those species which are already native in continental Europe and colonise naturally, for example through airborne dispersal will typically have co-occurred with many British species. In these cases the risks are likely to be relatively small and easily anticipated. With species colonising from other parts of the world as a result of human travel and trade, the consequences are less certain and climate change will add to the uncertainty as species which would not previously have been able to survive in the UK start to be able to do so.

Depending on the rate of climate change, introduction and dispersal that is more strongly influenced by climatic factors may become more frequent and the risk increase. For example, a shift towards warmer wetter winters is likely to favour the spread of fungi and related organisms. Species such as rhododendron might increase their elevation range in upland western areas if there are warmer conditions, increasing costs of control, and perhaps also increasing disease spread as rhododendron is a host for *Phytophthora ramorum*.

Adaptation

The threat from invasive species, pests and pathogens is taken very seriously in Wales and more widely in the UK. There is a UK-wide policy framework in place to manage this risk based on independent scientific reviews.

- A Tree Health and Plant Biosecurity Expert Taskforce reported in May 2013 and the first UK Chief Plant Health Officer took office in April 2014. A UK Plant Health Risk Register has been produced, along with a Plant Biosecurity Strategy and a Tree Health Management Plan, which addresses the recommendations of the Tree Health and Plant Biosecurity Expert Taskforce.
- Livestock diseases are covered by the EU Animal Health Strategy. The Animal and Plant Health Agency and the Forestry Commission are responsible for monitoring and responding to pests and disease threats to agriculture and forestry. Both have embedded climate change into their planning and surveillance arrangements.
- There is a Great Britain Invasive Non-native Species Strategy, as well various policy mechanisms such as Water Framework Directive, Habitats Directive and Marine Strategy Framework Directive and the EU Regulation on Invasive Alien Species. International frameworks are also in place, through the Convention on Biological Diversity and the Bern Convention. Risk assessment procedures are now increasingly used to identify problem species and to prioritise actions.

There has been progress in areas specifically aimed at addressing the risks from climate change, particularly through research to better understand the nature of the risks. Actions include the Tree Health and Plant Biosecurity Initiative research programme, research to fill the evidence gap on the effects of climate change on pests and diseases that affect livestock, and for environmental change factors to be considered for each risk in the new UK Plant Health Risk Register.

Urgency score

Sustain current action - Continue current efforts to reduce risks and monitor impacts.

Ne10: Risks to agriculture, forestry, wildlife and heritage from change in frequency and/or magnitude of extreme weather and wildfire events

Current and future risks

Wind damage to forests is a major problem to forestry in UK and across Europe where wind and snow storms cause approximately half of all damage to forests. Storms cause immediate damage (loss of timber stock, costs of clear-up), disruption to markets and processing and can increase subsequent risk of damage from insects, pests and wildfires. Predicting future changes in storm tracks is highly uncertain. However, warmer autumns with consequent later leaf loss, are likely to increase the risk of damage in deciduous species. Wind damage may also increase with higher levels of soil wetness, as waterlogging reduces rooting depth and consequently tree stability.

Wildfire represents a sporadic but serious risk to Wales's natural environment. It can affect forestry, agriculture and multiple habitats (grassland, heathland, woodland, peatland etc.) While wildfire can damage woodlands with loss of timber, habitat and ecosystem services, it also causes short-term disruption to local populations and infrastructure, and consequent costs, and may cause health risks. When organic soils, particularly peat, are affected by fire the damage can become extensive in depth and extent because of the large fuel supply and difficulties of suppression.

In 2012/13 there were 174 forest wildfires affecting an area of 107 hectares in Wales. Other key habitats affected by wildfire included mountain, heath and bog and semi-natural grassland. Projected increases in drier summers and higher soil moisture deficits would be expected to lead a large increase in the number of fires and the area affected. Climate modelling suggests that risk will increase by 30-40% in the Brecon Beacons, Pembrokeshire Coast and Snowdonia National Parks by the 2080s. However, this modelling does not account for indirect factors such as fuel loads, human behaviour and changes in land use. Increased tree mortality from droughts and from pests and diseases may in turn increase wildfire risk.

Adaptation

The risk of wind damage is well-understood in UK forestry, particularly for productive conifer plantations in the uplands. The planning of rotation lengths, harvesting areas and thinning regimes usually consider measures to reduce the risk. Further adaptation is not really possible, beyond current risk reduction planning strategies.

Wildfire was included in the UK National Risk Register and National Risk Assessment in 2013, meaning it is recognised in the same way as other risks such as flooding and pandemic flu. Fire events have been systematically recorded since 2009 with the Incident Recording System, meaning that data is being collected on the magnitude, extent, and other characteristics of wildfires. Improvements in approaches to fire-fighting may have contributed to a reduction in large outbreaks in recent years. Emergency planning currently includes preparedness and contingency for wildfire but the full extent of the risk and the identification of vulnerable areas remains unknown. The Forestry Commission published 'Building wildfire resilience into forest management planning' in 2014. Together, this should help ensure widespread uptake of management practices that reduce risk, such as the use of fire breaks, surveillance systems and public warnings. However, it is also possible that the conversion to continuous cover management systems in recent decades, with an increase in deadwood and forest floor litter, may be increasing the risk of more intense or extensive fires.

Urgency score

Sustain current action - Monitor impacts of extreme weather events on agricultural and forestry production. Continue to monitor impacts of wildfire and undertake further investigation to identify high risk areas, particularly those near to population centres.

Ne11: Risks to aquifers and habitats from salt water intrusion

Current and future risks

Inundation of salt water during storm surges can cause significant damage to agricultural crops and grassland. Regular inundation can result in soil salinization with implications for the viability of the land for continued production.

Saline intrusion can also affect groundwater as a result of over-abstraction (via pumps, boreholes or wells). The hydraulic gradient from the land to the sea can be weakened, and sometimes reversed, by the removal of freshwater. This removal can also be on a more permanent basis where there has been extensive land drainage. Because sea water is denser than freshwater, the intrusion will (at first) occur in the lower parts of the aquifer, with the freshwater-seawater boundary moving landwards. The intrusion of salt water into coastal aquifers can impact on water availability in those districts. Future risk to aquifers is expected to slowly increase with sea level rise and associated tidal surges.

Freshwater and terrestrial habitats in the coastal zone are at risk of saline intrusion. Coastal grazing marsh habitat is particularly vulnerable to the modification of vegetation communities, which support a large proportion of overwintering and migrating birds in key locations. Regular inundation may eventually cause some of this habitat to become saltmarsh, which may partly compensate for losses at the seaward margin (see Risk 12 below) but this in turn requires identification of replacement grazing marsh habitat. It has also been estimated that an average of around 4-6% priority freshwater habitats in the coastal floodplain could be lost per year due to salt water inundation, most of this being in designated areas. This does not include inundation caused by extreme storm surges.

Adaptation

The relatively slow transitional time of saline intrusion of aquifers (even with higher rates of sea level rise) provides time to adapt. Efforts to create compensatory habitat are being delivered through the requirements of the Habitat Regulations.

Urgency score

Sustain current action – continue to create compensatory habitat and monitor impacts on aquifers to assess whether risks are increasing.

Ne12: Risks to habitats and heritage in the coastal zone from sea-level rise; and loss of natural flood protection

Current and future risks

Coastal habitats are extremely valuable for wildlife and also provide a range of vital services, including protection from coastal flooding and storm surges. The coastal protection provided by saltmarsh has been demonstrated by modelling, which suggests that up to 50% of wave energy is attenuated in the first 10–20 m of vegetated saltmarsh. An 80 m width of saltmarsh has been estimated to reduce the height of seawall defence required from 12m to 3m resulting in capital cost savings of £2,600–4,600 per metre of seawall.

Coastal tourism is particularly important and contributes the largest proportion to the visitor economy. Much of the Welsh coastline is designated as Heritage Coast, with 75% of the coastline being protected and designated for environmental importance. The importance of the sea throughout Welsh history is clearly shown by the abundance of archaeological and historic sites found along Welsh coasts. These provide valuable evidence of human activity ranging from distant prehistory to Wales' recent industrial past. However, many are threatened by coastal erosion linked to climate change.

A proportion of the Welsh coastline (around 15%) is protected by hard engineering structures which prevent natural adjustment of coastal systems to a rising sea level, including the migration of habitats inland to remain in a similar position within the tidal frame (termed 'coastal squeeze'). The UKNEA estimated that coastal margin habitats have declined by 16% due to development and coastal squeeze over recent decades, but also highlighted that this estimate is poorly quantified.

Coastal habitats have also experienced the direct effects of climate change through changing temperature profiles, as similar to terrestrial and freshwater systems. This has been most evident with rocky inter- and subtidal species, where warmer 'southern' species are shifting northwards with colder, 'northern' species declining across the UK. The topshell *Gibbula umbilicalis* has extended its range northwards in Wales in the last decade and Horse Mussel reefs may disappear from Welsh waters in the next 20 years as a result of warming.

There is increasing evidence that the overwintering distributions of many coastal wading birds have shifted in recent decades in response to warming. Seabird breeding populations in the UK increased in size over much of the last century, but since 1999 these populations have declined by an average of 7.5%. Climate change is considered to be one of the main drivers of these declines.

The level of existing habitat loss on the coast implies that even under a low scenario for future sea level rise there will be continued loss of habitat without further implementation of adaptation measures that recognise the dynamic processes of the coast. The future magnitude of absolute sea level rise according to UKCP09 is between 12 – 76 cm (1 - 7.5 mm/yr) from 1990 - 2095, with the H++ scenario suggesting a higher upper end of 93 – 190 cm (10-19mm/yr) by 2100. Sea level rise will also continue beyond 2100 regardless of emissions scenario meaning there is a very long-term commitment to sea level rise.

The UK National Ecosystem Assessment projected coastal margin habitat losses to reach 8% by 2060. However, for higher sea level rise scenarios the potential losses may be significantly greater as the risk then increases of threshold effects due to the decreased buffering role of sediment supply in any adjustments, as for example due to the risk of a breach on a barrier coastline. NRW have estimated that around 2,300 hectares of Natura 2000 coastal habitat will be lost by the end of the century due to coastal squeeze, of which some 260 hectares will be lost by 2025. These figures will be revised as the scale of sea level rise is better understood. They do not take account of any losses arising from coastal squeeze away from "hold the line" areas.

As the current evidence suggests a continuation of sea level rise, the risk is likely to significantly increase with the possibility of the natural buffering resilience of coastal habitats and landforms being lost. It is also likely that areas that currently have not experienced major loss of habitat will experience it much more in the future. The risk is therefore of crossing a dangerous threshold and of becoming increasingly locked in to an unsustainable regime for coastal zone management that entails loss of habitat and the ecosystem services provided by that habitat/landform.

Adaptation

This risk is recognised at strategic level by the second generation of Shoreline Management Plans in Wales, with increased emphasis on long-term planning and sediment budgets. However, the response in practice remains piecemeal and dominated by 'hold the line' policies which are very likely to cause increased loss of habitats even at the lowest level of future SLR projections with much larger losses likely for higher SLR projections.

Urgency score

More action needed - more effort is needed to allow dynamic readjustment of coastal landforms and habitats, particularly in terms of increased sediment supply and realignment opportunities. This will have range of co-benefits for managing climate and non-climate related risks and avoid lock-in to a pathway where the long-term viability of coastal habitats and the services they provided. Realignment schemes are complex and often involve multiple actors, meaning that there are long lead-in times for action.

Ne13. Risks to and opportunities for marine species, fisheries and marine heritage from ocean acidification and higher water temperatures

Current and future risks

Extensive modification of maritime ecosystems has been attributed to long-term climate change. Sea temperature records in UK waters continue to show an upward trend, notwithstanding short-term variability.

Ocean uptake of CO_2 has increased surface ocean hydrogen ion concentration by ~30% to date, and decreased surface carbonate ion concentration by ~16%. These effects – ocean acidification – are expected to greatly intensify in the next 100 years in the absence of global emission reduction measures. Ocean acidification is a global-scale threat but impacts will be felt at the local and regional level. It is highly likely that UK coastal waters, ecosystems and habitats will be significantly impacted this century if global CO_2 emissions continue to rise. In the North Atlantic, ocean acidification has been occurring more rapidly in the European region than in the Caribbean or central Atlantic. In UK/European shelf seas, both observations and modelling show that CO_2 levels in near-surface seawater can currently vary between 200-450 ppm, contributing to a pH variability of as much as 1.0 (typically 0.3-0.4) over an annual cycle.

Extensive changes in planktonic ecosystems have been observed in terms of plankton production overall, biodiversity and species distribution. Species with warmer-water affinities are moving northward to replace the colder water species but are not numerically abundant or as nutritionally (i.e. less lipid-rich) important. Over the last five decades there has been a progressive increase in the presence of warm-water/sub-tropical species into the more temperate areas of the North-East Atlantic and a decline of colder-water species. The seasonal timing of some plankton production has also altered in response to recent climate change. This has consequences for plankton-predator species, including fish, whose life cycles are timed in order to make use of seasonal production of particular prey species.

Recent warming has caused some cold-water demersal (bottom-dwelling) fish species to move northwards and into deeper water (e.g. cod, whiting, monkfish), and has caused some warm-water demersal species to become more common or 'invade' new areas (e.g. John dory, red mullet). Centres of distribution have generally shifted by distances ranging from 48 to 403 km. Pelagic (blue-water) fish species are showing particularly marked distributional shifts, with mackerel now extending into Icelandic and Faroe Island waters (with consequences for management), whilst sardines and anchovies are invading Irish and North Sea environments. There is evidence that locations where high catches of cod, haddock, plaice and sole occur, have moved over the past 80- 90 years. Climate change may be a factor but fishing and habitat modification have also had an important effect. In recent years, warm-water species have appeared in greater numbers and their exploitation has become viable. Examples include boarfish, trigger fish, squid, anchovy, red mullet and seabass. In 2012, 937 tonnes of sea bass were landed in the UK and the Channel Islands, compared with 142 tonnes in 1984. International commercial landings, from the north-east Atlantic, of species identified as warm-adapted (e.g. grey gurnard, red mullet, hake) have increased 250% in the last 30 years.

There is strong evidence that warming has influenced the relative timing (phenology) of fish annual migrations and spawning events in European waters, with potentially significant effects on population sizes and juvenile recruitment. Observed declines in salmon are strongly correlated with rising temperatures in oceanic foraging areas, with temperature affecting growth, survival and maturation of salmon at sea.

Bioclimatic modelling suggests northward shifts for most fish species in the future, at an average rate of 27 km per decade (the current rate is around 20km per decade for common fish in the North Sea). Most seabird species in the UK are at the southern limit of their range. By the end of the 21st century, great skua and Arctic skua may no longer breed in the UK. Many features for which marine protected areas have been designated are potentially vulnerable to climate change, meaning the on-going utility of marine protected areas as a conservation tool for their current conservation features could be affected.

Projected changes to water temperature, acidity and primary productivity are likely to have implications for marine fisheries and aquaculture. Overall, the UK is expected to benefit from slightly (i.e. + 1-2% compared to present) higher fishery yields by 2050. However, the Irish Sea may see a reduction in yields by the 2050s. Models suggest that cod stocks in the Celtic and Irish Seas might disappear completely by 2100.

In the short term, climate change is unlikely to have a significant effect on UK-farmed marine fish (aquaculture). Rising water temperatures could cause thermal stress for some farmed cold-water fish species (e.g. cod and Atlantic halibut) and intertidal shellfish. However, increased growth rates for some farmed fish species (e.g. Atlantic salmon) may result from rising water temperatures and new farmed species (e.g. sea bass, bream) may be able to be cultivated. Farmed species may become more susceptible to a wider variety of diseases as temperatures increase. Any increase in harmful algal and jellyfish blooms may lead to additional fish kills and closure of some shellfish harvesting areas.

Adaptation

Legislation and policies for protecting and enhancing the marine environment are in place. Primarily these are, the EU Marine Strategy Framework Directive 2008 (MSFD), the Marine and Coastal Access Act 2009 and the EU Common Fisheries Policy (CFP).

The MSFD establishes a framework within which Member States are required to "take the necessary measures to achieve or maintain good environmental status" in the marine environment by the year 2020 at the latest. Implementation of the MSFD may result in the establishment of a marine monitoring programme similar to that for surface water bodies under the Water Framework Directive. If effective MSFD indicators are put in place, then it should be possible to monitor whether Good Environmental Status is being achieved in Welsh waters. The monitoring programme has been developed to specifically monitor the targets and indicators for GES as outlined in the UK Marine Strategy Part One. The programme of measures, published in 2015 has been developed to address these same targets and indicators. Implementing the directive is a cyclical process and will be reviewed periodically, to ensure that the targets and indicators set are effective in achieving GES. The MSFD has been written with the explicit knowledge that marine systems are dynamic and it includes adaptation and exception sections which require climate and environmental variability be taken into account.

Marine Protected Areas (MPAs) are fundamental to the conservation of marine biodiversity, ensuring marine ecosystems remain healthy, sufficiently connected as habitats and species are interlinked and resilient against change. The Welsh Government are working to deliver an ecologically coherent well managed network of MPAs that represent a diverse range of habitats and species and that contributes to UK and international networks of MPAs. MPAs will make a substantial contribution towards achieving Good Environmental Status as required under MSFD.

The first Welsh National Marine Plan will integrate economic, social and environmental considerations, providing clear policies and direction to decision makers and sea users on the sustainable use of our marine area. The marine plan places the ecosystem approach at the heart of decision making and includes emerging policies that support climate change adaptation and highlights sector specific issues and opportunities.

Working with industry and stakeholders, the Welsh Government are moving towards an ecosystem approach to the management of fisheries and more sustainable and environmentally accepted fishing practices, using reliable evidence bases. Through the reformed CFP, a framework will be established to manage fisheries sustainably and to achieve Maximum Sustainable Yield for all major fisheries by 2020. The impacts of climate change is one of the factors considered when setting quotas under the CFP. Quotas can be swapped each year between member states which could be used if distributions of managed stocks shift into new areas, or retreat from traditional ones. However, in practice such swaps are not always straightforward to implement.

A number of trends suggest that resilience of marine environment is improving. The area of marine protected sites has increased substantially in recent years. There has also been a sustained reduction in hazardous pollution levels since 1990 and the proportion of fish stocks being harvested sustainably has increased since 2000. Statutory marine plans are in place, or in the process of being produced and key organisations in the sector have recently reported under the Adaptation Reporting Power, including the Marine Management Organisation and Seafish, the commercial fishing trade body.

It is difficult to judge whether there is currently a significant adaptation shortfall, as mechanisms generally exist in the relevant legislation to enable climate change impacts to be addressed (for example through periodic reviews). The scale of risk faced in the future may mean that current interventions are unlikely to be sufficient. This is particularly the case with ocean acidification, which has the potential to have catastrophic impacts on marine ecosystems in UK coastal waters. However, it is not completely clear if any additional or alternative action is needed for adaptation beyond measures to improve resilience.

Urgency score

Research priority – Improvements in understanding are needed of potential impacts of climate change on marine ecosystems, especially changes in acidity, dissolved oxygen content and temperature. Improved understanding of the social and economic implications of climate change for the UK fishing industry is also needed. This will help to identify whether adaptation requires any additional or alternative actions to be taken.

Other risks

Other risks considered as part of the natural environment and natural assets chapter but considered to fall in to the 'watching brief' category across the UK include:

Ne14: Risks and opportunities from changes in landscape character. Landscape character has changed in Wales over the last few decades. Climate change has been a contributing factor, both directly through its effects on land cover and indirectly by influencing some land uses over others in specific locations. Changes in land cover and land use will undoubtedly continue to occur into the future and the magnitude of climate change (and responses to it) will be a key factor in influencing this change. Ancient woodlands and hedgerows are not only important ecosystems, but are also historic assets containing evidence for past human use. The potential effects of climate change on forestry, ancient woodland and hedgerows may be gradual but significant. Soil erosion, land-use change and replanting could all damage individual historic assets.

4. Infrastructure

Infrastructure across Wales is exposed to range of climate hazards. Impacts on some assets have the potential to cascade on to others as part of interdependent networks. Flooding poses the greatest long-term risk to infrastructure performance from climate change, but the growing risks from heat, water scarcity and slope instability caused by severe weather could be significant.

The Infrastructure chapter in the Evidence Report is structured by key sectors. The risks and opportunities from climate change to sectors are assessed and these are summarised for Wales, along with the urgency scores, in Table WS.3.

Table WS.3. Urgency scores for infrastructure

Risk/opportunity (reference to relevant section(s) of CCRA Evidence Report)	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
In1: Risks of cascading failures from interdependent infrastructure networks (4.4 to 4.9)	UK				More action to enhance arrangements for information sharing in order to improve understanding of critical risks arising from interdependencies.
In2: Risks to infrastructure services from river, surface water and groundwater flooding (4.4 to 4.9)	UK				More action needed to manage increasing risk to existing assets and networks and ensure increased risk is accounted for in design and location of new infrastructure.
In3: Risks to infrastructure services from coastal flooding and erosion (4.4 to 4.9)	England, Wales	Northern Ireland, Scotland			More action needed to manage increasing risk to existing networks (including flood and coastal erosion risk management infrastructure), from sea-level rise and increased rate of erosion.
In4: Risks of sewer flooding due to heavy rainfall (4.5)	UK				More action needed to deliver sustainable drainage systems, upgrade sewers where appropriate and tackle drivers of increasing surface runoff (e.g. impermeable surfacing in urban areas).
In5: Risks to bridges and pipelines from high river flows and bank erosion (4.5, 4.7, 4.8)		UK			More research needed on implications of projected changes in river flows on future risk of scour/erosion.
In6: Risks to transport networks from slope and embankment failure (4.7)	UK				More action needed to locate and remediate embankments and cuttings at risk of failure.
In7: Risks to hydroelectric generation from low or high river flows (4.8)				UK	Monitor impacts and be ready to adapt operations given observed impacts.
In8: Risks to subterranean and surface infrastructure from subsidence (4.5, 4.6, 4.7, 4.8)				UK	Monitor changes in temperature and rainfall patterns to update assessments of subsidence risk.

Table WS.3. Urgency scores for infrastructure

Risk/opportunity (reference to relevant section(s) of CCRA Evidence Report)	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
In9: Risks to public water supplies from drought and low river flows (4.5)	England, Wales		Scotland, Northern Ireland		New policies and stronger co-ordinated, cross-sector effort needed to deliver more ambitious reductions in water consumption and establish strategic planning of new water-supply infrastructure.
In10: Risks to electricity generation from drought and low river flows (4.8)				UK	Continue to monitor risks including as a result of deploying carbon capture and storage. Ensure appropriate siting of new infrastructure and use of cooling technologies.
In11: Risks to energy, transport and digital infrastructure from high winds and lightning (4.6, 4.7, 4.8)		UK			More research needed on the implications of increased vegetation growth rates on future risks of damage from falling trees in storms.
In12: Risks to offshore infrastructure from storms and high waves (4.7, 4.8)		England, Scotland		Wales, Northern Ireland	Monitor risks to deployment of any new offshore infrastructure.
In13: Risks to transport, digital and energy infrastructure from extreme heat (4.6, 4.7, 4.8)			UK		Continue current actions to reduce risks, maintenance and renewals of infrastructure networks.
In14: Potential benefits to water, transport, digital and energy infrastructure from reduced extreme cold events (4.5, 4.6, 4.7, 4.8)			UK		Continue current actions to reduce risks, including cold-weather planning and response.

In1: Risks of cascading failures from interdependent infrastructure networks

Current and future risks

Infrastructure networks do not operate in isolation, with services reliant on power, fuel supplies, and ICT. Transport links including local roads are important for logistics and to allow staff to travel to work. Vulnerable services, such as hospitals, are often not aware that their power supply is at risk from cascading failures. However, failures caused by interdependencies are not systematically recorded. Outputs from various research projects are beginning to quantify the scale of interdependency risks at the national level, but the scale of the risk remains largely unknown.

Adaptation

Individual infrastructure operators are also reviewing their dependency on other networks, in particular their reliance on power, ICT, and critical road and rail links However, as yet there is no systematic national assessment of interdependency risk, nor a comprehensive plan to address it.

Urgency score

More action needed - common standards of resilience would help with investment planning, and help emergency planners better understand the potential for service disruption arising from assets in their area. A good example of a common standard is ETR138, the 'resilience to flooding' adopted within the electricity transmission and distribution sector. Enhanced arrangements for information sharing on critical risks of interdependence are also required. This will help to create the right institutional conditions for adaption in the next five years and in the long-term.

In2: Risks to infrastructure services from river, surface water and groundwater flooding

Current and future risks

Flooding already accounts for significant losses in infrastructure services, with outages caused by flooding tending to last longer than other weather-related hazards (several days and in some cases weeks). Flooding was directly responsible for approximately 340,000 passenger delay minutes on the British rail network between 2006 and 2013 (accounting for 5% of all delays). The number of customer minutes lost from the GB high voltage electricity network from flooding between 1995 and 2011 was nearly 14,000 (1% of total). Although less frequent than other weather related causes of disruption such as storms and snow, flooding causes the longest average length of disruption per incident. Assets and networks across all infrastructure sectors are already exposed to river and surface water flooding (Table WS.4).

Table WS.4. Number/length of infrastructure assets and networks in Wales located in areas exposed to a 1:75 or greater annual chance of flooding from rivers and/or surface water (present day)

Receptor	River	Surface water
Clean and wastewater sites	6	19
Major electricity generation sites	6	0
Electricity transmission and distribution substations (>5,000 customers)	30	0
Strategic road network (km)	166	139
Rail network (km)	60	51
Rail stations	17	54
Mobile phone masts	25	15
Active landfill sites	1	17

Modelling for CCRA2 suggests the number of assets and length of existing infrastructure networks located in areas exposed to a high risk of river or surface water flooding is projected to increase overall climate change, with some sectors potentially facing significant increases. (Table WS.5).

Table WS.5. Projected change in number/length of infrastructure assets and networks in Wales located in areas exposed to a 1:75 or greater annual chance of flooding from rivers and/or surface water under a trajectory of a 4ºC rise in global mean temperature by the end of the century.

Receptor	River	Surface water
Clean and wastewater sites	+97%	+100%
Major electricity generation sites	No change	No change
Electricity transmission and distribution substations (>5,000 customers)	+77%	No change
Strategic road network	+65%	+228%
Rail network	+82%	+246%
Rail stations	+92%	+2%
Mobile phone masts	+162%	+150%
Active landfill sites	No change	+11%

Note: Assumes no additional adaptation beyond current plans.

Adaptation

The Welsh Government is responsible for flood and coastal erosion risk management policy and in accordance with the 2011 National Strategy for Flood and Coastal Erosion Risk Management in Wales funds flood and coastal defence works delivered by local authorities and Natural Resources Wales (£285 million being invested between 2011 and 2016). The Environment (Wales) Act 2016 has created a Flood and Coastal Erosion Committee that reports to the Minister for Natural Resources. It will provide an advisory role to Welsh Government and NRW on the management of all sources of flood risk and coastal erosion in Wales and will encompass the FCERM work of all Risk Management Authorities operating in Wales, Local Resilience Forums and other organisations and groups.

NRW's Flood Risk Management Wales Committee helps co-ordinate national and local delivery. In December 2014, the Welsh Government consulted on a new approach to allocating national funding to flood and coastal erosion alleviation projects, based on compiling a Flood Risk Index for each area in Wales and using this as a basis for prioritisation.

There is no published account of what has been achieved by efforts in recent years to improve the resilience of infrastructure systems in Wales to flood risk. Most sectors do not report on the resilience of their assets, networks and services. Few systematically describe the disruption that has been caused by flooding, and the actions that have been taken as a result. This is particularly the case with the non-regulated sectors (i.e. ports and digital networks) and for local infrastructure, especially minor road networks and highways.

To truly assess vulnerability to flooding there needs to be consideration of the resilience of systems as well as of the assets that combine to create systems. Networks may be resilient even if individual assets fail, if services can be provided by alternative means. Recognising this, the Cabinet Office has set a benchmark that "as a minimum essential services provided by Critical

National Infrastructure (CNI) in the UK should not be disrupted by a flood event with an annual likelihood of 1 in 200 (0.5%)". It is not explicitly clear how this benchmark has been interpreted by each specific sector, or the exact extent to which this standard is now in place. It is therefore uncertain to what extent this risk is being managed autonomously.

Urgency score

More action needed - There is a need for the development of consistent indicators of network resilience to flood risk across all critical national infrastructure sectors and networks. This will help to create the right institutional conditions for adaptation in the next five years and in the long-term. Consistent indicators of resilience will allow for improvements to be measured over time, so enabling better decisions in the near future, especially in relation to longer-term major risks, i.e. to build early interventions within an iterative adaptive management framework.

In3: Risks to infrastructure services from coastal flooding and erosion

Current and future risks

Wales has significant infrastructure assets located in coastal areas and so potentially exposed to flooding from the sea, with long stretches of railway (especially in the north and west) and roads next to the shoreline (Table WS.6).

Table WS.6. Number/length of infrastructure assets and networks in Wales located in areas exposed to a 1:75 or greater annual chance of flooding from the sea (present day)

Receptor	Number/length
Clean and wastewater sites	12
Major electricity generation sites	1
Electricity transmission and distribution substations (>5,000 customers)	15
Strategic road network (km)	68
Rail network (km)	68
Rail stations	14
Mobile phone masts	25
Active landfill sites	0

The storms of winter 2013-14 demonstrated the impacts that coastal flooding and storms can have particularly on road and rail services in Wales, with the Barmouth to Harlech rail link severely damaged by the storms and disrupted for several months. Nationally important infrastructure such as oil refineries (Milford Haven) and power stations (Wylfa, Aberthaw, Uskmouth and Pembroke) are also located on the coast.

Around 23% of the Welsh coastline is actively eroding, a natural process that can be exacerbated by heavy or prolonged rainfall and coastal storms. Erosion can have significant impacts on transport networks and some stretches of the road and rail network are in exposed areas.

Sea levels have already risen by around 15cm around the UK coast. Between 50cm and 1 meter of sea level rise is expected over the course of the rest of the century, increasing the likelihood of a severe 1-in-100 year coastal flood in west Wales to between a 1-in-10 and 1-in-20 annual chance. Modelling for CCRA2 suggests the number of assets and length of existing infrastructure networks located in areas exposed to a high risk of flooding from the sea is projected to significantly increase with climate change (Table WS.7).

Table WS.7. Projected change in number/length of infrastructure assets and networks in Wales located in areas exposed to a 1:75 or greater annual chance of flooding from the sea under a trajectory of a 4°C rise in global mean temperature by the end of the century

Receptor	% change
Clean and wastewater sites	+9%
Major electricity generation sites	No change
Electricity transmission and distribution substations (>5,000 customers)	+138%
Strategic road network	+25%
Rail network	+18%
Rail stations	+19%
Mobile phone masts	+49%

Note: Assumes no additional adaptation beyond current plans.

Coastal flooding is projected to become almost as important a driver of annual damages in Wales as river flooding.

Adaptation

Shoreline Management Plans (SMPs) are in place for the full length of the Welsh coastlines. SMPs set out coastline management policies (hold the line, no active intervention etc.) to the 2100s and are developed by Coastal Protection Authorities.

SMP policies have generally been agreed in the absence of detailed cost/benefit appraisal, and affordability considerations, and continuing to hold current defence lines may prove to be unaffordable in practice. This means that despite best intentions, SMPs may underplay the true risk of coastal flooding and erosion. However, local authorities have the flexibility to review their SMPs whenever they wish to do so, making them responsive to evolving situations on their coastlines. SMPs are regarded as living documents that can respond to changing risk scenarios.

A National Policy Statement designated under the Planning Act 2008 establishes the parameters for the development of new nuclear plants in Wales and identifies sites considered suitable for such development. The Nuclear NPS has identified locations for any new nuclear build that are considered to be defendable. These sites were initially selected at a strategic level based on specific criteria, which included the potential effects of climate change, and then any specific applications for sites have to provide detailed information on how climate change effects will be taken into account, including:

- coastal erosion and increased likelihood of storm surge and rising sea levels;
- effects of higher temperatures; and
- increased risk of drought, which could lead to a lack of available cooling water.

Specific sea level rise assessments have been conducted for major ports in Wales. Port operators cite some benefits from higher sea levels, including reducing the potential need to dredge harbours and channels.

Urgency score

More action needed - There is a need to assess whether 'hold the line' policies within SMPs are realistic and affordable in the context of sea level rise, and to identify infrastructure assets at risk should holding current defence lines be economically unviable.

This is needed to avoid lock-in to a particular pathway over the next few decades and will help to create the right conditions to adapt later where changes will long-lead in times are likely to be required, such as the relocation or rerouting of infrastructure networks inland.

In4: Risks of sewer and surface water flooding due to heavy rainfall

Current and future risks

Widespread flooding in 2007 damaged 55,000 properties across the UK, with the majority of damage blamed on drains and sewers being overwhelmed by heavy rain. The floods highlighted that traditional piped sewer systems cannot readily be adapted to deal with increased rainfall, particularly in densely urban areas.

There is a risk that sewer and surface water flooding may be exacerbated by the paving over of front gardens in urban areas. As only 4% of all UK residential paving sales in 2013 were of permeable design, it is highly likely that the majority of surfaces being used to pave over front gardens are impermeable (e.g. concrete block paving, asphalt, etc). Without additional action being taken, it is estimated that a combination of climate change, population growth and continued urban infill development all have the potential to increase the amount of surface water entering the sewer system. This is likely to lead to:

- increased frequency of the sewerage system / urban drainage network exceeding its capacity and increased frequency of surface water flooding when this occurs;
- increased sewer flooding of ~ 50% over next few decades;
- increased Combined Sewer Overspills (and associated impact on water quality);
- reduced capacity for new development (new waste water) in the sewer networks; and
- increased operating costs (associated with pumping more surface water and waste water treatment).

Adaptation

The amount of surface water entering sewer systems will need to be reduced over the long term in order to manage the risk of increased surface water and sewer flooding. Reducing surface water in sewers can be achieved with a variety of techniques, including SUDS and 'green and blue' infrastructure that can also being other benefits. This is likely to be required alongside the 'traditional' techniques of larger underground pipes and underground storage.

Water companies are responsible for the management of sewer flooding and are expected to develop Drainage Strategies to inform their business planning and future delivery, so that they manage flood risk and pollution incidents in a changing climate. As a result, water companies have committed to reduce the number of properties affected by sewer flooding by 33% over the forthcoming Asset Management Plan period (AMP6, 2015-2020).

Welsh Water has made a specific commitment to reduce the volume of rainwater draining into the sewerage system in its current Business Plan (2015-2020). The company has been delivering a "RainScape" programme, which aims to catch, treat and re-direct flows back into the natural environment or slow down the speed at which surface water enters sewers. A target has been set to reduce the volume of surface water entering the sewerage network even further, so that by 2020 the amount of surface water equal to the run-off from the roofs of some 25,000 properties will bypass sewers and be redirected to local watercourses via structures such as landscaped channels. Welsh Water will spend £60m over the course of AMP6 in order to achieve these targets.

There are, however, a number of barriers to water companies widely retrofitting SuDS. These include:

- Reducing surface water in sewers can only be done gradually over the long term, making it difficult to justify current investment to regulators and customers
- Uncertainties in implementing and maintaining SuDS compared to traditional drainage, including around costs, effectiveness and timescales of when benefits will be realised. This makes it more difficult to justify to regulators and customers.
- Capacity and resources in water companies to appraise, design, build and maintain a SUDS and green infrastructure.
- Water companies may not be able to implement all the types of surface water reduction actions on their own. It is likely to require coordination with other authorities and planning processes that govern surface water e.g. highways authorities responsible for road drainage and flooding authorities responsible for surface water flooding.

As well as retrofitting, ensuring that new development does not further add to the risk of sewer flooding is also a priority for managing this risk. National planning policy states that surface water run-off is to be controlled as near to the source as possible by the use of sustainable drainage systems, and local planning authorities are advised to impose conditions requiring SuDS to be provided on new developments. Technical Advice Note TAN 15 provides guidance to developers and local authorities on SuDS.

There is some evidence that SuDS uptake in new development remains low, although there is no monitoring in place within any of the UK nations. It is therefore uncertain whether key barriers to the use of SuDS are being addressed. These include developers retaining the automatic right to connect new homes to the public sewer system (for surface water) without regard given to their capacity and the issue of who has responsibility for the on-going maintenance of SuDS once they are in place.

Urgency score

More action needed - There is a need for higher uptake of SuDS in new development and for widespread retrofitting of SuDS schemes and green infrastructure into the built environment in order to relieve pressure on the public sewer system. Embedding long term planning (drainage strategies) in the management of sewer networks will help overcome barriers to water company action to reduce surface water in sewer networks. There is also a need to improve coordination between surface water processes; water company management of sewer networks, roads authority road drainage and local authority surface water management.

As well as directly reducing vulnerability to sewer and surface water flooding, this will also have benefits for managing a range of non-climate related risks, including improvements to water quality, biodiversity and amenity. SuDS are in most cases also cost-effective to implement now.

In5: Risks to bridges and pipelines from high river flows and bank erosion

Current and future risks

High and fast river flows can cause localised riverbank erosion, undermining structures such as bridges and exposing buried cabling and pipework, undermining structures such as bridges and exposing buried pipelines. Bridges carry services (gas, telecoms, power) as well as people and road/rail traffic. Loss of bridges can therefore have multiple impacts. Across the UK, bridge scour on average causes one bridge failure per year.

Peak river flows in west Wales are expected to increase by about 13% by the 2020s, 20% by the 2050s and 30% by the 2080s compared with the 1961-90 baseline. Despite this, there has not been any national-level modelling of how risk may increase in the future for Wales.

There are some significant uncertainties on the structural integrity of road and rail bridges, many of which were built over a century ago. It is also not known at a national level which bridges are used for gas pipelines/electricity cables, although service providers have this mapped at the local level.

Adaptation

Bridge scour is not considered as a separate risk in Network Rail's climate change adaptation programme for Wales, but a programme of bridge scour protection is underway that will significantly reduce the risk of bridge failure due to scour at the foundations. This will also reduce the number of areas that incur line restrictions during periods of flooding. However, a national assessment of bridge scour has not been performed for Wales and the structural integrity of road and rail bridges is not always known, many of which were built over a century ago. As with slope instability, this makes the proactive management of bridge scour more difficult.

Urgency score

Research priority - more research is needed to identify the number of bridges at risk of scour now and in the future and the amount of adaptation underway nationally. This will provide the early steps to enable better decisions in the near future (next 5 years), especially where measures may be required that have long lead times such as relocating or rerouting bridges.

In6: Risks to transport networks from slope and embankment failure

Current and future risk

Older, less well compacted earthworks such as those supporting the rail network are deteriorating at a faster rate than newer earthworks built to more modern construction standards. However, Network Rail's climate change adaptation plan for Wales suggests earthwork failures are rarely a cause of passenger disruption (£53,000 annualised Schedule 8 costs from landslips over the six year period to 2013/14, or 3% of weather-related passenger delay minutes). During the very wet winter of 2013/2014, rail routes in Wales experienced three landslides resulting in extended periods of speed restrictions.

Modelling shows that across low to high emissions scenarios soil moisture fluctuations will lead to increased risk of shrink-swell related failures. The issue is expected to be most acute in the high plasticity soils of south-east England but may also cause problems in Wales given the long lengths of road and railway located in often steep valleys. Increased incidences of natural and engineering slope failure effecting the road and rail network in the winters of 2012/2013 and 2013/2014 demonstrate their vulnerability to the type of intense rainfall events that are expected.

Adaptation

Network Rail's adaptation plan for Wales lists the risk of earthslips as a high priority for remedial action. Using a national tool, 166 risk sites have been identified and filtered down to a list of 60 where stabilisation works are thought necessary at this time. It is expected that 70-80% of these sites will be addressed during the current investment period to 2019. Network Rail now receives tailored weather warnings from the Met Office regarding soil moisture saturation and heavy rainfall alerts. The Welsh Government's draft National Transport Plan 2015 recognises the issue of slope stability for both road and rail services and steps are being taken in design standards to future proof assets against climate change.

In contrast to the rail sector, much of the trunk road network has been built since the 1950s, using modern materials and design standards, and has been maintained more consistently over recent decades. Disruptions to the network from severe weather can be managed in the same way as other causes, such as roadworks and major accidents, due to lasting physical damage to roads and assets being unlikely**.**

Urgency score

More action needed - further action is required to ensure that projected increases in heavy rainfall events are factored into long-term renewal programmes for earthworks and embankment renewals for the rail network. This will reduce vulnerability now, and is likely to be cost-effective to implement given that the risk is increasing with further asset deterioration combining with heavier and more frequent rainfall events.

In9: Risks to public water supplies from drought and low river flows

Current and future risks

Wales currently has a comfortable 12% (104 Ml/d) supply/demand surplus in its public water supply, with all water resource zones in Wales having a supply/demand surplus once target headroom is taken in to account.

Climate change is expected to restrict the supply of water whilst population growth will add to demand. However, the majority of 24 Water Resource Zones in Wales are projected to remain in surplus until at least the 2080s even under a high population and high climate change scenario, with only three reporting deficits of more than 5 Ml/d. Overall, Welsh Water has a projected deficit of 69 Ml/d by 2050s and 136 Ml/d by the 2080s, equivalent to 8% and 15% of the corresponding demands under such projections.

Adaptation

Water supply in Wales is regulated under the Water Acts of 2003 and 2014. Water companies are required to prepare Water Resources Management Plans (WRMPs) every five years. These set out how water companies plan to balance water supply and demand over the next 25 years, taking into account the effects of climate change as well as other factors such as population growth and reductions in abstraction required to improve the ecological condition of rivers and lakes. Water companies also submit their business plans to the economic regulator as part of a five-yearly process known as a Periodic Review. These are used by the regulator to set limits on the price customers pay for the supply of water and treatment of wastewater, the outcomes companies must deliver, and the incentives in place to support delivery. Regulators use the WRMPs to assess the measures companies' need to undertake to manage the risk of supply-demand deficits. The latest Periodic Review was completed in December 2014. This sets price limits for the next Asset Management Plan period, AMP6, from 2015 to 2020. The next WRMPs are due in 2019 to inform AMP7. The 2014 Water Act introduced a 'resilience duty' that requires Ofwat and the Secretary of State to secure the long-term resilience of water company supply systems and ensure that water companies take steps for the purpose of enabling them to meet, in the long term, the need for the supply of water. Water companies already plan for droughts as part of their Business Plans, and the Water Act also includes an additional power for the Secretary of State to direct water companies to plan for droughts of a specified magnitude.

In the current round of WRMPs, water companies have put forward plans to deal with projected deficits in their regions over the period to 2040. Collectively, these would reduce demand by 300 Ml/day, reduce leakage by 230 Ml/day and increase supplies by around 870 Ml/day. These measures, if fully implemented, are likely to be sufficient to deal with supply-demand deficits at the national scale under low to medium climate change projections by the 2050s, though not the high-end estimate of the potential deficit.

Steady progress has been made in reducing demand and leakage over the previous decade. The demand-side measures in WRMPs would go some way to reducing consumption per person, but only to around 135 l/day by 2040. Previous analysis by the ASC suggests more ambitious levels nearer to 115 l/day are technically feasible by 2040 with the wider uptake of cost-effective water efficiency and recycling measures. Almost all (90%) of the collective 300 Ml/day reduction in demand currently proposed by 2040 will have been achieved by 2025. This suggests that the next round of WRMPs in 2019 could ramp-up effort on demand-side measures in the second half of the 2020s and into the 2030s in order to deliver more ambitious, but technically achievable, reductions in consumption by 2040. More action is likely to be needed to achieve more ambitious levels of demand reduction, given the scale of behavioural change and uptake of technologies required. Customers do not generally comprehend the level of risk they are exposed to, and so are not in a position to express well-formed preferences about willingness to pay for improvements in resilience. Leakage rates fell sharply after the drought of 1995 but have since levelled off at around 22% of total public water supply. There was a slight increase in leakage rates in 2010 and 2011 when cold winters caused more pipes to burst. Leakage rates in cities in England and Wales (around 25% of supply) fall within the range of other European cities, where leakage levels vary from 5% to 50% of total supply. Steady progress on leakage is a necessary political precursor to interventionist action on demand. Without evidence that leakage is being actively managed to tolerably low levels, customers will not be willing to take active steps to manage demand themselves.

Supply-side measures begin to dominate in the current round of WRMPs from 2025 onwards. Measures such as effluent re-use, reservoir construction and the development of new and existing groundwater sources account for nearly all of the proposals to deal with future deficits from the mid-2020s onwards. Collectively, these measures are expected to bring an additional 870 M/l day of supply to the system by 2040, nearly three-times more than the expected savings from demand-side measures. Additional supply-side measures that are not in the current plans may also potentially be available, and could be included in the next round of WRMPs in 2019. These include options such as desalinisation and bulk transfer schemes between water companies. Proposed reforms to the abstraction regime may also potentially deliver extra sources of water, through improved catchment management, increased on-farm water storage and river restoration. However, there is some uncertainty on the feasibility, viability and potential scale of some of these measures.

Furthermore, a number of supply-side measures have long-lead in times and therefore require long-term planning. This is particularly the case with water supply infrastructure with a significant land-requirement such as reservoirs. Gaining planning permission for large-scale infrastructure can be time consuming. The absence of strategic long-term planning for water-supply infrastructure means that new development could be occurring in locations that may be required for water infrastructure in the future. It also means that investments being currently planned are not being tested for their effectiveness over extended timescales.

Urgency score

More action needed - Although the policy framework is broadly in place through the WRMP process and the new resilience duty under the 2014 Water Act, more action is needed in the next five years to (a) enable a significant ramping-up of demand-side measures and (b) put in place a more strategic, long-term planning process for supply-side infrastructure. More action will be needed in the next five years to ramp-up demand-side measures in the next round of WRMPs from 2019. Consideration will also be needed of whether the current economic regulatory regime should place further emphasis on the need for more ambitious reductions in consumption and leakage. Other policy interventions may also need to be considered, such as further regulations on water efficiency in new development or more proactive rolling out of metering.

The next round of WRMPs should also start considering the feasibility of implementing further supply-side options that may be needed in the second half of this century, and consider the lead times that would be necessary to take such action. Consideration should be given to a National Policy Statement on water supply infrastructure to be produced within the next five years that provides more certainty for the implementation of supply-side measures. Consideration should also be given to whether revisions to national planning policies are required, in order to ensure the safeguarding of land that may be required for new water-supply infrastructure in the future.

More action is also needed in the next five years to integrate drought planning with the WRMP process. This could include more stress testing of both WRMPs and Drought Plans with a wider range of climate change (particularly low flow and drought) scenarios. There is also a case for the next round of WRMPs to look further ahead (i.e. operate on a 50-year rather than 25-year time-frame).

In11: Risks to energy, transport and digital infrastructure from high winds and lightning

Current and future risks

High winds are a significant cause of disruption to electricity networks, causing 20% of all customer disruption between 1995 and 2011. Over 2 million customers suffered power cuts in the winter storms of 2014/15, of which 16,000 were without power for more than 48 hours. The majority of damage and disruption to the network from high winds is due to trees and branches falling onto power lines. Tree-related faults on the UK's electricity distribution network significantly increased between 1990 and 2006. The observed increase in the duration of the growing season, which has gained ten days in Northern Europe since the 1960s, is likely to be contributing to this trend. Lightning strikes were responsible for 8% of total disruption to electricity distribution networks between 1995 and 2011.

On the GB rail network, 5% of all passenger disruptions between 2006 and 2013 were due to high winds. As with electricity networks, the majority of damage is caused by trees or substantial branches being blown on to railway tracks, blocking services, causing damage to trains and bringing down cabling. There are an estimated 2.5 million trees growing near to the rail network and during the winter of 2013/14 there were 1,500 incidents of trees and other foreign objects being blown onto tracks. It is estimated that 60% of wind-blown trees came from land not owned by Network Rail. Other third party items, such as trampolines, garden sheds and polythene sheeting, also cause disruption. Network Rail report high winds as the second highest cause of weather–related disruption in Wales, with £350,000 annualised Schedule 8 costs.

Between a 4% to 36% increase in the numbers of faults due to lightning by the 2080s is projected (for low and high climate scenario respectively) for the electricity transmission and distribution network. Longer growing seasons are likely to result in further increases in vegetation growth rates which will, in the absence of additional management, increase the number of tree-related faults and disruption to electricity and rail networks. No projections exist for future storm or lightning damage to rail services.

Adaptation

There are vegetation management procedures and standards in place for both electricity distribution and rail networks and a significant amount of action being taken.

Electricity network operators have a statutory requirement to keep overhead power lines clear of vegetation for public safety reasons. Since 2006 operators have also been required to undertake a risk assessed programme of "resilience vegetation management". The Energy Networks Association (ENA) produced an Engineering Technical Report (ETR132) in 2006 to guide implementation against this requirement. The standard requires operators to deliver proactive tree cutting and felling programmes targeted towards critical overhead lines, to improve performance in storm conditions. Across the electricity distribution companies, £8 million a year was spent on implementing resilience vegetation management between 2011 and 2015. This is projected to increase to £15 million a year from 2016 to 2023, resulting in total expenditure of around £158 million over the period 2011 to 2023.

Network Rail has launched a Vegetation Management Capability Development Programme to introduce new standards and action to manage lineside growth.

However, there is limited modelling of the potential impacts of future increases in the length of the growing season for tree-related faults. It is also not clear whether sufficient action is being taken to improve resilience to the projected increase in faults to the electricity distribution network caused by lightning strikes.

Urgency score

Research priority - There is a need for further modelling of the risk of increased tree-related faults to energy and rail networks due to increased vegetation growth rates. There is also a need for better understanding of projected changes in maximum wind speeds and the frequency of such events. If maximum wind speeds were to increase it would have an impact on the strength design of overhead electricity lines, poles and pylons. This will help to create the right conditions to adapt later if it becomes apparent that additional interventions are likely to be required to manage the change in risk.

In13: Risks to transport, digital and energy infrastructure from extreme heat

Current and future risks

Rail and electricity transmission and distribution networks are the sectors most vulnerable to impacts during periods of high temperatures. Average summer temperatures in Wales are expected to increase by 1.9 - 5.8°C by the 2080s (medium emissions, p10 and p90 values). Hot weather has the potential to cause train service cancellations and speed restrictions, and require de-rating of overhead power lines. High temperatures can also affect what maintenance can be performed, for example making tensioning rail track difficult due to thermal expansion or by new road tarmac drying too quickly. However, Met Office analysis of historical fault data on electricity transmission and distribution networks found that solar heat faults are a relatively low risk compared with other weather-related causes of faults in Wales. Heat impacts caused less than £0.5 million to Network Rail in Schedule 8 compensation payments to the train operating companies over the eight years to 2013/14.

Increases in ambient temperatures across the UK due to climate change could lead to line de-ratings (reduction in maximum capacity) of 6 – 10% for typical distribution lines and 2 – 4% for typical transmission lines under a high emissions scenario for the 2080s. De-ratings on underground low voltage cables would be within 2 – 4% in the 2080s (high emission scenario) and 2 – 7% for cables carrying 11 kV and above for the same timeframe. Higher temperatures also reduce the efficiency of transformers, with projected reductions of 4 – 7% for 11 kV and 3 – 5% for >33 kV transformers for the 2080s (UKCP09 high emission scenario at the 90% probability level). Some components could de-rate by as much as 27% in some summer days in the 2080s. This climatic component of de-rating adds to the effect of other drivers that, based on current projections, are expected to place greater pressures on the need to uprate cables. For example load increases, which include low carbon loads such as electric vehicles, have been recorded at up to 2% per year by some distribution network operators.

Adaptation

Were it to become necessary in Wales, the de-rating of power lines during hot weather is a standard operational procedure that has no short or long-term consequences. Assets and equipment used in electricity networks conform to international standards and are proven in countries with analogous climates to that expected later this century. Electricity DNOs are already taking steps, such as to change their specification for poles carrying overhead lines to be 50cm to 1 metre taller to allow for increased sagging in hot weather without breaching ground clearance safety levels.

Adaptation in the rail sector is more difficult, due to the extent of exposure and the costs of upgrading track and lineside equipment. The risk of heat-related impacts has been assessed as part of the Network Rail's Wales Route Climate Change Adaptation Plan and assigned a 'medium' priority, below high wind and flooding, which already cause significantly greater problems. Given the scale of current impacts and the adaptation strategies underway this risk for all the relevant sectors in Wales is a watching brief.

Urgency score

Sustain Current Action - Planned levels of future activity are appropriate, but continued implementation is needed to ensure that the risk is managed in the future.

In14: Potential benefits to water, transport, digital and energy infrastructure from reduced extreme cold events

Current and future risks

Cold weather (including snow and ice) is a major cause of disruption to transport services, and electricity transmission and distribution. For example, snow and ice account for 13% of weather-related impacts to the UK high voltage electricity distribution network. The average number of extreme cold days is likely to diminish over the course of the century. Cold winters will still be possible, but are expected to become increasingly unlikely. There may be opportunities arising from fewer snow and ice days reducing winter disruption and maintenance costs.

However, a low probability H++ scenario involving slowdown of the gulf stream and low solar activity could reduce average winter temperatures from to around -5ºC, with daily temperatures falling to -18ºC. This scenario is unlikely this century but is physically plausible and cannot be ruled out.

Adaptation

Autonomous adaption to the decreasing incidence of severe cold weather days can be expected.

Urgency score

Sustain Current Action - Planned levels of future activity are appropriate, but continued implementation is needed to ensure that the risk is managed in the future.

Other Risks

Other risks considered as part of the infrastructure chapter but considered to fall in to the 'watching brief' category for Wales include:

In7: Hydroelectric generation affected by low flows in summer / high flows in winter. Hydroelectric generation is a major component of power capacity in Wales (around 25% of installed capacity) with two major pumped storage schemes at Dinorwig and Ffestiniog. Hydropower output may be reduced (particularly in summer) and increased in winter (representing an opportunity) and is vulnerable to both extreme flooding and drought. Excess water levels may need to be sluiced from reservoirs, leading to environmental damage downstream. Impacts of increased or reduced hydropower generation can be managed using normal operation procedures on the national grid.

In8: Subsidence risk to subterranean infrastructure. Falling and rising moisture levels - particularly in clay-rich soils - cause shrink-swell subsidence, the most damaging geohazard in Britain today (£300 million annual costs, BGS 2014). Subsidence has a strong regional pattern, with London and the east of England most susceptible. However, incidents tend to be isolated and localised, meaning incident response and recovery is likely to be the most cost-effective means of managing the risk by operators.

In10: Risks to energy generation from drought and low river flows. Power stations are a significant user of water, both freshwater from inland sources and tidal and coastal waters, although most of the abstracted water is returned to the environment. Power stations in Wales can generate about 10GW of energy, about 14% of the overall UK major non-wind generation capacity (DUKES July 2015). Most of the power stations are fossil fuel (coal or gas) on coastal or estuary sites, meaning there should be no shortage of cooling water available. One nuclear station is located in Wales (Wylfa, Anglesey), using sea water for cooling. There are currently no plans to install water-intensive carbon capture and storage (CCS) facilities in Wales, with CCS infrastructure more viable on the east coast on England and Scotland near to storage sites in the North Sea.

In12: Risks to offshore infrastructure from storms and high waves. The majority of offshore infrastructure in the UK is in the North Sea, so this is not a high priority risk for Wales.

5. People and the built environment

The CCRA Evidence Report suggests that there are potential health benefits from warmer winters in Wales, but more action is needed to manage current risks to people from cold temperatures through addressing fuel poverty.

Research is needed urgently in order to assess the need for additional action across a number of areas including risks to people from heat and flooding; risks to the viability of coastal communities from sea level rise; risks to buildings and cultural heritage from extreme weather; risks to the health and social care sector; and risks to health from changing air quality and from vector-borne diseases.

Table WS.8. Urgency scores for people and the built environment

Risk/opportunity (reference to relevant section(s) of CCRA Evidence Report)	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
PB1: Risks to health and wellbeing from high temperatures (5.2.2, 5.3.2, 5.5.3)	England	Northern Ireland, Scotland, Wales			There are around 2,000 heat-related deaths per year across the UK. The risk to health is projected to increase in the future as temperatures rise. The current and future level of risk in Wales is unknown for homes, hospitals, care homes, schools, offices and prisons. Policies do not exist at present to adapt homes or other buildings to higher temperatures projected for the future..
PB2: Risks to passengers from high temperatures on public transport (5.3.9)		Wales	England	Northern Ireland, Scotland	More information needed on risks to public transport in Wales.
PB3: Opportunities for increased outdoor activities from higher temperatures (5.2.3)				UK	Leisure and other activities are likely to be taken up autonomously by people as the climate warms.

Table WS.8. Urgency scores for people and the built environment

PB4: Potential benefits to health and wellbeing from reduced cold (5.3.3, 5.5.4)	UK				Currently there are between 35,800 and 49,700 cold-related deaths per year across the UK. Climate change is projected to reduce the health risks from cold, but the number of cold-related deaths is projected to decline only slightly due to the effects of an ageing population increasing the number of vulnerable people at risk. Further measures need to be taken in the next 5 years to tackle large numbers of cold homes and reduce cold effects on health, even with climate warming.
PB5: Risks to people, communities and buildings from flooding (5.2.5, 5.3.4, 5.5.1)	England	Northern Ireland, Scotland, Wales			Increases in flood risk cannot be avoided in a 4 degree world even under the most ambitious adaptation scenarios considered by research supporting the CCRA. Future spending plans and how these related to the level of risk in Wales are unclear.
PB6: Risks to the viability of coastal communities from sea level rise (5.2.6, 5.2.7)		UK			Research is needed to better characterise the impacts from sea level rise on coastal communities, thresholds for viability, and what steps should be taken to engage and support affected communities.
PB7: Risks to building fabric from moisture, wind and driving rain (5.3.4, 5.3.6, 5.3.7)		UK			More research is needed to better determine the future level of risk and what further steps might be appropriate.
PB8: Risks to culturally valued structures and the wider historic environment (5.3.8)		UK			Climate-related hazards damage historic structures and sites now, but there is a lack of information on the scale of current and future risks, including for historic urban green spaces and gardens as well as structures.
PB9: Risks to health and social care delivery from extreme weather (5.4)	England	Northern Ireland, Scotland, Wales			There is a lack of evidence regarding how the level of action within the health and social care sector in Wales relates to the level of risk.

Table WS.8. Urgency scores for people and the built environment

PB10: Risks to health from changes in air quality (5.2.2, 5.3.5, 5.5.5)		UK			More research is needed to understand the influence of climate change on ground level ozone and other outdoor air pollutants (especially particulates), and how climate and other factors (e.g. individual behaviour) affect indoor air quality.
PB11: Risks to health from vector-borne pathogens (5.5.2)		UK			Further research is needed to improve the monitoring and surveillance of vector species and related infectious disease, and to assess the extent to which current efforts are focussed on those infections that pose the greatest long-term risks.
PB12: Risk of food borne disease cases and outbreaks (5.5.6)				UK	Regulations in place to monitor and control food-related hazards should be kept under review.
PB13: Risks to health from poor water quality (5.5.6)			UK		Current policies and mechanisms to assess and manage risks to water quality in the public water supply should continue to be implemented.
PB14: Risk of household water supply interruptions (5.2.4)			UK		Policies are in place to safeguard the continuity of public water supplies during droughts and from burst pipes in cold weather. These risks should be kept under review to make sure long-term risks continue to be managed appropriately.

PB1: Risks to health and wellbeing from high temperatures

Current and future risks

High temperatures have a negative effect on human health and wellbeing. There is a robust relationship regarding the effect of temperature extremes on acute mortality. High temperatures are also associated with an increase in hospital admissions for respiratory causes, and there is some evidence suggesting an increase in GP consultations. At the UK level, there are around 2,000 heat-related deaths per year (high magnitude, high confidence). In Wales, there are currently around 2.4 excess deaths per 100,000 population (which with a population of 3.1 million equates to 74 excess deaths per year).

Indoor exposure to heat is likely to drive much of the current risk as people spend roughly 90% of their time indoors. However, there is a lack of evidence on current temperature trends in all building types in Wales.

The frequency of overheating thresholds being exceeded is projected to increase in the future. Heatwave events such as the 1976 or 2003 heatwaves in the UK are likely to become the norm between 2030 and 2050. The intensity of heat waves in Europe is projected to increase in the future by between 1.4ºC and 7.5ºC for a rise in global mean temperature of 2ºC. Uncertainties remain in the magnitude of the increased intensity because of sensitivity to the modelling of the physics associated with vegetation and drying of the soil. The population aged over 75 in Wales is also projected to increase from 9% in 2015 to 19% in 2085.

Heat-related mortality in Wales in the 2050s is estimated to increase to between 3.1 and 14.3 per 100,000, based on the UKCP09 medium emissions scenario. Assuming no population growth, this equates to between 96 and 443 deaths. With population growth this figure would be higher (high magnitude, medium confidence).

Adaptation

It is plausible that some degree of autonomous physiological adaptation will take place in response to gradual increases in mean temperature. However, it is less likely that this will occur in response to higher extreme temperatures, particularly if overall temperature variability increases, as people are less able to adapt to sudden increases in temperature over a short period of time. There is some evidence that people lack awareness of the risks to health from indoor high temperatures, and thus they are less likely to take measures to protect themselves.

The presence of air conditioning in housing is currently low across the UK (3% of homes). Although uptake of mechanical cooling may increase autonomously in the future, relying on air conditioning to deal with the risk would be a maladaptive solution as it expels waste heat into the environment – thereby enhancing the urban heat island effect – and can increase carbon emissions if powered from non-renewable electricity sources.

At present there are no policy levers in Wales to specifically control overheating through passive cooling or other means in existing homes. Wales no longer has a formal Heatwave Plan, but does publish public health guidance (Extreme Weather Public Health Alerts & Advice for Wales 2015). There have been some surveys of the effectiveness of these types of plans, but it remains unclear how effective these are at changing people's behaviour, so it cannot be assumed that such activities will necessarily manage the risk in the future.

Urgency score

Research priority - There is a lack of evidence on the total level of risk and the benefits of acting for all types of buildings in Wales. More research is also required to better understand how people behave in hot weather and the effectiveness of measures to encourage the public to protect themselves.

PB2: Risks to passengers from high temperatures on public transport

Current and future risks

Higher temperatures have been cited as a risk to the effective functioning of urban transport networks – such as on trains and buses - because of risks to commuter comfort and health. However, the exact level of risk for Wales is not well quantified (at least in the published literature). The current and future magnitude of this risk on an annual basis is unknown and it therefore has low confidence.

Adaptation

The current and future level of risk is not well understood, and it is not known if there is any work underway in Wales to assess the specific risks of overheating on public transport.

Urgency score

Research priority – more research is needed urgently to understand the level of risk and action underway, given the relatively high potential for heat related health impacts in Wales (see PB1).

PB4: Potential benefits to health and wellbeing from reduced cold

Current and future risks/ opportunities

Cold-related mortality is significant across the UK. In Wales, there are around 74 - 102 deaths per 100,000 population per year from cold (which with a population of 3.1 million equates to 2,295 – 3,160 deaths per year) (high magnitude, medium confidence). The risk in Wales is relatively high compared to other areas of the UK, which in turn remains high compared to other NW European countries.

Poor quality housing (cold homes) are a major determinant of the burden of cold related mortality and morbidity. Fuel poverty levels are therefore often used as a proxy indicator for exposure to cold, and have seen little change over the last decade. In 2011, 26% of households in Wales were classed as fuel poor.

Higher temperatures from climate change will reduce the risk of cold-related deaths but this will be offset to a large extent by the increase in the older population. One study projects a reduction in cold-related mortality in Wales in the 2050s to between 55 - 75 per 100,000 per year, based on the UKCP09 medium emissions scenario. Assuming no growth in population, this would equate to 1,705 – 2,325 deaths per year (high magnitude, low confidence).

Adaptation

The risk is projected to decline somewhat over time as winters warm, but will still be the largest weather-related driver of mortality in the 2050s without additional action. It is important that policies are further developed and implemented to address fuel poverty without increasing the risk of overheating. There is a lack of evidence on what policies are underway in Wales to reduce exposure to cold.

Urgency score

More action needed - Further work is needed to reduce fuel poverty, including understanding the level of action and its effects in Wales; and to put in place steps to ensure that further insulation of the housing stock does not increase overheating risk in the summer.

PB5: Risks to people, communities and buildings from flooding

Current and future risks

Flooding is a threat to life. Studies from other populations have shown that significant mortality events are mostly associated with flash flooding. There is no precise estimate of flood mortality for the UK, as the definition of a flood death can vary. Mortality associated with flooding can include related car accidents, and other accidents, e.g. from persons falling into fast flowing water. The wider social impacts of flooding are not well quantified but include lack of access to services and loss of school and work days. All income groups are at risk of adverse consequences, and low-income households may take longer to adapt or recover. Large systematic reviews of epidemiological evidence suggest that flooding has adverse effects on mental health and wellbeing. The main epidemiological evidence relates to common mental disorders (i.e. anxiety and depression) and measurable posttraumatic stress syndrome. There are a wide range of values given for the number of people affected after a flood event.

According to Sayers et al. 2015, there are 160,000 residential properties at any degree of risk from flooding across Wales, of which 51,000 (4%) are in areas at a 1-in-75 or greater annual chance of flooding or greater. This equates to 95,000 people at 1-in-75 or greater risk. The Welsh Government estimates the number of residential properties at any degree of risk from flooding as 148,150.[8] Current expected annual damage to residential properties in Wales is estimated to be £22 million (medium magnitude, medium confidence).

Assuming no population growth and a continuation of current levels of adaptation, by the 2080s, the projections from the CCRA suggest 142,000 people under a 2 degree scenario and 209,000 people under a 4 degree scenario would be living in areas of Wales at a 1-in-75 or greater chance of flooding in any given year (medium magnitude, medium confidence). Expected annual damage to residential properties in Wales is projected to rise by between 35 – 110% in the 2050s and 59 - 220% in the 2080s depending on climate scenario (medium magnitude, medium confidence).

Adaptation

The Welsh Government is responsible for flood and coastal erosion risk management policy and funds flood and coastal defence works delivered by local authorities and Natural Resources Wales, in accordance with the 2011 National Strategy for Flood and Coastal Erosion Risk Management in Wales.

The Environment (Wales) Act 2016 has created a Flood and Coastal Erosion Committee that reports to the Minister for Natural Resources. It provides an advisory role to Welsh Government and NRW on the management of all sources of flood risk and coastal erosion in Wales and encompasses the flood and erosion risk management work of all Risk Management Authorities operating in Wales, Local Resilience Forums and other organisations and groups.

In December 2014, the Welsh Government consulted on a new approach to allocating national funding to flood and coastal erosion alleviation projects, based on compiling a Flood Risk Index for each area in Wales and using this as a basis for prioritisation. A total of £285 million has been allocated for investment in flood and erosion risk management measures between 2011 and 2016. It is not known what effect this investment has had on the number and exposure of properties in areas at high risk of flooding.

Long-term investment scenarios were produced by Environment Agency Wales in 2009. The scenarios, which applied a central emissions scenario and accounted for population growth, identified the amount of investment required to hold flood risk at current levels and the funding needed to reduce long-term risk. The analysis suggested that annual spending would need to be three times current levels for the overall level of risk to not increase (in terms of number of properties) by the mid-2030s.

[8] https://naturalresources.wales/media/1039/flood-and-coastal-erosion-risk-management-in-wales-2011-2014.pdf

Investment in individual property protection measures began in 2010/11, and since then over 600 properties have benefitted, with over £850,000 invested by Natural Resources Wales. Analysis has not yet been conducted to consider what the cost-effective uptake of Property-Level Resilience (PLR) in Wales would look like and therefore how far current investment goes towards an economically optimal level. The Welsh Government published interim, non-statutory sustainable urban drainage (SuDS) standards in early 2016.[9]

Urgency score

Research priority - More evidence is needed to assess precisely how the current level of action relates to the level of risk in Wales. Some further actions that could help to understand the effects of current action on risk include:

- Reviewing future plans for flood defence spending and considering how the Government should balance future flood defence investment against other measures such as property-level and community-level flood protection measures.
- Improving the implementation of sustainable urban drainage systems/designing urban areas to better manage local flood risks.
- Better understanding of and accounting for the actual change in flood risk from new development on the floodplain.
- Capacity building at the community level.

PB6: Risks to the viability of coastal communities from sea level rise

Current and future risks

Monitoring and understanding sea-level rise at the local level is difficult as the actual level of sea-level rise at any one place depends on a wide range of factors including oceanographic features and the gravitational variation across the Earth. The current level of risk to the viability of coastal communities in Wales from sea level rise (not including coastal erosion) is thought to be low (low magnitude, high confidence), but the future risk is uncertain and could be significant.

Some locations in Wales are known to be at risk from long-term changes to the coastline, such as the village of Fairbourne. Baseline rates of coastal erosion are between 30 and 100 metres per century. With sea-level rise, the rates could be 1.75 – 2.5 higher than the baseline due to strengthened wave action and other factors (equivalent to 52 – 250 metres per century). The Shoreline Management Plan for Fairbourne states that while the village's defences can and should be maintained for several decades (c. 40 years) in the long term the defences are unsustainable. The dominant factor in the case of Fairbourne is the rate of sea-level rise, about which there is much uncertainty.

Adaptation

Shoreline Management Plans (SMPs) are in place for the full length of the Welsh coastline. SMPs set out coastline management policies (hold the line, no active intervention etc.) to the 2100s and are developed by Coastal Protection Authorities.

[9] http://gov.wales/docs/desh/publications/151230-suds-standards-en.pdf

The SMPs set out the risks to coastal areas from erosion and sea-level rise and indicate how local authorities and other bodies can plan and implement coastal management in terms of holding the line, managed realignment and no active intervention. It is not known whether the approaches and actions implied by the plans are being adopted. The plans in general do not consider the impacts of loss of coastal communities and what measures should be taken to manage this change. The coastal policies emerging in the SMP for Fairbourne provide several approaches for different parts of the coast near Fairbourne involving holding the line, managed realignment and no active intervention, to be brought in as sea-level rise proceeds. By 2105 there would be no active intervention along the whole of the Fairbourne section of coast. From 2055 managed realignment would include relocation of Fairbourne residents and businesses.

Urgency score

Research priority - There is a need to assess the need for long-term plans – including and in addition to shoreline management plans - for coastal communities across Wales that are at risk of being lost as a result of sea level rise.

PB7: Risks to building fabric from moisture, wind and driving rain

Current and future risks

Building fabric can be damaged following a flood through damp, mould and the deposition of salts and sediments as a result of being flooded.

Moist atmospheric conditions can also affect the fabric of buildings. During warmer spring and autumn weather, the moisture removal capacity of outdoor air may be reduced, meaning additional ventilation may be required to adequately remove moisture produced inside a building. Reverse condensation, or interstitial condensation, may occur in spring and autumn, when damp walls are heated by solar radiation to the extent that moisture can migrate towards the cooler interior of the building.

In many locations, particularly in coastal areas, buildings may be exposed to driving rain. The installation of full-fill cavity wall insulation in locations with wind-driven rain can lead to damp, as the insulation retains water that penetrates the façade, and can bridge moisture into the inner walls. There have been no population-wide studies that link the prevalence of mould in buildings to flooding or other climate risks.

There are no projections of future damage to buildings in Wales caused by damp/mould, driving rain and wind (unknown magnitude, low confidence).

Adaptation

Part C of the Building Regulations for England and Wales covers resistance to moisture. As yet there are no published studies that assess the effectiveness of these regulations or other policies and actions in protecting buildings against damp, mould, wind and driving rain.

Urgency score

Research priority - Further research is needed to understand the following:

- The degree of current and future risk of different types of buildings or buildings in different areas to driving rain, mould, and damp.
- What adaptations are taking place at a national level, and how widespread these are.

PB8: Risks to culturally valued structures and the wider historic environment

Current and future risks

Climate change is likely to affect culturally-valued buildings and their immediate surroundings, such as parks and gardens, from the effects of extreme events (e.g. flooding, erosion, land instability, or wind storms) and longer-term, chronic damage to a building fabric. NE14 also considers risks to the wider historic landscape including archaeological sites.

Although some strategic planning, risk assessment work, case and scoping studies have been conducted, and there is some understanding of how climate change might affect historic building materials, there is little or no quantitative information on the level of current and future risk for historic buildings and grounds in Wales. Many listed buildings are in private hands and there are is no national-level assessment of what risks these buildings face from climate change (unknown magnitude, low confidence).

Adaptation

Although the risks to historic buildings and gardens are not quantified at the national scale, there are plenty of case study examples which show that there are impacts from extreme weather now, and these are likely to increase in the future (see Chapter 5 of the Evidence Report for examples). Work is in progress to better understand risks and adaptation options including weather proofing and additional flood protection. The Sectoral Adaptation Plan for the historic environment of Wales seeks to identify specific gaps in knowledge across the range of historic asset types, as well as developing strategic actions on policy and awareness raising, for example. The Plan builds on the research report "A strategic approach for assessing and addressing the potential impact of climate change on the historic environment of Wales", published in September 2012. This plan developed a series of risk metrics that assessed the significance of the impacts based on indications of the extent, severity and sensitivity of the class of historic asset.[10]

In general, although a general strategic position has been laid and an approximate scale of buildings under threat has been estimated (e.g. 500 culturally important buildings may be situated on the Welsh flood-plains) an overarching plan and appropriate adaptation actions are not yet in place.

Urgency score

Research priority - Measures should continue to be put in place in Wales to better quantify the current and future risks to the historic built environment from climate change, and assess appropriate measures to put in place.

PB9: Risks to health and social care delivery from extreme weather

Current and future risks

Floods, storms, snow, cold and hot weather and heatwaves affect health system infrastructure and service delivery through effects on staff, buildings and equipment.

Heatwaves cause problems with the functionality of hospitals as well as the thermal comfort of patients and staff. Research indicates that that in general, older designs are at less risk of

10 http://cadw.gov.wales/docs/cadw/publications/Climate_Change_on_the_Historic_Environment_of_Wales_EN_CY.pdf

overheating than more modern buildings. The relative risk of heat-related mortality is higher in care homes and nursing homes than in the general population, even after accounting for the health status of residents. Qualitative studies suggest that problems may occur associated with poorly adapted equipment, structural design and care practices.

There are currently 10 hospitals and 45 care homes in Wales that are located in areas at a 1-in-200 chance of flooding or greater in any given year (low magnitude, low confidence). Chapter 5 of the Evidence Report also gives numbers for emergency services stations and GP surgeries.

Cold spells and snow storms are very disruptive due to staff not being able to travel to work (as observed during the cold winter of 2010-11). Cold weather can also affect healthcare infrastructure and increase demand on health services.

Future projections indicate an increase in number of GP surgeries, care homes, emergency service stations and hospitals in the flood risk zone, with the largest change in risk generally shown for care homes. Wales (and England) show bigger increases in risk than Scotland and Northern Ireland (medium magnitude, low confidence). By the 2050s under a 4 degree scenario, the numbers of hospitals in Wales located in areas at a 1-in-200 annual chance or greater increases to 13 - 14 and the number of care homes increases to 62 – 64 (assuming no population growth). Future projections of risk are not available for other hazards such as heat and cold.

Adaptation

There is no evidence available on how the health and social care sector in Wales plan for extreme events and what the overall level of resilience is. Across the UK as a whole, there is some evidence of inconsistencies in terms of planning. For example:

- It has been observed that the continuing trend towards greater levels of personalisation, devolution and fragmentation of health and social care are creating a more complex web of responsibilities for preparedness and response to climate related risks.
- The risks of healthcare professionals being unable to reach to patients may also change in the future as home-based care becomes more common. Impacts from extreme weather on transport networks may become more important.
- Problems of organisational management and communication between different groups of health and social care personal may make response to severe weather events less efficient. Although individual service providers may be familiar with severe weather plans and protocols, problems of communication between personnel in different parts of the health and social care system can present a difficulty in implementing severe weather plans efficiently.

Low-energy and relatively low cost options are available to adapt existing hospitals and design new buildings for improved thermal comfort and operational resilience during heat waves. However, it is not known how important such adaptations might be in the future in Wales, and the current extent of the problem is not known.

Urgency score

Research priority – More evidence is needed to assess how current plans in Wales relate to the current and future level of risk. The potential for cost-effective adaptation to overheating in healthcare facilities is thought to be high, but the risk in Wales is currently unknown. Plans might also be needed that consider how a greater reliance on home-based care may alter the risks to patients and healthcare delivery from extreme weather.

More consideration could also be given to how the planned move towards home-based care may alter the risks to patients and healthcare delivery from extreme weather. This work is needed now to create the right conditions for future care models to be flexible and resilient to shocks from extreme weather.

PB10: Risks to health from changes in air quality

Current and future risks

It has not been possible to find evidence specific to Wales for this risk.

At the UK-wide level, determinants of outdoor air quality include levels of ground-level O3, NOx, particulates (PM10, PM2.5), and aeroallergens (mould and pollen). At present, between 6 and 9 million people across the UK suffer from chronic respiratory conditions (asthma and chronic obstructive pulmonary disease) that make them especially vulnerable to air pollution (high magnitude, high confidence). The increased proportion of diesel-fuelled traffic in the UK, and the failure of European emission standards for diesel cars to deliver the expected emission reductions of nitrogen oxides, have resulted in difficulties meeting EU air quality limit values for nitrogen dioxide (NO_2), prompting infraction proceedings by the European Commission against the UK.

Climate-sensitive air pollutants include ground level ozone and aeroallergens such as pollen. There is sufficient evidence that short-term exposure to ground-level ozone increases mortality, respiratory hospital admissions and, acknowledging more uncertainty, cardiovascular hospital admissions. The effects of weather and climate variability have been studied for pollen, but not for all species. Higher temperatures, the presence of high concentrations of carbon dioxide, different patterns of rainfall and humidity may be associated with extended growing seasons.

Some thunderstorms have also been associated with increased hospital admittances for asthma exacerbations ("thunderstorm asthma").

Although higher ambient temperature can lead to increased ozone concentrations, studies have concluded that future changes in emissions are a more important driver of future ozone concentrations than changes in temperature. Higher temperatures may trigger regional feedbacks during stagnation episodes (still weather) that will increase peak ground level ozone, but these effects are not as important a driver of future concentrations as future emissions. Average ozone levels over Europe are expected to decrease generally in future in conjunction with lower emissions of ozone pre-cursors; except in one scenario where high methane emissions offset this increase. In polluted areas with high nitrogen oxide levels, warming is likely to trigger feedbacks in local chemistry and emissions, increasing levels of ozone. Recent studies have suggested that the occurrence and persistence of future atmospheric stagnation events in mid latitudes, which influence air pollution levels, may increase due to climate change, but these effects are very uncertain.

The impacts of climate change on future pollen-related disease include changes to length of pollen season, pollen abundance, and changes in allergenicity. There is a very complex relationship between pollen abundance and seasonality and climate factors, and this also varies by pollen species.

Projections of future changes in thunderstorm activity are very uncertain.

The overall impact from climate change on air quality is uncertain, so it is not possible to determine the magnitude of the future risk (unknown magnitude, low confidence).

Adaptation

There is an obvious need to continue to put in place measures to reduce the effects of vehicle and other emissions on air pollution. However, the need for further action in Wales to reduce the impacts of climate change alone on air pollution is unclear.

Urgency score

Research priority - Research is needed to assess how changes to climate other than increasing temperatures, such as changing wind patterns and blocking episodes, could impact on air pollution levels. Long-term trend data on the number of children and adults living with chronic respiratory conditions in Wales would also be valuable.

PB11: Risks to health from vector-borne pathogens

Current and future risks

It has not been possible to find evidence specific to Wales for this risk, which relates to changes in the incidence of Lyme disease (the only vector-borne disease established in UK), and the introduction of new vector-borne diseases (such as West Nile Virus disease, dengue, malaria, Chikungunya, Zika and other arboviruses).

Climate extremes are known to have major effects on host-pathogen interactions in a variety of ecosystems. For example, the 1976 heat-wave, and 1976-1977 16-month UK drought, led to reduced river flows, ground and surface water. Disease impacts were detectable in animals (including livestock, wildlife and fish) and plants in terrestrial, freshwater and marine ecosystems.

Tick species that transmit Lyme Disease are currently distributed throughout the UK. The *Ixodes ricinus* ticks are mostly encountered in the countryside, but are also present in urban parks.

Quantitative predictions of the impact of climate change are uncertain, but it is likely that the range, activity and vector potential of many ticks and mosquitoes will increase across the UK up to the 2080s. Higher temperatures in the future will increase the suitability of the UK's climate for invasive mosquito species, facilitating invasion by new species that can transmit diseases in the long-term. It is not possible to quantify the likelihood of the introduction of new diseases. The risk of introduction of dengue and Chikungunya viruses is contingent on the risk of invasion by non-native mosquito vectors, which remains low in the near-term, but risk may increase with more significant warming in later decades. The two most important species are *Aedes aegypti* and *Aedes albopictus*; both breed readily in urban environments. The UK is currently at little or no risk as neither of these *Aedes* vectors are present in the country and there is no imminent threat of invasion of *Aedes aegypti*. By contrast, the gradual northward spread of *Aedes albopictus*, combined with or facilitated by climate warming, suggests it is only a matter of time before this species reaches the UK.

The risk of introduction of malaria is thought to remain low. Projections for 2080s, under a variety of emission scenarios, only indicate a small risk of malaria transmission in the UK.

Lyme disease may shift in altitude and incidence in the UK in response to climate change. However, future trends in agriculture, land use, wild animal populations and tourism will play as large or a larger role as climate in determining future patterns of the disease.

Adaptation

Surveillance and monitoring activities are underway in all four UK countries. The Public Health Wales Communicable Disease Surveillance Centre (CDSC) exists to monitor the incidence of disease vectors and pathogens. It is not known how effective monitoring programmes across the UK (including in Wales) are at controlling emerging vectors and the extent to which the programmes are able to prioritise funding for surveillance of vectors and pathogens that pose the biggest risk from climate change.

Urgency score

Research priority - There are likely to be benefits from improved monitoring and surveillance of emerging infections. Better understanding is needed of the eco-epidemiological drivers that determine the distribution of the UK's existing arthropod vectors and the pathogens that they might carry at finer spatial scales than is possible from current studies. Better ongoing surveillance for the importation of exotic arthropod vectors and pathogens would also be beneficial. Field-based research could also be conducted to understand the impact of environmental change and climate change adaptation strategies on disease vectors.

PB13: Risks to health from poor water quality

Current and future risks

There is limited evidence regarding the association between gastro-intestinal pathogens and rainfall. In the UK outbreaks of cryptosporidiosis have been linked to heavy rainfall affecting public drinking water supplies. There is a lack of evidence for Wales related to the future risks from gastro-intestinal pathogens in drinking water related to climate change.

The transmission of marine pathogens (through sea water) is also potentially a risk from climate change as some marine pathogens are sensitive to higher sea surface temperatures. Evidence is very limited for the UK, although there is evidence from the Baltic Sea. The current level of magnitude of the risk is unknown, and it therefore has low confidence. Increasing sea temperatures around the UK may result in an increase in marine *vibrio* infections. However, the public health implications of this are not clear, including whether it would lead to a detectable increase in human disease (unknown magnitude, low confidence).

Adaptation

The Water Industry Act 1991 (the 1991 Act) sets out the legal framework for ensuring good quality drinking water supplies. Water utilities are responsible for providing drinking water of sufficient quality. The Drinking Water Inspectorate within Defra is the regulator for drinking water quality in England and Wales. The Water Health Partnership for Wales is an initiative that brings together relevant agencies to work together more effectively to protect public health by ensuring the provision of safe drinking water. Agencies in the Partnership include the Drinking Water Inspectorate (DWI), Welsh Government, local authority public and environmental health, the water companies and Public Health Wales.

CEFAS have developed an early warning and forecasting tool for waterborne pathogens including *Vibrio*. The Welsh Government also has a pan-Wales response protocol for harmful algal blooms.

Urgency score

Sustain current action. Policies and mechanisms are in place to deal with future risks to water quality in public supplies. There may be a lack of action with respect to private water supplies, but it is not known at present what the level of future risk may be. In Wales, 80,000 people are connected to a private supply.

PB14: Risk of household water supply interruptions

Current and future risks

The UK has experienced repeated periods of low precipitation. Some of these have lasted longer than anything experienced recently (e.g. mid 1880s to early 1900s). The most severe and widespread drought conditions in the UK in relatively recent times were those peaking in 1976 where at the UK level rainfall was 59% of the 1981 – 2010 average. Less frequently there are restrictions on the industrial and agricultural use of water that temporarily affects employment. Even more rarely there are restrictions on domestic supplies that can affect health and well-being, but standpipes have not been used in response to a drought since 1976. A range of health issues arise when tankers, standpipes and/or bowsers are used. There is also an unknown risk to households connected to private water supplies. In Wales, there are approximately 14,000 private water supplies that serve approximately 80,000 people.

Water supply interruptions can also be caused by flooding and cold weather. These impacts are quite rare in Wales so it is difficult to provide an estimate of magnitude that is akin to an annual average.

The future risks to health from drought are amongst the most difficult to estimate because the science of estimating prolonged and extensive low rainfall patterns is insufficiently advanced. As temperatures rise this may dry the ground and create conditions in which droughts become more likely. Analysis of H++ scenarios for the CCRA looking at the upper end of the impacts that might be expected suggests that 6 month long droughts in summer might be more frequent in the future with rainfall deficits of up to 60% of current averages. Medium term multi-annual droughts of up to 18 month duration may become more common. Longer term droughts, similar to those in the historical record, remain possible (unknown magnitude, low confidence). The probability of cold events that cause problems with water supply is likely to decline in the long-term as winters become warmer.

Adaptation

Water utility companies are mandated to account for drought in their water resources management plans. When droughts occur, emergency powers can be used to restrict water supplies and advice is issued to reduce consumption (e.g. hosepipe bans, requests to water gardens with water that has already been used). Plans to avoid health and wellbeing impacts ensure that vulnerable individuals who need access to plentiful water are not adversely affected (e.g. dialysis patients or those with high laundry requirements). However, a community's ability to cope with severe droughts where standpipes need to be used is not well-researched in the UK, including in Wales, as it is such a rare event.

Water companies also have to ensure that pipe leakages are managed to a sustainable economic level.

Urgency score

Sustain current action - Policy levers are in place to deal with the public health implications to security of water supplies from droughts and cold weather. Continued testing and implementation of measures to maintain security of supply remains important to allow for adaptation if the risk increases in the future.

Other risks

Other risks considered as part of the people and built environment chapter but considered to fall in to the 'watching brief' category for Wales include:

PB3: Opportunities for increased outdoor activities from warmer temperatures. Climate change is increasingly recognised as a factor that may influence the recreational use of outdoor environments. The effects of climate change on outdoor recreation have only recently been studied in detail, and very little evidence is available for the UK. Climate change would have differing impacts depending on the activity. For example, the number of people partaking in certain outdoor recreational activities-such as boating, golfing and beach recreation is estimated, under medium emissions scenarios, to increase by 14 to 36% in the next few decades. A study in Switzerland also projected a significant increase in the use of outdoor swimming pools, with increases of > 30% expected for August and September in the future.

For Wales and the UK more widely however, the current and future magnitude of benefit is unknown and this benefit therefore has low confidence. Autonomous adaptation to take advantage of any benefits is thought to be plausible, though there is little evidence to support this assumption made by the authors.

PB12: Risk of food borne disease cases and outbreaks. Salmonellosis incidence is sensitive to temperature; incidence increases by 10% per degree increase in temperature above 6^{o}C. However, salmonella incidence is declining due to improvements in control measures. Across England and Wales, there were around about 7,500 cases of salmonellosis recorded in 2013, down from just over 14,000 in 2004. Infection with campylobacter is now the most important source of food borne disease in the UK. In 2012, there were 65,000 reported cases of Campylobacter infection across England and Wales, the highest total level of infection since 2000. Campylobacter shows a strong seasonal pattern but the reasons for the spring increase in infections are not well understood. Several epidemiological studies have reported a positive association with temperature but the relationship is non-linear. An association with rainfall has also been reported although not in studies from the UK. The magnitude of the current risk is low (high confidence). There are a large number of pathways through which climate change may affect food borne disease and contamination in the future. Only a few of these pathways have been investigated. Modelled studies project an increase in the risk of salmonella but these studies do not take into account that the overall number of cases are currently declining. Overall, there are limited grounds for assuming that an increase in average temperatures would tend increase the transmission of campylobacter. The future level of risk is currently projected to be low, and therefore it is thought unlikely for further action on the basis of climate change to be beneficial in the next five years.

6. Business and industry

Flooding and extreme weather events which damage assets and disrupt business operations pose the greatest risk to Welsh businesses now and in the future. This could be compounded by a lack of adaptive capacity. New regulations or other government intervention made necessary by climate change also poses an indirect risk to businesses.

Government has a role in enabling, facilitating and supporting private sector adaptation through policies, regulation and other measures such as information sharing and raising awareness. Resilient infrastructure, in particular power, fuel supply and ICT, is crucial in enabling businesses to minimise disruptions to their operations from climate change risks.

Table WS.9. Urgency scores for business and industry

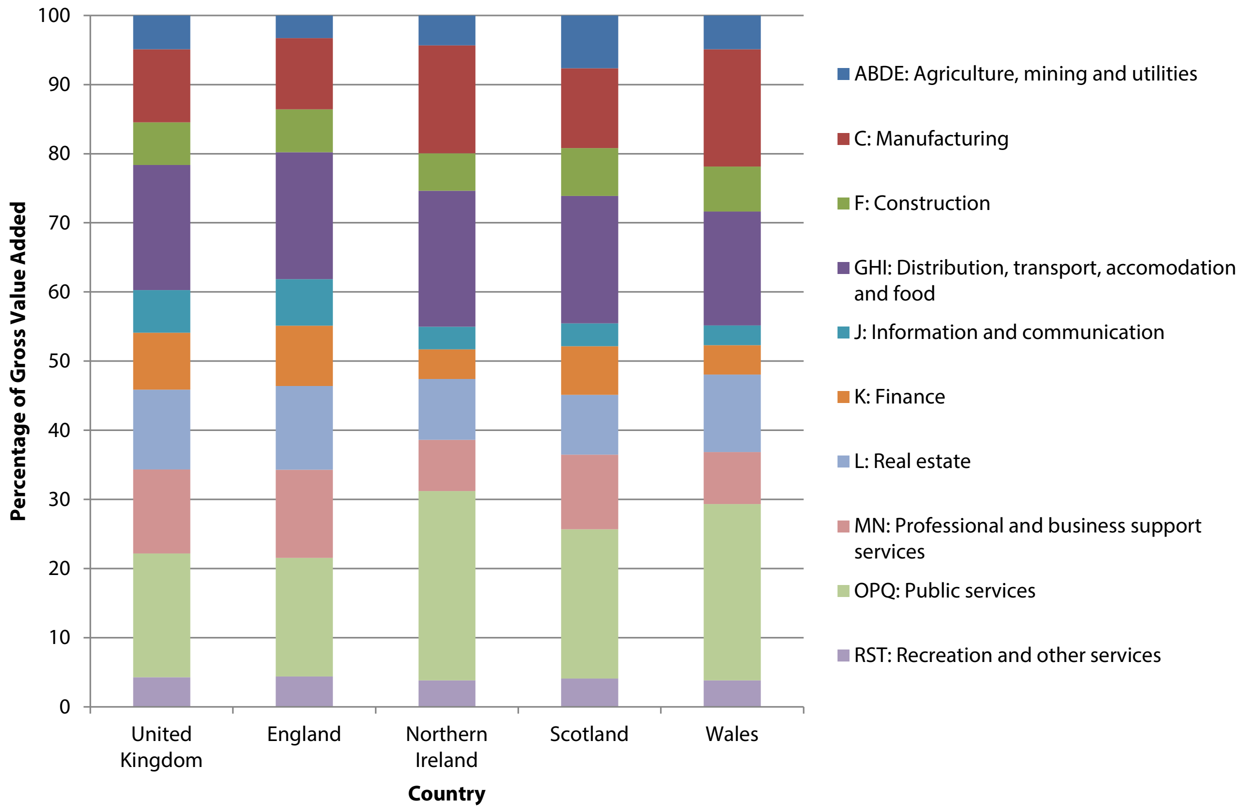
Risk/opportunity (reference to relevant section(s) of CCRA Evidence Report)	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
Bu1: Risks to business sites from flooding (6.2.2, 6.2.3)	England	Northern Ireland, Scotland, Wales			More research is needed in Wales to understand uptake of flood protection measures by businesses and how spending plans on defences and other measures may or may not protect individual businesses.
Bu2: Risks to business from loss of coastal locations and infrastructure (6.2.2, 6.2.3)		UK			More research needed on costs and benefits of adaptation options for different coastal areas.
Bu3: Risks to business operations from water scarcity (6.2.4, 6.2.5) NB: Also see related infrastructure risk In9.			UK		Sustain current actions to create more flexible abstraction regimes and promote water efficiency among businesses.
Bu4: Risks to business from reduced access to capital (6.3)				UK	Monitor and research action by regulators, banks and insurance firms, and information disclosures by UK companies.
Bu5: Risks to business from reduced employee productivity, due to infrastructure disruption and higher temperatures in working environments (6.4.2, 6.4.3, 6.4.4, 6.4.5)		UK			More research needed on disruption to ICT, power and transport infrastructure which prevents workers accessing premises or working remotely, and on impacts of higher temperatures on employee safety and productivity.

Table WS.9. Urgency scores for business and industry					
Risk/opportunity (reference to relevant section(s) of CCRA Evidence Report)	**More action needed**	**Research priority**	**Sustain current action**	**Watching brief**	**Rationale for scoring**
Bu6: Risks to business from disruption to supply chains and distribution networks (6.5) NB: Also see related international risks It1 and It3.			UK		Sustain and monitor the uptake of existing guidance which helps businesses improve the resilience of supply chains and distribution networks, particularly at the international level.
Bu7: Risks and opportunities for business from changes in demand for goods and services (6.6)				UK	Monitor sales of adaptation goods and services within the UK, and by UK companies.

Context

Figure WS.3 compares the distribution of Gross Value Added (GVA) among sectors by UK country for 2014. The relative contribution to GVA of the finance sector is higher in England and Scotland (9 and 7% compared to 4%), whereas the relative contribution of manufacturing is higher in Northern Ireland and Wales (17 and 16% compared to 10 and 12%). Public services make up a higher proportion of Wales' GVA (26%) than for the UK as a whole (18%).

Figure WS.3. Distribution of Gross Value Added among sectors by UK country, 2014



Source: ONS (2015).

Table WS.10 compares the distribution of workforce jobs in the UK and Wales in 2015. Like for Gross Value Added, there are differences in the proportion of workforce jobs accounted for by different industry sectors. For example, manufacturing accounts for approximately 160,000 workforce jobs or 11% of the total in Wales, whereas it accounts for 2.6 million or 8% of the total in the UK. 390,000 or 27% of workforce jobs in Scotland are in Wholesale and Retail Trade; Repair of Vehicles and Human Health and Social Work Activities, a similar proportion to the UK overall.

Table WS.10. Percentage of workforce jobs by industry section, 2015

Industry	United Kingdom (%)	Wales (%)
A : Agriculture, Forestry And Fishing	1.2	2.6
B : Mining And Quarrying	0.2	0.1
C : Manufacturing	7.8	11.0
D : Electricity, Gas, Steam And Air Conditioning	0.4	0.6
E : Water Supply; Sewerage, Waste Management	0.6	0.7
F : Construction	6.6	7.4
G : Wholesale And Retail Trade; Repair Of Vehicles	14.7	13.2
H : Transportation And Storage	4.6	3.6
I : Accommodation And Food Service Activities	6.7	7.4
J : Information And Communication	4.0	2.0
K : Financial And Insurance Activities	3.4	2.3
L : Real Estate Activities	1.6	1.4
M : Professional, Scientific And Technical Activities	8.7	6.3
N : Administrative And Support Service Activities	8.4	6.5
O : Public Administration And Defence	4.4	6.1
P : Education	8.7	9.0
Q : Human Health And Social Work Activities	12.4	13.9
R : Arts, Entertainment And Recreation	2.9	3.2
S : Other Service Activities	2.6	2.5
T : Activities Of Households As Employers;...	0.2	0.1
Total (%)	100.0	100.0
Total (Thousands)	33,783	1,452

Source: ONS (2016d) accessed through NOMIS.
Note: Data are seasonally adjusted. Workforce jobs are the sum of: employee jobs, self-employment jobs, HM Armed Forces and government-supported trainees. The number of people with jobs is not the same as the number of jobs. This is because a person can have more than one job. Industry sections are classified according to the Standard Industrial Classification 2007.

The proportion of private sector enterprises accounted for by Small and Medium Enterprises (SMEs) is similar in Wales to the UK as a whole. 99.9% of private sector enterprises in Wales are SMEs, with the vast majority of these having fewer than 10 employees. SMEs in Wales account for 75% of private sector employment and 59% of turnover, more than for the UK as a whole (60% and 47% respectively).

Table WS.11. UK and Wales private sectors

Size of business	UK			Wales		
	Businesses	Employment (thousands)	Turnover (£, millions)	Businesses	Employment (thousands)	Turnover (£, millions)
Micro	5,146,400 (95.5%)	8,461 (32.7%)	672,815 (18.1%)	203,240 (95.5%)	354 (41.8%)	20,690 (25.3%)
Small	203,525 (3.8%)	3,968 (15.3%)	543,058 (14.6%)	8,170 (3.8%)	160 (18.9%)	13,651 (16.7%)
Medium	32,560 (0.6%)	3,183 (12.3%)	537,996 (14.5%)	1,185 (0.6%)	115 (13.6%)	13,842 (16.9%)
Large	6,965 (0.1%)	10,260 (39.7%)	1,956,409 (52.7%)	200 (0.1%)	215 (25.4%)	33,527 (41.0%)
Total	5,389,450 (100%)	25,871 (100%)	3,710,278 (100%)	212,795 (100%)	846 (100%)	81,710 (100%

Source: BIS (2015a).
Note: Size of business is determined by the number of employees. Definitions are: Micro (0 to 9 employees), Small (10 to 49 employees), Medium (50 to 249 employees) and Large (More than 250 employees).

Bu1: Risks to business sites from flooding

Current and future risks

Flooding poses a significant risk to business sites, both in terms of damage to assets and in preventing employees from being able to access work premises.

Total damages to businesses in Wales from the 2013/14 winter flooding were estimated to be £3.4 – 4.6 million. Forty-six businesses in Wales were estimated to have been affected. Damage per business asset was estimated at between £9,200 and £110,000, with a best estimate of £82,000 (for both England and Wales). All damages were from coastal flooding. Natural Resource Wales noted that potential losses from the January 2014 flooding included visitors choosing not to visit the Welsh coastline, and visiting other parts of the UK or overseas instead. These behavioural changes do not necessarily represent economic losses to the UK as a whole, but would represent a financial loss to Wales and Welsh communities located on the coast.

The Welsh Government has also reported that the extreme weather events and storms of winter 2013/14 caused considerable disruption for many tourism businesses in Wales through loss of access to premises as a result of flooding events and infrastructure disruption, such as energy and ICT.

Analysis by Sayers et al. (2015) for the ASC found that:

- For the present day, approximately 86,000 non-residential properties in Wales are at risk of flooding (1:1000 year or less). Of these, 34,000 are at risk of significant (1:75 year or less) flooding. The direct impacts of flooding result in expected annual damages to non-residential properties of £59 million.
- By the 2050s the number of non-residential properties in Wales at risk of significant flooding is projected to increase between 19% and 50%. Expected annual damages are projected to increase between 29% and 96%, equivalent to a £17 million to £57 million increase. [Scenario: 2°C or 4°C, not including population growth and assuming the continuation of current levels of adaptation]
- By the 2080s the number of non-residential properties in Wales at risk of significant flooding is projected to increase between 34% and 73%. Expected annual damages are projected to increase between 55% and 200%, equivalent to a £32million to £118 million increase. [Scenario: 2°C or 4°C, not including population growth and assuming the continuation of current levels of adaptation]

Adaptation

In Wales between 2011 and 2016 around £285 million was invested in flood and coastal erosion risk management. It is not known what effect this investment has had on the number of non-residential properties in areas at high risk of flooding across Wales**.** However, there is evidence of investment in improved flood defences which protect local businesses on a case-by-case basis. One example is the Lower Swansea Vale £6.7 million project which provides protection to 284 businesses and industrial premises employing more than 10,000 people. The project has also implemented other measures such as flood warning, awareness raising and emergency planning within the area.

By law, Natural Resources Wales must produce Flood Risk Management Plans, at the River Basin District scale, for the whole of Wales every six years starting from 2015. They also provide a business flood plan template, and report that more than 1,000 communities and individual businesses in Wales now have their own pre-prepared flood plans. Research for the UK (which included some respondents from Wales) suggested that the proportion of private sector organisations saying they have a business continuity plan in place for flooding increased from 42% to 58% between 2008 and 2013. In general, the smaller the business, the less chance there is that they have a plan in place.

The Welsh Government published interim sustainable urban drainage systems (SuDS) standards in 2015. These also include standards for biodiversity and amenity. The Welsh Government is still considering how to progress Schedule 3 of the Flood and Water Management Act 2010, which relates to standards for the design, implementation and maintenance of SuDS.

Natural Resource Wales carried out a review of the December 2013 and early January 2014 coastal storms, which concluded that more needed to be done to ensure coastal communities are resilient to future flooding. Natural Resource Wales launched a delivery plan at the beginning of 2015 setting out how recommendations from the review of 2013/14 coastal floods would be taken forward.

Urgency score

Research priority - More research is needed to understand future spending plans and the uptake and impact of flood protection measures in Wales, and ensure that businesses have the right incentives, information and tools to adapt to increasing flood risk. Around four-fifths of UK businesses with continuity plans in place report that the benefits of having one exceed the costs of producing one, suggesting they are cost-effective to implement. However, the uptake of such plans remains low, particularly among SMEs.

Bu2: Risks to business from loss of coastal locations and infrastructure

Current and future risks

Coastal flooding, erosion, sea level rise and tidal and storm surges can lead to the loss of coastal business locations. Coastal flooding is estimated to contribute to 34 per cent of total expected annual damages from flooding to Wales for the present day, including both residential and non-residential properties.

Monitoring and understanding the effects of sea-level rise on risk at the local level is difficult as the actual level of sea-level rise at any one place depends on a wide range of factors including gravitational variation across the Earth and a number of oceanographic factors. The current level of risk to the viability of coastal communities and their businesses in Wales from sea level rise is thought to be low (low magnitude, high confidence), but the future risk is uncertain and could be significant. Reliance on maritime logistics and infrastructure can mean that certain sectors, for example, chemical manufacturing, oil and gas and tourism are more exposed to coastal climate change impacts. How much these sectors in Wales are at risk from permanent coastal change has not been quantified to date.

In the future, damages from coastal flooding in Wales could increase by around 300% by the 2080s from a baseline of £28 million present day. [Scenario: 4°C, not including population growth and assuming a continuation of current levels of adaptation]

Estimates suggest that, in the short-term (0 to 20yrs), no non-residential properties in Wales are at risk of coastal erosion. This is estimated to increase to 52 in the medium-term (20 to 50 years ahead) and 182 in the long-term (50 to 100 years ahead). This represents less than 0.1% of all non-residential properties in Wales.

Adaptation

Shoreline Management Plans (SMPs) are in place for the full length of the Welsh coastlines. SMPs set out coastline management policies (hold the line, no active intervention etc.) to the 2100s and are developed by Coastal Protection Authorities.

The SMPs set out the risks to coastal areas from erosion and sea-level rise and indicate how local authorities and other bodies can plan and implement coastal management in terms of holding the line, managed realignment and no active intervention. It is not currently known how progress compares to the level of risk. These plans do not consider the impacts of loss of coastal communities and businesses, and what measures should be taken to manage this change.

Many industrial facilities also already have active risk management procedures and a level of existing protection, so autonomous adaptation is likely for these assets. However, smaller businesses, for example those involved in coastal tourism, may be less aware of the risk or able to protect themselves and will therefore be more exposed.

Government commitments and autonomous adaptation discussed under step 2 for Bu1: Risks to business sites from flooding are also relevant here.

Urgency score

Research priority - The possible realignment or retreat of coastal protection structures due to increasing erosion and flood risks will have an impact on businesses located in the affected areas. Research is required to understand the costs and benefits of different adaptation responses to loss of coastal locations for business, and therefore provide the early steps for cost-effective adaptation.

Bu3: Risks to business operations from water scarcity

Current and future risks

Water is used by industry for cooling and heating, washing products, dissolving chemicals, suppressing dust, and also as a direct input to products. Without sufficient water, production in many businesses would have to be reduced or stopped.

Abstraction by industry, excluding agriculture and energy, is currently estimated to be around 111 billion litres in Wales in 2014. This represents 3% of total abstractions from all sources except tidal sources. Currently in Wales, abstraction demand is lower at times of low flows than the available resource once environmental flow requirements are taken into account in all but once catchment in southern Wales, where demand is slightly higher than the available resource (low magnitude, medium confidence).

In addition to varying by location, current risks of water scarcity also vary by sector; some industrial sectors are more water-intensive than others. WRAP (2011) published analysis of freshwater availability and use in the United Kingdom, which suggested that, using the Standard Industrial Classification (SIC) 2007, the manufacturing sector was the biggest abstractor in 2006, being responsible for approximately 93% of direct abstractions in Wales. The vast majority of this was accounted for the manufacture of basic metals.

Under the most extreme upper bound climate and population scenarios for the 2050s and 2080s, in large parts of Wales it is projected that at times of low flows, there would be no water available for human use assuming that ecological flow requirements as currently set out would be met (high magnitude, medium confidence). At lower climate and population scenarios, there would be sufficient water for human use in all catchments, with generally more water available for use in western Wales compared to eastern Wales.

The approach taken to adaptation influences the severity of the impact of the proportion of the available resource used in the future. The difference between a 'No additional action' and 'Current objectives+' scenario may make the difference between a projection of surplus or deficit.

Adaptation

The Welsh Government published reforms to the water abstraction licencing system at the beginning of 2016. These reforms aim to allow more flexible responses to short term changes in flows and encourage efficient water use. Natural Resource Wales would be able to instigate risk-based reviews to consider changes abstraction limits. Measures such as allowing businesses to take water at high flows may mean pressures are less than they otherwise would be.

There are signs that water use is being better managed by many businesses. Around one-third of the observed decline in water use since 2000 can be attributed to a fall in production levels in large water using sectors. The remaining two-thirds of the decline can be attributed to improvements in water intensity.

Evidence from the Federation House Commitment (FHC) shows a decrease in water intensity in the food and drink manufacturing sector. The Water use excluding that used in product at FHC sites fell by 16% between 2007 and 2013; and water intensity, measured in m3 per tonne of product, fell by 22% over the same period. 4% of FHC signatories' sites were in Wales.

Urgency score

Sustain current action – Sustained effort will be needed to ensure that the abstraction regime is sufficiently flexible and that businesses are able to build on their existing progress in becoming more water efficient.

Bu5: Risks to business from reduced worker productivity, due to infrastructure disruption and higher temperatures in working environments

Current and future risks

Infrastructure disruption

There is no Wales-specific evidence available for this risk. According to a UK survey by the Chartered Management Institute et al. (2013), staff being unable to come into the office either due to travel disruption (63% of respondents) or school closures/child care costs (46%) were the most common impacts of extreme weather on surveyed organisations, followed by external meetings or business trips being cancelled (43%). The most common measures taken by surveyed organisations in response to extreme weather were to allow staff to work remotely (53%), to prioritise resources on key projects (34%) and to postpone work until the weather improved (29%).

Baglee et al. (2012) assessed that major ICT disruption due to climate change is considered to be relatively low for large businesses. Risks for smaller companies could be greater, particularly if they are located in relatively remote areas where they may be dependent on single electricity and telecommunications connections. Many homeworkers depend on ICT infrastructure to allow them to work remotely. Of people in work between January and March 2014, 4.2 million or 13.9% were homeworkers, two-thirds of whom were self-employed. Homeworking was most prevalent within the agriculture and construction industries. It is not known what proportion of those classified as homeworkers would be affected by weather-related disruptions to ICT infrastructure.

Projections of future impacts of infrastructure losses on business productivity are not available.

Higher temperatures

There is no Wales-specific evidence available for this risk. . In general, when temperatures exceed certain thresholds in the workplace for a long enough period of time, the productivity of workers has been observed to fall. There is uncertainty regarding the amount of productivity loss and on the annual average impact across the UK. The 2003 European heatwave is estimated to have resulted in a loss in manufacturing output in the UK of £400 - £500 million (2003 prices), but it is unclear how much of this impact was due to reduction in worker productivity.

Workers engaged in heavy outdoor manual labour, particularly in the agriculture, construction and heavy industry sectors, and depending on the sport, professional athletes, are likely to be at the greatest risk of heat stress. Employees working in offices built in the 1960s and 1970s could also be at risk of thermal discomfort. These types of building typically have poor ventilation systems and are often high-rise properties with single glazed windows that maximise solar gain.

Modelling in UK CCRA 2012 suggested the future impacts on productivity could be large. Upper bound results suggested that the cost of loss in productivity due to building temperature could increase from a baseline of £770 million in 2010 to between £850 million and £1.6 billion in the 2020s; between £1.1 billion and £5.3 billion in the 2050s and between £1.2 billion and £15.2 billion in the 2080s.

Adaptation

Research for the UK (which included some respondents from Wales) suggested that the proportion of private sector organisations saying they have a business continuity plan in place increased from 42% to 58% between 2008 and 2013. Evidence suggests that organisations often activate business continuity plans only after they have been impacted by an extreme weather event. Extreme weather was the most commonly cited reason for activating a BCM plan, cited by 69% of managers surveyed with BCM plans in their organisation. In congruence with this, the most commonly cited reasons for not implementing a BCM were "We rarely get significant levels of disruption in our business", "We deal with disruption as and when it happens" and "Not a priority," respectively cited by 45, 43 and 37% of surveyed managers without a BCM in their organisation. Therefore, BCM plans may increase in future as organisations become more likely to experience extreme weather events.

While not necessarily linked to disruption from extreme weather events, increasing numbers of businesses have been offering workers the option of teleworking. The Confederation of British Industry (2011) reports that "Five years ago, just 13% of firms offered teleworking for employees in at least certain roles some of the time, but now nearly six in ten (59%) do so. This increase has been made possible by improved technology, allowing people to work more effectively away from the workplace.

Businesses have an obligation under the health and safety at work regulations to ensure workplaces are adequately ventilated and temperatures during working hours are reasonable. To support businesses in meeting this requirement, the Health and Safety Executive has published workplace temperature guidance. However, there are no standard upper limits of acceptable working temperatures, so it is up to individual companies to determine what is reasonable. The Chartered Institution of Building Services Engineers (CIBSE) organised an overheating task force. This was in response to the challenge of building comfortable, low-energy buildings. For example, increasing indoor winter temperatures can lead to lightweight, highly insulated buildings that respond poorly in the summer. One of the task force's outputs was a technical memorandum to inform designers, developers and others responsible for defining the indoor environment in buildings about predicting overheating.

Little is understood about the impacts of heat on productivity and how this varies among occupations. Therefore there is little assurance that workplace temperature guidance and building standards are sufficiently accounting for this risk.

Urgency score

Research priority- There is a need for further research to better understand key interdependencies between business and infrastructure, the types of employment at greatest risk, and the effectiveness of planned or autonomous adaptation. Research will provide the early steps to understanding these interdependencies, and in the case of higher temperatures, adapting workplace temperature guidance and building standards. For example, how building temperatures can be kept in a tolerable range for thermal stress or thermal discomfort reflecting the building's use.

Bu6: Risks to business from disruption to supply chains and distribution networks

Current and future risks

There is a lack of Wales-specific evidence for this risk. The impacts of extreme weather events vary by type and among businesses, depending how diversified their supply chains and transportation routes are. Regional trade statistics indicate the value of Wales' exports increased from £8.6 billion in 2005 to £12.2 billion by 2015. Over the same time period the value of Wales' imports increased from £6.4 billion to £7.1billion. At the UK level, the Business Continuity Institute's Supply Chain Resilience Report for 2015 found that adverse weather was third most cited reason for supply chain disruption over the previous 12 months, with 50% of surveyed businesses reporting it. Disruptions to supply chains can have significant negative consequences for businesses. Studies have found that share prices can fall by between 7% and 30% on average following failures in the supply chain, relative to benchmarked companies.

One of the key current and future climate risks for supply chains and distribution networks is extreme weather causing damage and disruption to domestic transport infrastructure (roads, rail, ports and airports). For the businesses concerned, this is likely to result in unfulfilled orders, breach of delivery contracts, loss of revenue and damage to reputation. Flooding in particular can have long-lasting impacts on transport networks and cause widespread disruption.

Food, clothes and electronic equipment are important UK consumption goods which appear to be at comparatively high risk from international supply chain interruptions. The largest climate risks to supply chains appear to be in the earlier stages of product manufacture. These tiers of the supply chain are less likely to be understood and managed by UK businesses. A larger proportion of the total value generated in the earlier stages of production is generated in countries that are at a moderate or higher risk from climate change. Evidence suggests that disruptions in the earlier stages of a supply chain are common. A recent survey by the Business Continuity Institute (BCI) found that 42% of supply chain disruptions originated below the first tier of immediate suppliers.

Climate change is expected to increase the risk of weather-related disruptions, particularly for supply chains that involve more vulnerable countries, particularly in South and South East Asia, along with Sub-Saharan Africa. Domestically, the effects of climate change on UK transport infrastructure are significant; the length of railway line located in areas exposed to flooding more frequently than 1:75 years (on average) increases in the 2080s by 53% and 160%; the length of major roads by 41% and 120%; the number of railway stations by 10% and 28%. [Scenario: 2°C or 4°C, not including population growth and assuming the continuation of current levels of adaptation]

Adaptation

Many large companies are considering the risks from climate change to their supply chains and distribution networks and collaborating with their suppliers. This can have wider positive effects and increases the resilience of smaller businesses in their supply chains.

A lot of guidance for businesses on managing their supply chains and distribution networks already exists. However, there is a lack of evaluation to provide sufficient assurance that this guidance is effective and affecting business decisions on the ground. Findings from the Chartered Institute of Purchasing and Supply (CIPS) suggest that many British firms do not fully understand supply chain complexity and that "inadequately trained supply chain professionals" amount to a skills gap.

Guidance and research tends to be high-level and generic. There is a gap therefore, in assessing risks to specific sectors, key areas and vulnerable pinch-points, both for domestic and international supply chain interruptions. Little is known about how the resilience of UK infrastructure affects business' ability to create resilient supply chains and distribution networks.

Urgency score

Sustain current action - International elements of UK businesses' distribution and supply chains are already impacted, and expected to be more at risk as they may take place in countries deemed highly vulnerable to climate change and less able to adapt. Despite the range of surveys and case studies, data are mostly limited to those reported by larger multi-national companies and it is difficult to evaluate the impact and effectiveness of existing adaptation measures, and existing guidance and tools. Therefore it is important to sustain action in this area to continue increasing understanding and enabling businesses with guidance and tools which are proven to be effective.

Other risks

Other risks considered as part of the business and industry chapter but considered to fall in the 'watching brief' category for Wales are:

Bu4: Risks to business from reduced access to capital. We do not have any evidence that is specific to Wales for this risk. Future outputs from the finance and insurance sectors, including research, need to be carefully monitored to ensure that both banking and insurance sectors are acknowledging and adapting to future climate change. The state of information disclosures and how smaller businesses' access to capital and insurance also needs to be monitored to consider if future intervention may be necessary.

Bu7: Risks and opportunities for businesses from changes in demand for goods and services. We do not have any evidence that is specific to Wales for this risk. Identifying market opportunities and managing risks are core business activities– unless prevented by regulation or hampered by low adaptive capacity, it is expected that companies will respond to growing risks and opportunities. There is a risk that businesses will be unable to overcome adaptive capacity constraints, and therefore ongoing monitoring is important. Small businesses are generally likely to have lower adaptive capacity so would be the least likely to take adaptation action.

7. International dimensions

Climate change will impact upon water security, agricultural production and economic resources around the world. These impacts can compound vulnerability in other countries, which can in turn exacerbate risks from conflict, migration, and humanitarian crises. The main risks arising for the UK from climate change overseas are through impacts on the food system, economic interests abroad, and increased demand for humanitarian aid.

Some of the policy areas relevant to these risks, such as international development and defence, are non -devolved (shown with a * below). Other areas, such as food security and safety policies are devolved to the Welsh Government. In any case, cooperation within the UK, as well as with other countries, is key to managing these risks.

Table WS.12. International dimensions of risk

Risk/opportunity (reference to relevant section(s) of CCRA Evidence Report)	More action needed	Research priority	Sustain current action	Watching brief	Rationale for score
It1: Risks from weather-related shocks to international food production and trade (7.2)	UK				At the present, there is no co-ordinated national approach to ensure the resilience of the UK food system. Coordinated approaches require broad participation across policy, industry and research.
It2: Imported food safety risks (7.2)		UK*			There is a gap in surveillance systems to monitor food safety at source and through complex international supply chains.
It3: Risks and opportunities from long-term, climate-related changes in global food production (7.2)		UK			The UK may increase its comparative advantage in specific areas of agricultural production in the future. Trends in global agricultural production and consumption need further monitoring and assessment.
It4: Risks to the UK from climate-related international human displacements (7.3)	UK*				A more proactive strategy to work in partnership with other countries is needed to provide rapid legal and basic assistance to migrants and to build long-term resilience in exposed regions. Otherwise overseas development efforts will increasingly be diverted to provide humanitarian (i.e. emergency) aid.

It5: Risks to the UK from international violent conflict (7.4)		UK*			Further evidence is needed to understand the appropriate balance between long-term development aid (resilience building, disaster risk reduction, state stability) and responsive interventions (peace-keeping, humanitarian aid).
It6: Risks to international law and governance (7.4)		UK*			There is a lack of systematic monitoring and strategic planning to address the potential for breakdown in foreign national and international governance and inter-state rivalry, caused by shortages in resources that are sensitive to climate change.
It7: Opportunities from changes in international trade routes (7.4)				UK	Potential changes in trade routes are already being assessed and the issue should continue to be monitored.

It1: Risks from weather-related shocks to international food production and trade

Current and future risks

Food security encompasses availability, price and access to a healthy diet. The key issue surrounding food security in Wales, as it is for the rest of the UK, is not an absence of food, but issues related to price. Price volatility affects affordability and access to nutritious food for lower income households, and the farming sector through feed prices. The issues of food price volatility are already high on policy agendas following, for example, global food price surges in 2008 and 2010. Of the 20 years from the end of 1992 to 2012, eight showed a globally significant major production loss associated with one or more extreme weather events (high magnitude, medium confidence). Changing patterns of weather, especially extreme weather, are likely to increasingly impact on global food production. The increasing global interconnectedness of food systems via trade increases the susceptibility of the food system to propagation and amplification of weather-related production shocks via price volatility. It is very difficult to quantify these effects due to the myriad of influencing factors, but as the risks are high now, without additional action they are also projected to be high in the future. The profile of international trade will amplify underlying climate risks, since trade represents only a small part of total production, and major trade is restricted to a small number of large producing countries.

Adaptation

Food production and manufacturing are devolved policy areas in relation to domestic production, while overarching goals on UK-wide food security are non-devolved. As such, the resilience of the Welsh food system also depends on UK-wide policies. As discussed in Chapter 7 of the Evidence Report, the UK Government does not have an explicit policy on addressing the resilience of the food system that encompasses both international and domestic production. The UK Government monitors the volatility of food prices, but it is unclear how these data are used for strategic, forward planning. Relying on market forces alone to manage price volatility works under "normal" conditions, but unprecedented events affecting a country abroad, coupled with over-compensatory market responses from other countries, can amplify shocks that propagate globally. Climate change is likely to increase the occurrence of these 'unprecedented' events, and the market is not likely to bear the costs of adapting without an immediate impact on prices.

The Wales strategy 'Food for Wales, Food from Wales 2010/2020' (WAG, 2010) is a ten year policy statement that sets out the policy direction. This is supported by the 'Towards Sustainable Growth: An Action Plan for the Food and Drink Industry 2014 – 2020'. The strategy recognises the integration of the Welsh food system into UK and European systems and its influence from the wider global context.

Urgency score

More action needed - There is no food security strategy at the Welsh or wider UK level that links domestic and international food production and imports. There also are multiple benefits to the economy from improved management of knowledge to tackle the systemic vulnerability of the food system (e.g. resilient to climate and non-climate shocks), and from improving the functioning of international trade and markets (trade possibilities, building in-country sustainability of production, with long term benefits). Many of these benefits require international co-ordination with EU countries and the WTO.

It2: Imported food safety risks

Current and future risks

Food quality and safety can be directly affected by disease, toxicity and substitution if prices rise following a production shock. There is a lack of evidence specific to Wales for this risk. At the UK level, climate change impacts could amplify existing quality and safety issues within supply chains. Risks include environmental contamination associated with increased flooding, increased pesticide use in response to new/emerging pests or diseases, and transmission of disease and toxicity through food.

Foodborne pathogens, such as salmonella, and their associated diseases are more prevalent in higher ambient temperatures. While these risks are global, the interaction with supply chains represents an increasing level of imported risk to the UK. The risks in a 4°C world are significantly greater than those in a 2°C world.

Mycotoxin risks are likely to increase with temperature and water stress during growth of major cereal crops: approximately a quarter of the global annual maize crop is contaminated and the toxins have been detected in cereal-based foods. These risks are often managed by temporary import restrictions, disrupting international trade and cereal availability.

There is insufficient evidence to assign magnitude categories to the level of current and future risk for imported salmonella and mycotoxin (unknown magnitude, low confidence). Other disease outbreaks within the food chain have caused significant damages in the past. For example, the direct cost of the 2001 outbreak of foot and mouth disease in the UK was $1.6 billion in compensation to farmers (source: Lloyd's); the return period of an outbreak of foot and mouth disease is estimated to be about 1-in-15 years.

Adaptation

The Food Standards Agency (FSA) is responsible for developing and implementing food safety policy in England, Wales and Northern Ireland and is the UK Competent Authority with respect to EU law on food safety. Policies are similar around the UK as they reflect EU frameworks. Current policies establish controls on animal food imported from the EU and all types of food imported from countries outside the EU. The duties of port health authorities include: ensuring that only products that are safe to eat enter the food chain; safeguarding of animal and public health; and checking compliance with EU rules and international trading standards.

However, as for risk It1, the interconnected nature of food systems makes the scope for effective unilateral intervention limited. In the case of food safety, the problem is compounded due to the difficulty of detecting disease, authenticity and toxicity. Changes in climate and geopolitics, coupled with the complex and international nature of supply chains, mean that addressing food safety through monitoring points of entry alone is unlikely to be an effective strategy on its own.

Urgency score

Research priority - Identifying elements of supply chains at risk allows targeting to close loopholes and provide consumer assurance. Other interventions include increased surveillance and prediction, coordinated mechanisms for obtaining rapid expert advice, and maintenance of strategic food stocks. These actions might be carried out by the industry, but the potential risk would justify at least some consideration of further policy intervention.

It3: Risks and opportunities from long-term, climate-related changes in global food production

Current and future risk

Average, long-term changes in the climate will alter global agricultural systems, affecting production, trade and the sustainability of agriculture in every global region. This will alter the comparative advantage and signals to UK food markets and food production, resulting in a number of risks, depending on the still uncertain trajectories of agriculture in different world regions.

Within Europe, overall yields under a 'business as usual' projection (3.5 degrees of global warming compared to pre-industrial) have been projected to decrease by around 10% by the 2080s. This change is not evenly distributed, however, with Southern Europe experiencing 20% decreases.

Adaptation

UK agriculture could gain a comparative advantage in specific products, relative to the other parts of Europe, notably due to projected yield decline in southern European countries due to water scarcity and heat. At the same time, a strategic approach might be needed to manage potential risks arising from any intensification of Welsh agriculture. Increased production could have consequences for longer-term soil productivity, landscape and biodiversity, for example. Both the risks and opportunities are potentially high magnitude (low confidence), but quantifications are heavily scenario-dependent.

Urgency score

More research needed (at UK level for global trend, at Welsh level for domestic trends). Wales may have an increased comparative advantage in specific areas of agricultural production in the future. However, this depends on trends in global agricultural production that need further monitoring and assessment; and on the future sustainability of Welsh agriculture, especially in terms of water and soils. There is evidence that soil fertility in Wales has declined in recent decades and the number of areas classified as 'poor quality' agricultural land is projected to increase (see Chapter 3 of the Evidence Report). Any action that manages demand at domestic level (e.g. reducing food waste, changing diets and thus reducing obesity) has multiple benefits of reducing the risk of both unsustainable practices and reliance on imports. Many of these actions have clear co-benefits for health, long-term food security and climate change mitigation.

Given high levels of uncertainty concerning long-term comparative advantage and the implications for domestic production and sustainability, there are significant benefits to managing the UK farm sector for systemic resilience to climate change. Resilience is beneficial for avoiding land use and technological lock in.

Other risks

Other risks, although they are listed as urgent, are the responsibility of the UK Government rather than the Welsh Government. These are described in the Urgency Scoring Tables for Chapter 7 of the Evidence Report. These risks are therefore not reported in detail here but are summarised below.

It4: Risks to the UK from climate-related international human displacements. There is limited evidence for migration movements primarily caused by climate change, but widespread evidence that climate change acts as a compounding factor for migration. More action is needed at EU level to ensure the policy framework on migration incorporates and anticipates climate change impacts on existing migration flows. For the UK, national and EU level restrictions on regular migration authorised by law and policy is unlikely to reduce flows of international migrants linked to income and wealth inequalities and to effects of conflict or persecution either within or between states, with the risk of people smuggling and trafficking. Therefore continued and further action is needed at UK and international level to enhance long term stability and sustainable development overseas. This has multiple benefits: for receiving countries, economies and people, to which UK economy and trade is also likely to benefit; as well as helping managing the other risks discussed in this section.

It5: Risks to the UK from international violent conflict. Climate change will likely increase the demand for humanitarian assistance, conflict intervention and peacekeeping. Co-ordination with other countries on building resilience and development in conflict prone countries would bring benefits associated with displacement risks as well as conflict risks. This risk is a research priority, as further evidence is needed to understand the appropriate balance between long-term development aid (resilience building, disaster risk reduction, state stability) and responsive interventions (peace-keeping, humanitarian aid).

It6: Risks to international law and governance. There is a lack of systematic monitoring of the trends and strategic planning to address potential breakdowns in other countries' and international governance, and the threats posed by inter-state rivalry, due to shortages in resources sensitive to climate change. This risk is therefore a research priority at UK level.

It7: Opportunities from changes in international trade routes. The opening up of Arctic trade routes presents an opportunity for increased trade. However, potential changes in trade routes are already being assessed and the issue should continue to be monitored.

8. Cross-cutting issues

The previous sections summarise the key climate change risks and opportunities for Wales, based on the urgency of further action to manage these risks now and in the future. This concluding section builds on the evidence presented in Chapter 8 of the Evidence Report and summarises some of the wider issues that are common to each of the previous sections. These issues are important to consider in order to fully understand the risks from climate change and when developing appropriate adaptation responses.

Interactions among risks

Interactions among risks are important to consider when developing cross-cutting adaptation strategies. CCRA2 does not try to identify the most important interactions among risks, rather it provides a framework to assess these interactions. This framework consists of grouping the CCRA risks based on the impacts that they have on six societal objectives: natural capital, water security, food security, well-being, economic prosperity and global security.

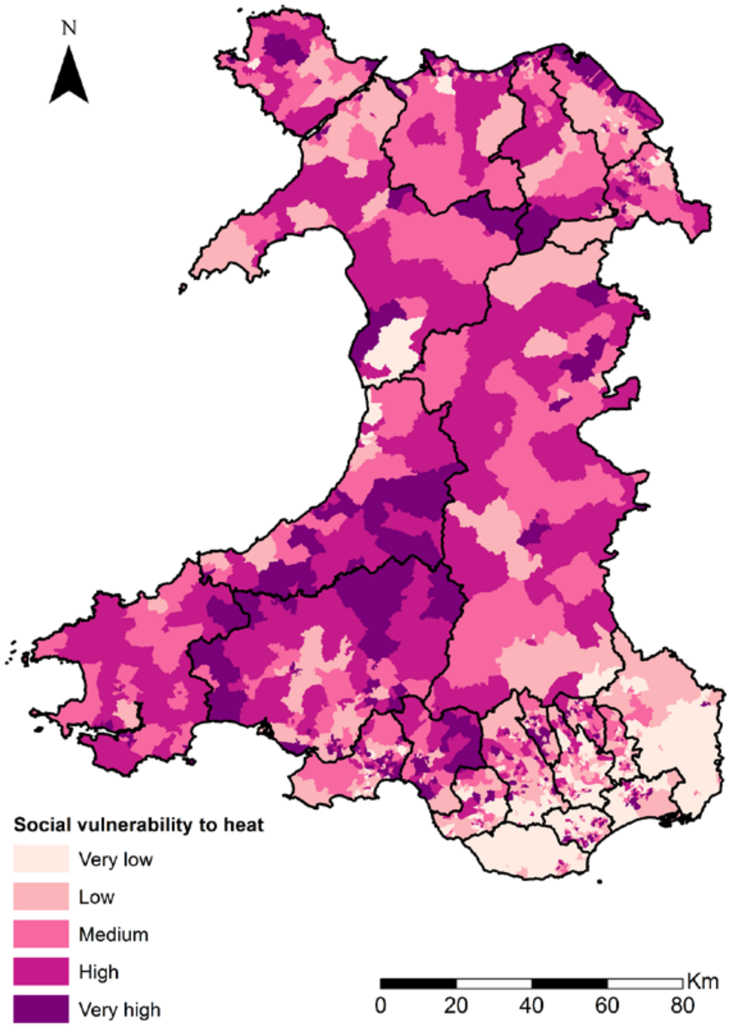
For example, food security in Wales could be impacted by increasing constraints to agricultural production from a combination of reduced water availability (Ne5); increased soil aridity and erosion (Ne3); the continued loss of soil carbon from intensive agricultural practices (Ne4); and sea level rise (Ne11).

Well-being in Wales can be affected by risks from flooding (PB5) and heat (PB1), for example through impacts on people's physical and mental health and life expectancy, as well as people's living conditions and disposable income, and through direct economic damages to properties (PB5). Flooding also impacts on jobs and income through, for example, employers closing businesses temporarily, being forced to change employment conditions, or leaving an area due to unacceptable flood risks (Bu1). Flood, heat and water risks impact on the social environment, for example through the potential loss of social cohesion and historic places (PB8), and to the natural environment (Ne13).

Distributional impacts

The evidence suggests that the effects of climate change on people will be strongly influenced by their social, economic and cultural environment. Low income households are particularly susceptible to climate change impacts, though they might also benefit the most from the positive implications of climate change. Powys, Carmarthenshire and Rhondda Cynon Taff have the highest proportion of socially disadvantaged communities located in flood risk areas. Cardiff and Rhondda Cynon Taff are also exposed to surface water flooding. The most socially disadvantaged neighbourhoods exposed to heat risk in the future are projected to be in Cardiff, Swansea, Newport and Rhondda Cynon Taf (Figure WS.4).

Figure WS.4. Social vulnerability to high temperatures in future in Wales



Source: Kazmierczak, A., Brookfield, C., Cavan, G. and Lindley, S. (2016) Climate Change Vulnerability Mapping in Wales. Welsh Assembly Government, Cardiff. Base map is Ordnance Survey data © Crown Copyright and database right 2015.
Note: The hazard is based on the UKCP09 climate projections for 2050s (high emissions scenario; 10%, 50% and 90% probabilities). The climate variables considered included the change in the temperature in the warmest day and night, and the projected mean maximum daily summer temperatures. No socio-economic projections have been considered.

Institutional frameworks for adaptation

There is evidence that the institutional framework for adaptation in Wales has the potential to deliver cross- cutting adaptation. The reporting cycles set up by the Wellbeing of Future Generations Act and Environment Bill will be key to measuring progress in addressing climate vulnerabilities. Some barriers however still exist, in particular regarding how interactions among risks are considered and tackled.

Adaptive capacity

Addressing risks require the capacity to look at them systemically, as well as having the knowledge, information, tools and resources to do so.

The main research gaps identified by the CCRA for Wales include:

- Possible land-use changes, impacts on soil conditions and understanding resilient varieties/species and cropping regimes.
- Understanding the scale of the risk to freshwater species from higher water temperatures, and effectiveness of adaptation measures.
- Understanding the magnitude of the risk to marine ecosystems.
- Understanding the future risk from overheating for buildings and public transport.
- The impacts of future spending plans on flood defences on level of residual risk.
- Characterising the impacts on coastal communities, thresholds for viability, and what measures should be taken to manage this change.
- Quantitative information on the level of current and future risk for Welsh historic buildings and their surroundings, including historic urban greenspaces and gardens.
- Disease vector monitoring, and surveillance and research, on the extent to which efforts are focussed on those diseases posing the biggest risk with climate change.
- Understanding the costs and benefits of adaptation options for coastal areas vulnerable to sea level rise.
- Understanding impacts of disruption to ICT, power and transport infrastructure which prevents workers accessing premises or working remotely, and on impacts of higher temperatures on employee safety and productivity.

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