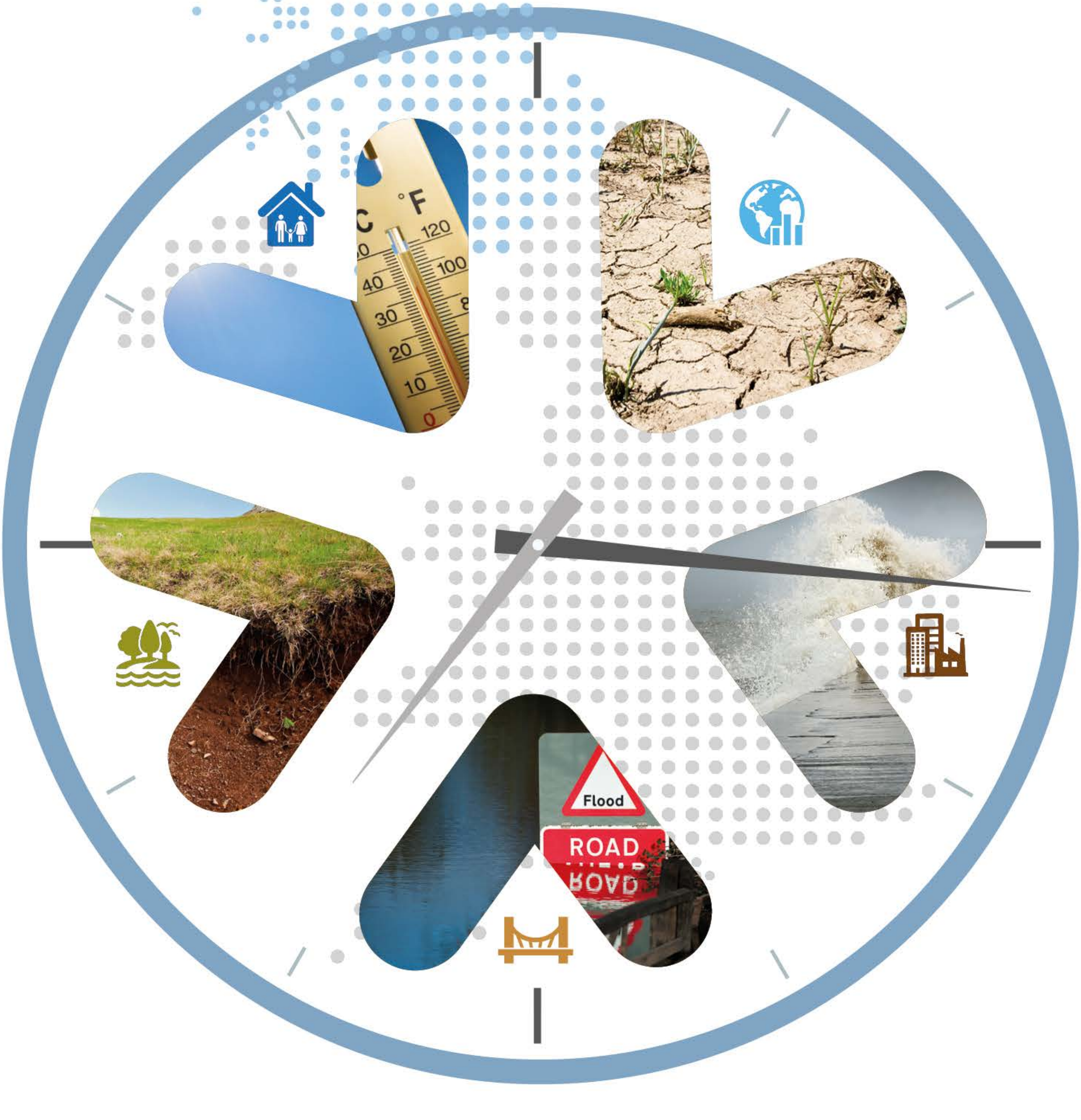
Committee on Climate Change

UK 2017 | Climate Change Risk Assessment

UK Climate Change Risk Assessment 2017 Evidence Report

Summary for Scotland



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

Contents

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1. Introduction

1.1 Context

Scotland's population was about 5.4 million in 2015. Its population density is among the lowest in Europe, although there is significant variation between densely populated areas, mostly in the Central Belt (incorporating Glasgow, Ayrshire, Falkirk, Edinburgh, Lothian and Fife), and areas such as the Western Isles and Highlands. Some rural communities are reliant on private water supplies and non-mains power supplies. There are approximately 800 islands in Scotland, of which about 100 are inhabited.

Covering about 2% of Scotland's land area, Scotland's rivers and lochs contain 90% of the UK's surface freshwater. There is around 21,000 km of coastline which makes up about 12% of Europe's coast. The area from the coast to its fishery limits is around six times the size of the land area of Scotland. Agricultural holdings account for over 70% of Scotland's total land area and nearly a fifth is woodland. Parts of Scotland are mountainous, with ranges in the Highlands and hills in the Southern Uplands. Most of the industrial areas of Scotland are concentrated in the Central Belt.

Scotland has relatively lower temperatures and higher levels of precipitation than other regions of the UK. However, there is regional variation with the Western Highlands being exposed to relatively more wind, rain and snow than Eastern Scotland.

This document summarises the Scotland-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.

The Adaptation Sub-Committee will publish in September 2016 a separate independent assessment of progress towards implementing the objectives, proposals and policies in the Scotland Climate Change Adaptation Programme (SCCAP).

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

1.2 The CCRA2 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 have been assessed in a three-step process (see Figure Sc1 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 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 as follows:

- 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, to summarise the ASC's advice on each risk for the next round of national adaptation programmes. The urgency categories are designed to be mutually exclusive, so that each risk 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).

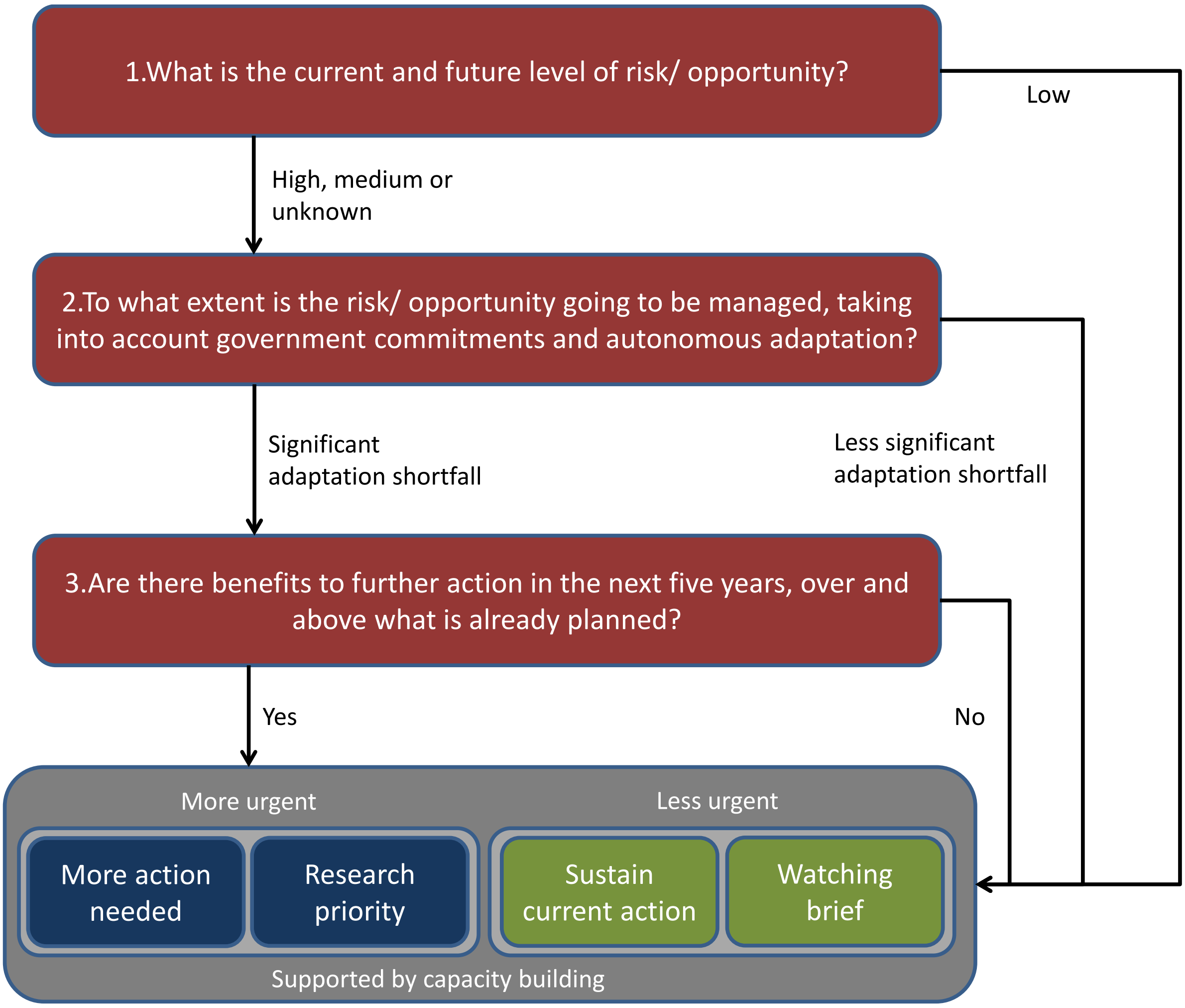
- **More action needed.** New, stronger or different Government policies or implementation activity – over and above that already planned – are needed in the next five years to reduce long-term vulnerability to climate change.

- **Research priority.** Research is needed 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 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 Scotland. However, in most cases the urgency score for Scotland 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 Sc1. 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 Scotland

2.1 Observed changes

Observed national changes in land temperature in Scotland have been similar to the UK average over recent decades. The average UK land temperature in the decade 2005 -2014 was 0.9°C warmer than 1961-1990 (Kendon et al., 2015a).

Annual rainfall over Scotland has increased since about 1970, to a level about 13% above the average for the early decades of the 20th century. All seasons contribute to the increase. Annual rainfall for Scotland increased by 7% between 1961-90 and 1981-2010.

Extreme temperature and rainfall values are not available separately for Scotland. The average count for hot and wet UK days per year during 1981-2010 was 4.63, compared with 3.65 for 1961-90. Statistical results from extreme value analysis suggest that the UK daily maximum and minimum temperature extremes have increased by just over 1°C since the 1950s (Brown et al., 2008), and that heavy seasonal and annual rainfall events have also increased (Jones et al., 2013).

Sea level trends are also difficult to break down for Scotland. 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 Scotland comes from the 2009 UK Climate Projections (UKCP09). 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 change by between -2% - +31% for the same scenario.[3]

Table Sc1 shows how extreme summer temperatures and winter rainfall are projected to change for Edinburgh, 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 Sc1. 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
Edinburgh	23.5	24.8	26.2	27.9	63.4	63.5	70.0	78.4
Belfast	25.9	26.5	28.5	30.9	70.3	70.6	76.9	84.6
Cardiff	31.7	31.9	34.7	38.1	73.6	76.6	79.8	83.6
London	34.4	34.1	37.2	40.6	56.1	57.8	62.5	68.3

Source: Brown et al. (2014).
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.

Sea level for Edinburgh is expected to increase by approximately 20 – 40 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 estimated for a physically plausible high++ scenario based on in direct observations of past climate change events, 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 Scotland

The Climate Change (Scotland) Act 2009 created a framework for both mitigating and adapting to climate change. The Act established legally-binding annual targets to put Scotland on a trajectory to meet at least an 80% reduction in greenhouse gas emissions by 2050 compared with 1990 levels.

The Act also put in place requirements to prepare Scotland for climate change and adapt to its impacts. Ministers are required to publish programmes setting out objectives, proposals and policies to address the risks and opportunities facing Scotland identified within the most recent UK Climate Change Risk Assessment.

The Scottish Government published a non-statutory Adaptation Framework in 2009, accompanied by 12 Adaptation Sector Summaries, followed by updated Sector Action Plans in 2011. The first statutory Scotland Climate Change Adaptation Programme (SCCAP) was published in May 2014, with the next programme due to be published in 2019.

Ministers are required to provide the Scottish Parliament with annual updates on progress with the implementation of the statutory adaptation programme; two such reports have been published to date, in May 2015 and 2016. The 2009 Act also makes provision for an independent assessment of progress towards implementing the objectives, proposals and policies in the statutory adaptation programme. In June 2014 Ministers requested the Committee on Climate Change's Adaptation Sub-Committee (ASC) undertake this assessment, and this is due to be published in September 2016.

Sections 46 and 96 of the 2009 Act require public bodies to exercise their functions in a way that contributes towards the delivery of the Act's emissions reduction targets and any statutory adaptation programme. Following consultation, the Scottish Government laid a statutory order (in November 2015) amending sections of the Act, requiring public bodies (currently 151 organisations) to publically report their actions on both adaptation and mitigation.

3. Natural environment and natural assets

Climate change poses risks to Scotland's soils, natural carbon stores, agriculture, wildlife and coastal habitats and seas. More action is needed to manage these risks. More evidence is also needed to fully characterise other climate change risks and opportunities that are likely to be important for Scotland, including changes in agricultural and forestry productivity and land suitability, as well as impacts on freshwater and marine ecosystems.

The Natural Environment and Natural Assets chapter in the 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 Sc2.

Table Sc2. Urgency scores for the 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 and size 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. More action to factor climate change into conservation planning and site management.
Ne3: Risks and opportunities from changes in agricultural and forestry productivity and land suitability (3.3)		UK			More research into developing integrated land-use planning based upon changing land suitability. More research needed on the nature and scale of changing land suitability and its impacts. More research needed into crop varieties, tree species and agricultural systems that are resilient to climate change.
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.

Table Sc2. Urgency scores for the natural environment and natural assets

Ne5: Risks to natural carbon stores and carbon sequestration (3.3)	UK				More action needed to restore degraded carbon stores, particularly peatlands. More research needed to account for climate change impacts on carbon stores in the UK GHG projections.
Ne6: Risks to agriculture and wildlife from water scarcity; and flooding(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.
Ne7: Risks to freshwater species from higher water temperatures (3.4)		UK			More research needed on the scale of risk and effectiveness of adaptation measures.
Ne8: Risks of land management practices exacerbating flood risk (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. Implement catchment-scale planning for flood risk management. Review potential for adverse flood risk outcomes from land management 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. Develop cross-sectoral initiatives for risk assessment and contingency planning.

Table Sc2. Urgency scores for the natural environment and natural assets

Ne10: Risks to agriculture, forestry, wildlife and heritage from changes 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 freshwater habitats from saltwater intrusion (3.5)			England, Wales	Northern Ireland, Scotland	Continue action 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 (3.8)				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 conditions, 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 Scotland, there is evidence of species moving northwards and uphill, with new colonisations from the south, but losses of cold-loving species at the margins of their southern range. 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.

Mean snow cover duration from October to May in the central Scottish Highlands has decreased between 1979 and 2003, during which time both mean temperatures and mean precipitation have increased. This is affecting the composition of montane vegetation, with the decline of some arctic-alpine species. Repeat surveys of snow-bed vegetation over the past 50-60 years show a shift towards more homogeneous communities, with an increase in generalist species (e.g. Highland Rush) and declines in specialist species such as snow-bed liverworts. As a result, the species richness of dwarf-shrub heath and oceanic-montane liverwort-rich heath habitats is declining. These changes are thought to be due to a combination of increasing temperatures, shifts in precipitation patterns, and changes to grazing regimes.

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. Bioclimatic envelope modelling predicts that species associated with cold montane habitats are likely to see continued contraction of their range to the most northern and high-altitude locations. This is a significant risk for some species in Scotland that are currently at their southern range margin, including iconic species such as the Ptarmigan and Mountain hare. Snow cover and its duration are projected to further decrease, with the possibility of no snow cover below 900 metres by the 2080s. This could lead to the loss of snow-bed communities through the invasion of more competitive species from lower altitudes. Blanket bog bioclimatic space is also projected to reduce in the UK by the 2080s, with only parts of the west of Scotland expected to remain bio-climatically suitable.

The impact of changes in climate space on the persistence of local populations of plants and animals is complex. For each species, the impacts will be affected by potential and actual rates of migration, the nature of connectivity across the landscape, other biotic interactions (e.g. novel pests and pathogens, dependency on other species which move at different rates), and the presence of refugia – small areas which buffer the widespread impacts of environmental change through locally distinctive slope, topography, aspect or hydrology. While some species may be able to manage their adaptation autonomously, others will require translocation or assisted migration, either towards distant suitable future habitat or at least locally towards refugia.

These changes will make meeting existing conservation objectives increasingly challenging and potentially have implications for the provision of ecosystem services in the long-term, such as carbon storage, clean water provision and pollination.

Adaptation

The 2020 Challenge for Scotland's Biodiversity was published by the Scottish Government in 2013 and is Scotland's response to the UN CBD's Aichi Targets and the EU Biodiversity Strategy. It supplements and updates Scotland's Biodiversity: It's in Your Hands (2004). A Route Map to 2020 was published in 2015 and includes 15 Priority Projects including actions for restoration of peatlands, woodlands, and freshwaters, as well as other actions for species and land management. The three documents together comprise the Scottish Biodiversity Strategy. Meeting the aspirations and targets in the Scottish Biodiversity Strategy would do much to improve the resilience of habitats and species to current and future climate change, and to safeguard the provision of vital ecosystem goods and services. However, additional effort over the next five years is very likely to be needed in order to be on-track to meet these targets.

Ne1 and Ne2 together form a set of 'environmental change' threats to habitats, wildlife and the natural heritage in Scotland. In responding to these, Scottish Natural Heritage has developed a set of adaptation principles. These principles are also reflected in the 2020 Challenge. They suggest improving site condition, removing external stressors and increasing connectivity, which reflect the principles in the Lawton report in England ('bigger, better, joined'). These have been supported by practical actions such as in the Central Scotland Green Network. However the adaptation principles also cover a broader range of actions including planning for inevitable change, changing objectives and management measures and species translocation.

There is also an active debate and development process around resilience between researchers and government agencies in Scotland. For example, research on resilience in woodlands is being carried out by Forest Research, James Hutton Institute, Centre for Ecology and Hydrology and other partners. This is being used in policy and practice development through the Scottish Tree Health Advisory Group, and in SNH and Forestry Commission Scotland guidance. More work needs to be done to consider how resilience to environmental change can be included in designated site management.

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 to bring climate and environmental change more explicitly into conservation planning at site level and at wider scales. SNH's adaptation principles form a basis for this, but their interpretation and practical application needs to be developed in terms of:

- specific measures and actual management changes;
- acting under uncertainty, for example by applying different actions in different places as a hedging strategy;
- modifying objectives, especially towards maintaining ecosystem functions; and
- planning for and anticipating necessary changes in spatial distribution, for example by identifying and securing refugia, or beginning slow-acting transformations in sensitive sites like upland streams.

These need to develop in conjunction with continuing efforts to bring ecosystems into good condition (particularly in terms of grazing impacts and non-native invasive species), and to improve connectivity.

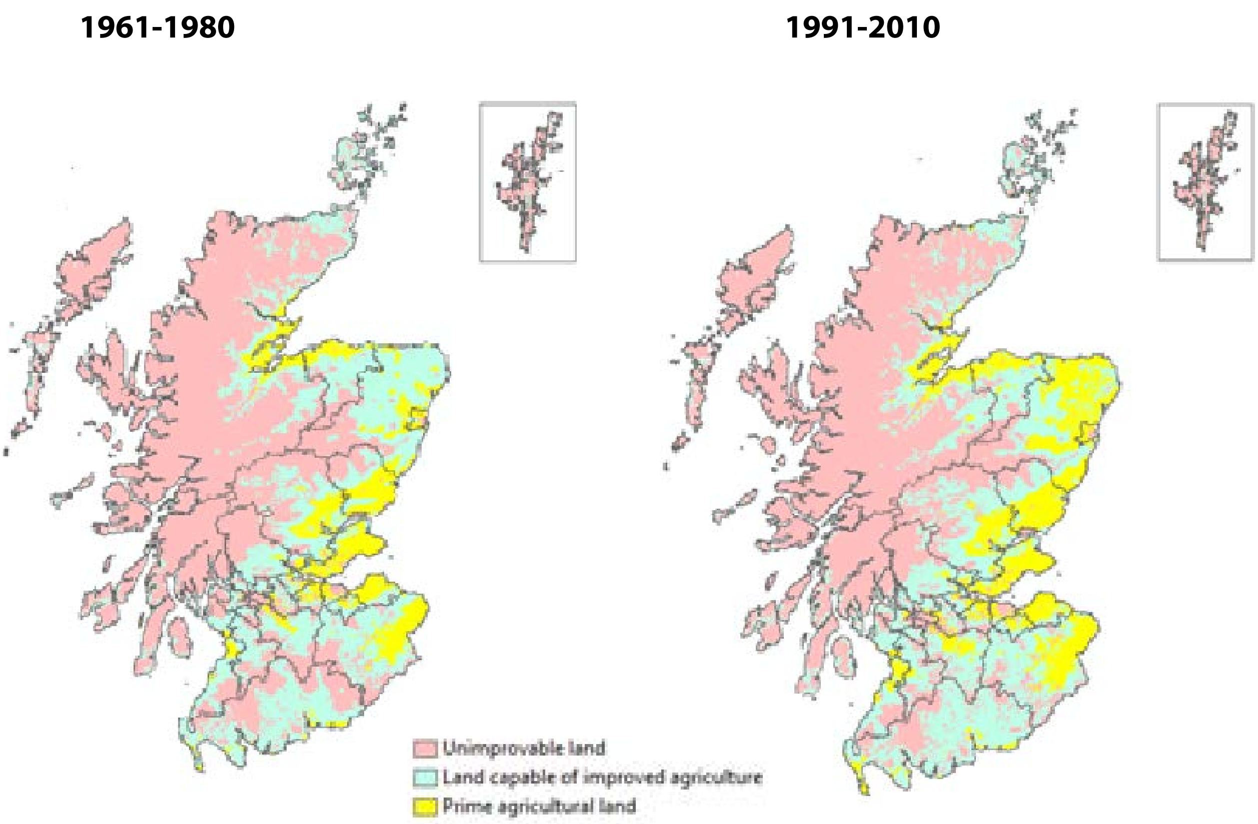
Overall this section describes a range of actions which can be applied to different species, habitats and ecosystem functions to meet adaptation objectives. How this toolbox is to be used is a further challenge – there are likely to be knowledge gaps, cost limitations, long lead-in and lag time effects, incompatible objectives and unexpected outcomes within this wider environmental change. A process of clear prioritisation is likely to be important, perhaps based around the ecosystem functions and services deemed to be of most value.

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. In Scotland, there has been a small expansion (ca.4%) in the area defined as Prime Agricultural Land (PAL) since the 1960s due to a shift in average conditions towards warmer, drier summers (Figure Sc2).

Figure Sc2. Changes in agricultural land capability in Scotland, 1961-1980 and 1991-2010



Source: ClimateXChange Adaptation Indicator NA2 - *Area of Prime Agricultural Land*, from Brown & Castellazzi, 2014.

Only a very small area of prime agricultural land (3-4%) is currently at moderate to severe drought risk, although there has been small increase in drought risk for parts of eastern Scotland due to a shift towards higher soil moisture deficits since the 1980s. Maize is more tolerant of drier conditions than grass and requires a minimum temperature higher than grass to grow effectively. The area under maize in Scotland has approximately trebled (564 ha to 1,318 ha) between 2004 and 2014.

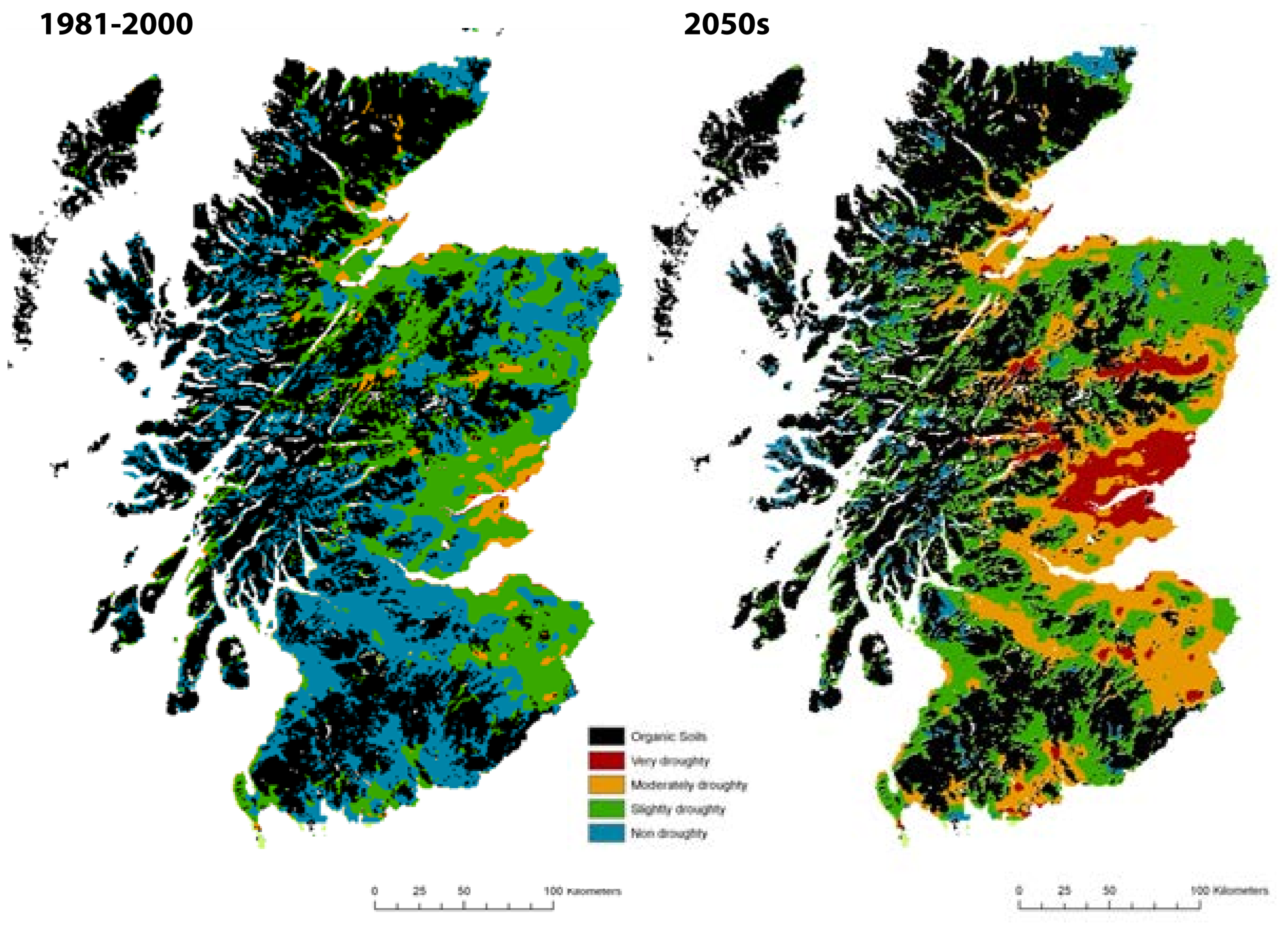
The overall area of land in the UK severely constrained by wetness has slightly reduced since the 1960s. However, some locations, e.g. south-west Scotland, have experienced an increase in wetness constraints due to wetter winters. A projected trend towards warmer drier summers is expected to increase the risk of heat stress in sensitive crops (e.g. winter wheat) and to 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 difficulties during colder conditions. In winter, the extended growing season may provide opportunities for longer outdoor grazing, but this could be counteracted if increased precipitation increases the risk of damage to swards by poaching. Grassland productivity is most likely to decline in drier areas in the east.

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. 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 peat. As a relatively high proportion (36%) of Scottish forests is on peat soils, the potential benefits of higher CO_2 concentrations for forestry may be minimal.

The warming climate allows for a potential expansion of land used for agriculture and forestry in Scotland. Many areas that are currently marginal for cultivation due to climatic limitations could experience an improvement in land capability. There is the potential for the area of prime agricultural land to expand by 20- 40% by the 2050s. However, at the same time, models predict that up to 40-50% of prime agricultural land in the 2050s will be at moderate to severe drought risk, particularly in Tayside and Fife (Figure Sc3). For potatoes this would suggest an additional ca. 50 mm of irrigation water demand during the summer. To put this figure in context, the typical values for irrigation in areas with highest demand in Scotland are currently around 170 mm per year.

Figure Sc3. Projected drought risk for wheat production in Scotland in the 2050s compared to 1981-2000 baseline



Source: Climate XChange Adaptation Indicator NA29 - *Drought risk to agricultural land*, from Brown et al (2011).
Notes: HadRM3 SCP q3 scenario.

Adaptation

Farmers and foresters will be likely to take advantage of new opportunities autonomously. This could occur through changing land use, and in the selection of crop, grass and tree varieties and species that are well-adapted to future environments. Opportunities are also likely to arise as a result of genetics and adaptive crop breeding.

However, autonomous adaptation will largely happen reactively and is less likely to maximise opportunities at a larger scale. It will be necessary to ensure ready access to the necessary genetic variation through the continuing maintenance of germplasm collections, particularly as investment in genetics and crop breeding has a long lead time between research and large-scale field implementation.

Land use planning is mainly based upon protecting prime agricultural land from development, on the assumption that prime land will remain so into the future. Unlike the rest of the UK, Scotland has a statutory Land Use Strategy (LUS). This has established a series of principles and proposals for sustainable land use explicitly account for the changing suitability of land for agricultural and forestry production.

Urgency score

Research priority - There is a need for a realistic assessment of the suitability of current agricultural and forestry systems in Scotland given the projected changes in land capability. This could include reviewing the potential costs and benefits from more widespread production of 'novel' crops, as well as changes in current land uses (e.g. increased cropping of marginal land currently used for livestock). 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.

Ne4: Risks to soils from increased seasonal aridity and wetness

Current and future risks

Studies report no change in overall total soil organic carbon (SOC) stock across Scotland over the past 25 years, although between 1998 and 2007 there was a statistically significant decline of 9.3% in mean SOC concentrations in arable and horticultural soils (from 35.6g/kg to 32.3 g/kg). A simultaneous reduction in mean total nitrogen concentration suggests that processes such as erosion, deep ploughing and increased decomposition may be responsible, with agricultural intensification being the dominant factor. However, 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.

Modelling suggests that annual erosion rates are less than one tonne per hectare per year for the majority of Scotland under current (1971-2000) rainfall patterns and land uses. This level is generally recognised as being tolerable, as it is unlikely to result in the deterioration or loss of soil functions. However, losses of two or more tonnes per hectare per year are predicted in arable areas of eastern Scotland, depending on which crops are grown. Field studies have also identified localised losses in the region of 18-22 tonnes per hectare. Long term (1980-2013) data on suspended sediments in many Scottish rivers show a mixed picture, with increases and decreases. Sedimentation reduces levels of dissolved oxygen available for freshwater species, and so can cause significant ecological damage. In general, the greater the proportion of arable cropping in a catchment, the greater the increase in suspended sediment loads. There is also a strong geographical distribution with catchments draining into the Moray Firth showing an increase in suspended sediment, whilst those catchments in the central belt seeing a decrease.

The risk of water-based soil erosion is expected to be higher with projected increases in the frequency and intensity of heavy rainfall events. The compaction 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.

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 Scottish Soil Framework was established in 2009 to co-ordinate actions to protect soils. It describes key pressures, particularly climate change, and relevant policies to combat those threats. The framework's vision is that soils are recognised as a vital part of the Scottish economy, environment and heritage to be safeguarded for existing and future generations.

There are a number of policy interventions that provide farmers with some incentive to conserve soils. These arise primarily from the Common Agricultural Policy (CAP). Farmers must provide a minimum level of crop or crop residue cover to protect the soil, take measures to prevent erosion, and maintain soil organic matter levels in order to qualify for the full single farm payment. In 2013, 11% of arable land in Scotland was under a reduced tillage regime (defined as any system that leaves a minimum of 30% crop residue as soil cover) and 8% under zero tillage (i.e. direct drilling). Conventional inversion tillage is used on the remaining 81% of arable land. The proportion of arable land left bare (and so at high erosion risk) increased from 15% in 2010 to 19% in 2013. There was over the same period a slight increase in the use of cover crops, from 2% to 3%, but this remains a very low level overall. Furthermore, low levels of inspection make it difficult for the soil protection requirements under Pillar 1 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.

Scottish Planning Policy (2014) states that the land-use planning system should seek to protect soils from damage such as erosion or compaction. Where peat and other carbon rich soils are present, the SPP is clear that applicants should assess the likely effects of development on CO_2 emissions and that developments should aim to minimise this release.

Autonomous responses to the changing climate (e.g. cultivation of steeper slopes; expansion of maize cropping) may increase erosion risks further in the future.

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 and encourage the wider uptake of soil conservation. Measures to reduce erosion (e.g. cover crops) or the impacts of erosion (e.g. buffer strips) could be targeted better towards vulnerable locations. Long-term monitoring of soil health, in terms of SOC levels, erosion rates and soil biota is also needed, particularly of carbon-rich soils, linked to different land management strategies to address knowledge gap of the magnitude of this risk and its geographical variations.

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 the UK'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.

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 are 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. When in a pristine condition, peatlands are usually waterlogged and actively sequester carbon due to retarded decomposition rates and colonisation by peat-forming species, notably Sphagnum. Peatlands occupy around 10% (23,000 km^2) of the UK's land area and store over 3 billion tonnes of carbon. Scotland holds the majority (64%) of the UK's peat resource. Peatlands are particularly sensitive to changes in soil moisture regime. Widespread historical drainage, afforestation and adverse management have resulted in around 35% of peatlands in Scotland showing signs of erosion. Warmer and drier conditions could have adverse implications for the viability of already stressed peatland habitats and their species, particularly bryophytes (mosses and liverworts).

At 15% of land cover, Scotland has the highest proportion of woodland area in the UK with over 1.2 million ha. As a result, over half (55%) of the 15 million tonnes of CO_2 sequestered by UK forests in 2014 was in Scotland.

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 nitrogen deposition, recovery from sulphur deposition, and forest management changes).

However, higher temperatures and changes to soil moisture regimes could increase carbon losses due to enhanced soil respiration. 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). Any significant expansion of intensive agricultural production to the northern and western areas of Scotland in response to changing climatic conditions would also be likely to have negative implications for soil and forest carbon stocks. Future projections of CO_2 emissions and sequestration from soils and forests do not currently account for the direct or indirect implications of climate change.

Adaptation

A programme of peatland restoration has been undertaken through Peatland Action, within the context of the National Peatland Plan. Increasing the rate of restoration to 22,000 ha per year, as set out in the Report of Proposals and Policies 2, is a key action in Scotland's statutory National Planning Framework 3. There is also a policy aspiration to increase the proportion of woodland cover to 25% by 2050.

Data concerning the role of offshore habitats as sinks of carbon is comparatively scarce. The Scottish Government is working with SNH to increase understanding of the distribution of blue carbon habitats, their condition and potential contribution; and review and develop policies on blue carbon and consider proposals to capture their potential. SNH have recently published a report which provides the first comprehensive assessment of the carbon budgets and potential blue carbon stores in Scotland's coastal and marine environment. However, GHG emissions and removals from coastal and marine ecosystems are currently not accounted for at all in the UK GHG Inventory. The impacts of climate change are also not accounted for in future projections of GHG emissions and removals from soils and forests.

Urgency score

More action needed - Further action is needed to restore degraded peat habitats and create new woodlands in appropriate locations. More investigation of carbon storage in soils under agricultural land use in Scotland is also required, particularly given the need to reduce greenhouse gas emissions from the agricultural and land-use sectors. Further research is required to helping develop understanding and potential of blue carbon. Action is also needed to ensure that the UK GHG inventory fully captures all carbon stores and that GHG emission projections from the Land Use, Land Use Change and Forestry sector account for the impacts of climate change on carbon stores.

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

Current and future risks

Scotland has a considerable freshwater resource. There are approximately 125,000 km of running waters (rivers and burns), over 27,000 lochs and lochans, an estimated 198,000 ponds and 220 km of canal habitat. This represents around 90% of the volume of surface freshwater in the UK.

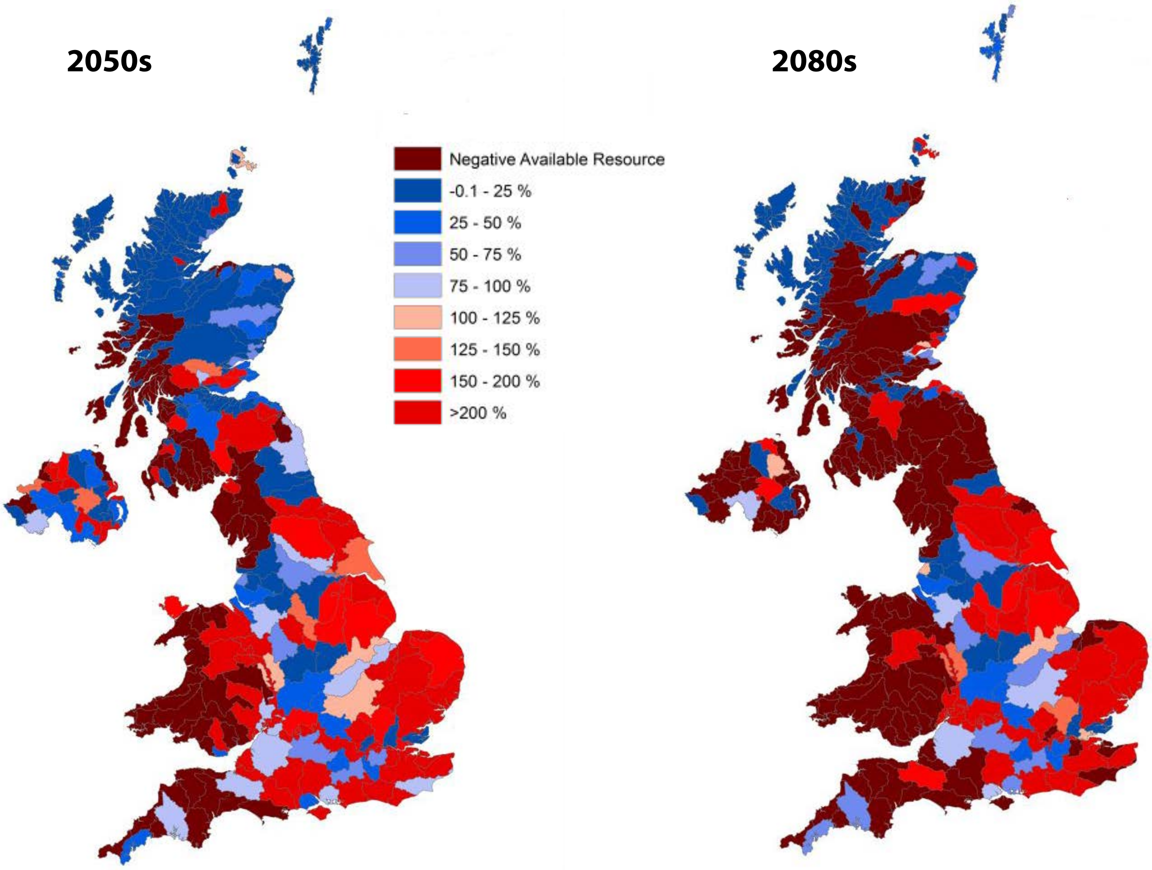
Freshwater species are highly sensitive to low flows, as the quantity of water determines the level of dissolved oxygen available. Low flow conditions can also reduce dilution of pollutants. High flows and their associated sediment loads can cause significant ecological damage, e.g. to fish spawning 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. sewage outfalls).

Just less than 17 million cubic metres of water was abstracted for irrigation in Scotland during 2013, which amounted to 39% of total licensed abstraction. The vast majority (88%) of abstraction of irrigation occurs in June, July and August, primarily in the eastern side of the country. The Tay region alone accounts for over 10 million cubic metres. Abstraction for irrigation currently causes 4% of Significant Water Management Issues (SWMIs) in Scottish water bodies. Abstraction for other purposes (such as renewable energy generation and public water supply) causes a further 17% of SWMIs. Point-source pollution causes of 11% of SWMIs and diffuse pollution just under one quarter (24%).

Future projections of river flows imply changes across the seasons, with increases in average winter flows and reduced spring and summer flows. Irrigation demand for water in the 2050s is projected to increase. If current environment flow requirements are fixed, then a high proportion of catchments in Scotland in the 2050s are projected to not be able to meet minimum environmental flow requirements during periods of low flows. By the 2080s this is projected to be the case for the majority of catchments, with only the northern most catchments projected to have sufficient water resources available for both the natural environment and human uses in a dry year (Figure Sc4). This suggests an increased risk of water restrictions in the land use sector. Allowing environmental flow rates to change in proportion to 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.

Any increase in incidents of low river flow may also mean that discharge consents will become unviable, with consequences for where regulated activities can be sited. New approaches to discharge may be required (e.g. tankerage) where flows can no longer accommodate discharges in an environmentally acceptable way.

Figure Sc4. Abstraction demand in (a) 2050s and (b) 2080s as a percentage of the available resource under high climate and high population growth scenarios, assuming no additional action adaptation and fixed minimum environmental flow requirements.



Source: HR Wallingford (2015) for the ASC.

Notes: The percentage of available demand is based on the average of Q95 and Q70 low flow conditions. The high climate scenario is from UKCP09, High, 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 150,000 ha of arable agricultural land is at high risk from river flooding (10% annual chance of inundation) and overall, an estimated 7% of Scotland's prime agricultural land is located within flood risk areas. A high proportion (33%) of all agricultural land in Scotland is situated within the 5km coastal area, but a relatively small area of arable land (17,000 ha) is currently at high risk of coastal flooding. However, inundation of arable 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 prime agricultural land at a 1-in-75 annual chance of flooding (all sources) is projected to increase by 21% by the 2080s if global mean temperatures rise by 2°C, and as high as 43% under a 4°C temperature rise scenario.

Adaptation

The EU Water Framework Directive requires that all surface water bodies (rivers, lakes, estuaries and coastal waters) should have good ecological status by 2027. 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. However, there is no clear mechanism in place that accounts for the consequences of changes in flow for meeting the WFD targets.

The Scottish Environment Protection Agency (SEPA) is currently trialling a whole catchment approach to abstraction management, working with land managers in catchments that have been identified at risk. Actions focus on crop requirements, water efficiency, irrigation programming and use of storage ponds.

Policy measures include those which aim to reduce to risk to agricultural land from flooding and those that aim to use flooding of agricultural land as a means of reducing the risk of flooding elsewhere. From 2015 to 2020 the Scottish Government's Agri-Environment Climate Scheme provides £350m for measures such as control of flooding through natural flood risk management. Farmers can receive payments for a number of Management Options and Capital Items through the scheme.

The way land is used and managed can either enhance or reduce high and low flows. 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 that are likely to be reducing the natural capacity of soils to manage flows continue, particularly in the uplands.

Urgency score

More action needed - Further action is needed to improve the condition of water bodies as ecological restoration can also take many decades, meaning that there are long lead-in times for action. More action is also needed 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.

Innovative schemes to reduce water demand in water-stressed areas are required. This can be achieved through implementing the Controlled Activities Regulations (CAR) and in the longer term, reviewing the potential ecological impacts of any future relaxation of environmental flow requirements. Targeting of schemes based upon whether water-resource zones are primarily groundwater or surface resources is required, as they have different sensitivities and recovery times. This will have range of co-benefits for managing climate and non-climate related risks and avoid lock-in to a pathway where a high proportion of Scotland's water bodies could potentially be ecologically degraded in the future with climate change.

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 rivers and lakes at similar rates to regional air temperatures since the 1970s with an average warming of 0.03°C/yr reported between 1990-2006 across the UK. 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. Elevated water temperatures are also likely to compound other anthropogenic pressures, such as eutrophication and acidification, particularly in water bodies that are already adversely affected by these pressures.

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 and lochs 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 and 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. Fluvial carbon fluxes are an important mechanism of carbon loss from organic (peat) soils through dissolved organic carbon (DOC). The loss of DOC is caused by rainfall but is also associated with solar radiation and temperature. A number of studies report increases in DOC concentrations in freshwater sites across the UK, including in Scotland. Some of this observed increase in DOC is likely to be due to soils responding to reductions in sulphur deposition since the 1990s, although it has also been suggested that burning and overgrazing may have disrupted the natural buffering capacity of the soil. Increased westerly winds, storminess and sea salt episodes may also be a factor.

Adaptation

The primary mechanism for managing the risk of higher water temperatures is the Water Framework Directive. Increasing water temperatures, combined with changes to flow, will make meeting the WFD targets even more challenging. However, there is no clear mechanism in place that accounts for the consequences of changes in water temperature for meeting the WFD targets.

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 also has long lead times. SNH are currently undertaking research to inform strategic programme of riparian woodland creation.

For some species (e.g. Arctic fish such as vendace) translocation is being trialled as a last resort option. There is however a lack of evidence on the scale of possible translocation required, as well the potential wider ecological implications.

Urgency score

More research needed - Research is needed to identify suitable areas for riparian tree planting to inform the development of a strategic programme of 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 risks

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. This results 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 Scotland or the UK.

Agricultural land accounts for 71% of Scotland'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 protect the natural floodplain from inundation. The impact of agricultural embankments on downstream flood risk is complex, embankments can force water downstream into built-up areas where much more significant damage can be caused, however in some instances they may reduce downstream impacts during large events by preventing the flood plain filling at the start of an event so that there is capacity available during the peak of an event. 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 drainage and rotational burning 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 surface water flood risk. This risk will be exacerbated where soils are degraded and compacted due to land management practices.

Adaptation

As noted in Ne5 above, 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. As noted in Ne6 above, from 2015 to 2020 the Scottish Government's Agri-Environment Climate Scheme provides £350m for measures such as natural flood risk management. Farmers can receive payments for a number of Management Options and Capital Items through the scheme.

There is increased interest in how land practice changes can help to reduce flood peaks and downstream flooding, as seen with the increasing recognition of Natural Flood Management (NFM) schemes, which aim to maximise the use of natural fluvial and landscape features to reduce flood peaks. SEPA has published a Natural Flood Management Handbook to provide a practical guide to the successful implementation of natural flood management. The guidance provided is informed by demonstration projects and studies undertaken by SEPA and partners that have highlighted some of the requirements for the effective delivery of natural flood management. As most NFM 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 field experiments in suggest 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 flood protection in the same way as with conventional flood defences. As with any type of flood risk management scheme, NFM schemes also generally require ongoing maintenance.

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 Scotland. An estimated 1,160 non-native species sub-species have become established in the wild in Scotland. Of those, where adequate data were available, since the 1950s non-natives that increased their range outnumbered those that decreased by a factor of six.

The increase in this risk is primarily due to human activity, 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.

Invasive species like rhododendron are presently substantial problems for Scottish forestry, affecting ground and understorey flora, and competing for water and nutrient resources and inhibiting natural tree regeneration. Invasive species were present in 19% of Scottish native woodlands surveyed in 2014, with well over half (65%) of these being rhododendron. For some woodland types the proportion with invasive species present is much higher, for example 30% for upland oakwood.

Freshwater ecosystems are also being significantly affected, with invasive non-native species identified as a pressure in 32% of all freshwater habitat features in Scotland. 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.

A warmer climate allows 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. Fluke was responsible for considerable disease and death in Scottish sheep in winter/spring of 2012-2013 and there has been an upward trend in diagnoses in both sheep and cattle over the past 10-15 years in Scotland. Serious epidemics predicted to become the norm by the 2020s, especially in the north and west of the country.

There has been a rapid increase over the last 6-7 years in the potential exposure of Caledonian pinewood to the fungal disease Dothistroma needle blight (DNB), often referred to as 'Red Band Needle Blight'. An estimated 9% of core Caledonian pinewood areas are now within 1km of a known DNB infection. The fungus was not known in Scotland until 2002 and there is some evidence to suggest that increased rainfall in spring and summer, coupled with a trend towards warmer springs, is optimising conditions for spore dispersal and infection.

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 cause the risk to increase. For example, a shift towards warmer wetter winters is likely to favour the spread of fungi and related organisms. Although rhododendron occurs throughout the eastern Highlands, it is usually less vigorous there. However, the possibility of warmer and wetter winters in the east as a result of climate change may alter this pattern, potentially 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 Scotland and more widely in the UK. The IUCN considers non-native species to be the second most serious threat to global biodiversity after habitat loss. There is a UK-wide policy framework in place to manage this risk informed by 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 an Invasive Non-Native Species Framework Strategy for GB, as well various policy mechanisms such as WFD, Habitats Directive and Marine Strategy Framework Directive and the EU Regulation on Invasive Alien Species. Risk assessment procedures, which take account of climate change, are now increasingly used to identify problem species and to prioritise actions. A Statutory Group on Non-Native Species, chaired by SNH, continues to develop capability in Scotland to respond to invasions, track responses and learn from them. The Non-Native Species Action Group is completing a prioritisation exercise to determine what species are a priority for Scotland; both for long term management and for prevention. Work will now start to develop improved management of, and surveillance for, those priority species. The Action Group also supports the delivery of relevant parts of the Scottish Biodiversity Strategy Route Map Priority Projects.

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 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, landscapes and heritage from changes 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 Scotland 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 Scotland'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 be widespread in depth and extent because of the large fuel supply and difficulties of suppression.

In 2012/13 there were 479 forest wildfires affecting an area of 268 hectares in Scotland. The Fire and Rescue Service (FRS) spent 334 hours fighting wildfires over this period. Other key habitats affected by wildfire included 384 hectares of mountain, heath and bog and 685 hectares of 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 Cairngorms 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 include measures to reduce the risk. Further adaptation is not generally possible, beyond current risk reduction plans and strategies.

Wildfire is 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. Guidance is provided on adaptation and resilience building, including the Scottish Government's Wildfire Operational Guidance 2013. Similarly, 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.

Historic Environment Scotland also collect data on the condition of, and risks to scheduled monuments and archaeological sites.

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.

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

Current and future risks

The majority (79%) of Scotland's 21,000 km coastline is hard and rocky, and therefore largely resilient to coastal change; however the remaining 21% may experience coastal changes alongside increases in flood risk. A very large proportion of infrastructure and other important sites and assets lie behind the soft coastline, including roads, railways, property and golf courses (see In3 below).

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 metres of vegetated saltmarsh. An 80 metre width of saltmarsh has been estimated to reduce the height of seawall defence required from 12 metres to 3 metres resulting in capital cost savings of £2,600–4,600 per metre of seawall.

Some recent studies identify salt marsh and sand dune habitats responding to changes in sea level, sediment supply and tidal inundation. These dynamic sites have the ability to respond to anticipated changes, as they have for the preceding millennia. However, where the coastline is protected by hard engineering structures, or other land uses (e.g. agriculture, infrastructure and industry) the natural adjustment of coastal systems to rising sea levels is less likely and less able to occur. Whilst the land-ward movement of habitat through 'roll back' is most common in sand and gravel habitats affected by sea level rise, it may possible within some salt marsh dominated locations. In many cases in Scotland, upper salt marshes appear to have changed little in recent decades, whilst lower salt marsh altitudes appear to be increasing. Whilst similar changes have been noted internationally, further research is required to appreciate how widespread these changes are across Scotland. However, in the majority of cases in Scotland, upper salt marsh appears little changed, unlike the lower saltmarsh which appears to be increasing in altitude. There is a lack of understanding of the dynamism, resilience and vulnerability of these habitats and the ecosystem services they provide in the face of sea level rise.

The UKNEA estimated that across the UK coastal margin habitats have declined by 16% due to development and coastal squeeze since the 1940s, but also highlighted that this estimate is poorly quantified.

On developed shores (i.e. those with built assets) storm events cause coastal erosion and flooding which can and do threaten coastal assets. Here the loss of habitats from development pressure or losses along the sea-ward edge through retreat or surface lowering can worsen flood risk. Investigations in England and Wales showed the systematic loss of habitats seaward of, and alongshore from, sea walls. Whilst a comparable national assessment has not yet been undertaken in Scotland, individual assessments suggest comparable trends.

In north-west Scotland, the distinctive machair habitat has been identified as particularly vulnerable to sea level rise. The main machair areas are separated from the foreshore by systems of coastal dune ridges that provide protection from the sea, but in places the dunes have been removed by erosion. Much of the machair is not only low-lying, but in some cases below the high water mark, meaning even small changes in sea level could have a large influence on the habitat.

An estimated 25,840 ha of coastal habitats in Scotland are very highly susceptible to coastal erosion and 17,890 ha remain susceptible once defences and coastal sediment are taken into account. The proportion of designated sites that are very highly susceptible to coastal erosion is 4,248ha (SSSIs), 2,190ha (SAC) and 2,922ha (SPA). The continued presence of these habitats is largely dependent on the free movement of sediment (via erosion, transport and deposition).

Coastal habitats have also experienced the direct effects of climate change through changing temperature profiles, as with terrestrial and freshwater systems. This has been most evident with rocky inter- and subtidal species, which show warmer 'southern' species are shifting northwards with colder, 'northern' species declining. 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 unless further implementation of adaptation measures take place that recognise the dynamic processes of the coast.

There is increasing evidence that the overwintering distributions of many coastal wading birds have shifted in recent decades in response to warming. In the last decade, this has resulted in declines in usage of east coast sites in favour of The Netherlands. 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 pattern of palaeo and historical sea level change across Scotland is variable. Whilst areas peripheral to the former ice sheet have experienced longstanding submergence, the interior has experienced longstanding uplift. The present uplift at its maximum is 1.7 mm/yr whilst much of the coast has an uplift rate closer to 1 mm/yr. All areas are now experiencing relative sea level rise and there is an observed increased frequency of floods within the tide gauge record at Aberdeen, Millport and Stornoway.[4] The future magnitude of absolute sea level rise according to UKCP09 is between 1-7.5 mm/yr from 1990-2095, with an extreme H++ scenario suggesting a higher upper end of 10-19 mm/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 NEA projected coastal margin habitats losses to reach 8% by 2060. However, for higher sea level rise scenarios the potential losses may be significantly greater as the risk of threshold effects then increase 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. As the current evidence suggests an acceleration 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 habitats and landforms.

Adaptation

Shoreline Management Plans are in place for some sections of the 'soft' Scottish coastline where dynamic coastal processes are occurring and this has been identified as a local priority. Where present, 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. The National Coastal Change

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[4] Aberdeen 1946-2007, Millport 1978-2007 and Stornoway 1976-2007.

Assessment will identify areas that are at risk from erosion. Local authorities can consider how best to address the risks identified by the NCCA and whether a SMP would be beneficial.

CCRA1 noted the absence of coastal change analysis between historical mapping and modern datasets in Scotland. This analysis is being undertaken as part of the National Coastal Change Assessment and will be complete by late 2016. It will provide the historical context and anticipated future erosion for all soft coasts in Scotland (results are available via www.dynamiccoast.com). This, alongside SEPA's flood hazard maps, intends to support the vulnerability assessments and adaptation planning obligations within Shoreline Management Plans, Local Development Plans, Scottish Planning Policy, Flood Risk Management Plans and National and Regional Marine Plans. National Marine Planning policies also include the need to consider areas for adaptation, including managed realignment.

The condition and risk of coastal archaeological sites is available from Coastal Zone Assessment Surveys commissioned by Historic Environment Scotland.[5]

There is considerable opportunity for the enhancement of coastal habitats for natural flood and erosion management. Whilst such approaches are more commonplace within freshwater catchments (see NE8), there is a research gap for coastal habitats and Natural Flood Management.

Urgency score

More action needed - more effort is needed to understand and allow dynamic readjustment of coastal landforms and habitats, particularly in terms of increased sediment supply and adaptation opportunities. Whilst the NCCA is ongoing the consequential implications for natural heritage, flood risk management and cultural heritage need to be considered and put in place adaptive measures. 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 provide are threatened. 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 from pre-industrial levels, 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 greenhouse gas 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

[5] http://scharp.co.uk/about/czass/

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.

Preliminary modelling indicates that much of the North Sea seafloor is likely to become seasonally undersaturated (during late winter/early spring) with regard to aragonite by 2100 under high CO_2 emission scenarios. By 2060, over 85% of known deep-sea cold water coral reefs in UK waters (mostly to the West of Scotland) could be exposed to waters that are corrosive to them and many other shell-forming organisms as a result of under-saturation of aragonite. Seven marine protected areas are designated for the protection of cold water corals. Ocean acidification may also pose a significant threat to the UK shellfish industry, but more research is required.

Extensive changes in the planktonic ecosystem have been observed in terms of plankton production overall, biodiversity and species distribution. In the North Sea the population of previously dominant and important cold water zooplankton species has declined in biomass by 70% since the 1960s. Species with warmer-water affinities are moving northward to replace the species but are not numerically abundant or as nutritionally important (i.e. less lipid rich). 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 colonise 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 and the range of black guillemot, common gull and Arctic tern may shrink to such an extent that only Shetland and the most northerly tips of mainland Scotland will hold breeding colonies. 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 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 and English Channel 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, while those in the North Sea are expected to decline. Climate change has been reducing the maximum sustainable yield of cod in the North Sea by around 32,000 tonnes per decade.

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

Policies for protecting and enhancing the marine environment and biodiversity are in place, primarily the EU Marine Strategy Framework Directive (2008) and the Marine (Scotland) Act (2010). The MSSFD 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 Scottish waters, although this will depend on the scale at which assessments are conducted. 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.

The impact of climate change is one of the factors considered when setting quotas under the EU Common Fisheries Policy. 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 or negotiate.

A statutory marine plan is now in place and regional marine plans are currently being developed. The National Marine Plan sets out how actions under the Plan need to be adapted to take into account the effects of climate change. In the future, marine planning will be improved by greater understanding of how climate change may alter marine ecosystems. Key organisations in the sector have recently reported under the Adaptation Reporting Power, including Seafish, a non-departmental public body set up by the Fisheries Act 1981 to improve efficiency and raise standards across the UK seafood industry.

A number of trends suggest that resilience of the 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.

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 clear if any additional or alternative action is needed for adaptation beyond current measures to improve resilience.

Urgency score

Research priority - Improve understanding of the potential impacts of climate change on marine ecosystems, especially changes in acidity, dissolved oxygen content and temperature. Improve understanding of the social and economic implications of climate change for the fishing industry and for range of ecosystem services provided by marine natural capital. Need 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 and considered to fall in to the ‘watching brief’ category across Scotland include:

Ne11: Risks to aquifers, agricultural land and freshwater habitats from saltwater intrusion. Future risks to aquifers are expected to slowly increase with sea level rise and associated tidal surges. However, the relatively slow transitional time of saline intrusion of aquifers (even with higher rates of sea level rise) provides time to adapt should issues begin to arise.

Ne14: Risks and opportunities from changes in landscape character. The character of the Scottish landscape has changed over the last few decades. Climate change is only one of many contributing factors, though effects land cover and indirectly influences 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.

4. Infrastructure

Infrastructure in Scotland 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 sector. The risks and opportunities from climate change to sectors are assessed and these are summarised, along with the urgency scores, in Table Sc3.

Table Sc.3. Urgency scores for infrastructure risks

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 needed 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 research needed to better understand risk to existing networks, including flood and coastal erosion risk management infrastructure which protects other systems, 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 slopes, 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 as necessary.
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 Sc.3. Urgency scores for infrastructure risks

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		Northern Ireland, Scotland		Keep current efforts to reduce risk through long-term water resource planning under review.
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 including use of suitable cooling technologies.
In11: Risks to energy, transport and ICT 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		Northern Ireland, Wales	More research needed to assess climate risks to existing and planned offshore renewable energy 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, including maintenance and renewal 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 to maintain current cold-weather planning and response capabilities.

In1: Risks of cascading failures from interdependent infrastructure networks

Current and future risk

Infrastructure networks do not operate in isolation, with services in particular 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 via 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

The importance of interdependencies between networks is recognised and the Cabinet Office has begun focusing on cross sector vulnerabilities as part of their annual resilience review. Individual sectors 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. The onus rests with individual organisation to identify and manage interdependent risks in the same way as they would any other business risk.

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 risk

Infrastructure across all sectors are exposed to coastal, river, surface water and groundwater flooding. 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).

The impact of flooding on the rail network in Scotland is not known. Flooding was directly responsible for approximately 340,000 passenger delay minutes on the GB rail network between 2006 and 2013 (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 infrastructure sectors are already exposed to a high likelihood of river and surface water flooding (Table Sc4).

Table Sc4. Number/length of infrastructure assets and networks in Scotland 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	No data	
Major electricity generation sites	16	0
Electricity transmission and distribution substations (>5,000 customers)	34	14
Strategic road network (km)	994	779
Rail network (km)	279	435
Rail stations	13	46
Mobile phone masts	86	0
Active landfill sites	1	1

Note: Assumes no additional adaptation beyond current plans. The numbers in this table differ to SEPA statistics on assets at flood risk. Box Sc.1 provides an explanation and further details on the differences between the CCRA modelling and SEPA statistics.

Box Sc.1. Differences between the CCRA2 modelling and SEPA flood risk data

Estimates of current flood risk

CCRA2 has used new projections of future flood risk in the UK (Sayers et al., 2015, for the ASC). The projections have been developed using a Future Flood Explorer (FFE). The FFE uses existing flood risk data to create an emulation of the flood risk system that is capable of exploring the impact of climate change on a range of risk metrics, such as properties, infrastructure assets and agricultural land. The FFE relies upon nationally available datasets from England, Northern Ireland, Scotland and Wales to provide a consistent UK wide view of changes in flood risk arising from all sources.

Flood Risk Management (FRM) Strategies in Scotland (published in 2015) estimate present-day flood risk. The underlying flood risk data prepared by SEPA for the FRM Strategies was used in the FFE.

The FFE aggregates the flood risk data provided by each UK country to a Calculation Area scale in order to model future flood risk. This inevitably involves simplifying the underlying datasets that often have a greater spatial resolution. For this reason, there are inevitably some differences between the estimates of current flood risk between the FFE and the data provided by SEPA. A series of verification tests were applied to compare outputs of the FFE with the present day risk metrics supplied by the national flood authorities. Overall, the results of these tests provided assurance that the FFE is reproducing present day risk adequately and as such the estimates of future changes are fit for purpose.

Use of the 1 in 75 year return period

The national flood authorities in England, Wales, Scotland and Northern Ireland all assess flood risk using slightly different bands of probability. The flood probability bands also vary according to the source of flooding. For the purpose of CCRA2, these differences were rationalized into a single banding expressed in terms of a return period in years of: a) more frequent than 1:75, b) between 1:75-200 and c) less frequent than 1:200. These bands were used to assess all flood sources across the UK to ensure consistency in reporting. The results of the modelling were primarily reported in terms of the highest likelihood band (1:75).

FRM Strategies in Scotland are based on a suite of flood hazard and risk information. This suite includes high probability (1 in 10-year), medium probability (1 in 200-year) and low probability (1 in 1000-year) flood scenarios in addition to a consideration of the impacts of climate change. The 1 in 75-year return period is not included in the flood hazard suite.

It should be noted that the 1 in 75 year return period used in Sayers et al. is not a standard return period used for flood risk assessments in Scotland so that results presented in the CCRA2, interpolated from Scottish data, may therefore not directly relate to information published in the Strategies. Reference should be made to FRM Strategies for more detailed information on flood risk in Scotland (http://apps.sepa.org.uk/FRMStrategies/).

The risk of river and surface water flooding is expected to rise, as patterns of rainfall become more intense. Western areas of Scotland in particular could be subject to significant increases in heavy winter rainfall. 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 significantly increase with climate change (Table Sc5).

Table Sc5. Projected change in number/length of infrastructure assets and networks in Scotland 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
Major electricity generation sites	+23%	No change
Electricity transmission and distribution substations (>5,000 customers)	+22%	+35%
Strategic road network	+47%	+70%
Rail network	+47%	+71%
Rail stations	+37%	+48%
Mobile phone masts	+19%	No change
Active landfill sites	No change	+15%

Notes: Assumes no additional adaptation beyond current plans. The numbers in this table differ to SEPA statistics on assets at flood risk. Box Sc.1 provides an explanation and further details on the differences between the CCRA modelling and SEPA statistics.

The performance of flood risk management infrastructure is also subject to climate change impacts. The most significant of these is a reduction in a standard of protection. For example, by the 2080s, modelling for the ASC calculates that, even if current adaptation efforts continue, the number of residential properties in the UK at a 1-in-75 or greater annual chance of flooding will almost double from 860,000 today to 1.7 million by the 2080s. Concrete flood risk management infrastructure will deteriorate faster if subjected to more frequent and extreme periods of freeze–thaw. Prolonged hot dry periods are likely to accelerate desiccation of surface soils on earth embankments.

Adaptation

The Scottish Government is responsible for flood and coastal erosion risk management policy and action is being delivered in accordance with the Flood Risk Management (Scotland) Act 2009. Funds for flood and coastal defence works are included in the General Capital Grant to local authorities. Until 2015/16 the funding was distributed to local authorities with a competitive element based on the funding requirements for large new projects costing more than £2 million. From 2016/17 onwards it will be distributed in line with the priorities set out in the 14 Flood Risk Management Strategies published in December 2015 which, taken together, provide the first ever national plan for flood risk management in Scotland and set out a programme for investment over the next 6 years.

There is no published account of what has been achieved by efforts in recent years to improve the resilience of infrastructure systems in Scotland 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 clear how this benchmark has been interpreted by each sector, and whether this minimum standard of flood resilience is now in place. It is therefore uncertain whether this risk is being managed either autonomously or through Government policy.

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 adaption 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 risk

Scotland has significant infrastructure assets located in coastal areas and so potentially exposed to flooding from the sea. Key infrastructure assets located in the coastal zone include power stations, ports and road and rail networks (Table Sc6)

Table Sc6. Number/length of infrastructure assets and networks in Scotland located in areas at 1:75 or greater annual chance of flooding from the sea (present day)

Receptor	Number/length
Clean and wastewater sites	No data
Electricity generation sites	1
Electricity transmission and distribution assets	6
Strategic road network (km)	141
Rail network (km)	31
Rail stations	7
Mobile phone masts	14
Active landfill sites	0

Some stretches of the Scottish coastline are actively eroding, exposing some road and rail networks. A particular location at risk is on the East Coast Main Line, just north of the border at Lamberton Beach, adjacent to the A1 Trunk Road. Here the cliff face is being scoured away and starting to encroach towards the railway. Research that preceded the Scottish National Coastal Change Assessment (NCCA) has identified that £1bn of roads, £2bn railway line and £0.5bn of housing lies within land which is inherently susceptible to coastal erosion.

There are around 110 ports in Scotland, nine of which are classified as major. Several dozen ports in the Highlands and Islands support lifeline ferry services. Scottish ports in total handle around 96 million tonnes of cargo every year with an estimated trade value of £65bn. There were 17,000 ship arrivals at Scottish ports in 2008, and over 9.5 million passengers per annum pass through Scottish ports.

More than 60% of Scotland's energy generating capacity is provided by three major power stations (each of them has capacity above 1,000MW): Hunterston B, Torness and Peterhead. Hunterston B and Torness are nuclear power plants, Peterhead is gas-fired. Hunterston B is at a low risk of coastal flooding. All power stations in the UK at risk of flooding have a high standard of protection (i.e. at least higher than 1-in-1,000 year).

By the 2080s, in Scotland, between 20cm and 60cm of sea level rise is expected, increasing the likelihood of a severe 1-in-100 year coastal flood to between a 1-in-20 and 1-in-60 annual chance. Whilst the funnel shape of the North Sea magnifies storm surges as they travel southwards, Scotland remains at risk from storm surges and similarly the estuaries and inlets can magnify surge levels.

Projected rises in mean sea level rise could increase scour potential by 16% for vertical structures, such as sea walls. Coastal defences will be particularly vulnerable where the 'toe' height of defence foundations is exposed to stronger and near continual wave action.

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 Sc7).

Table Sc7. Projected change in number/length of infrastructure assets and networks in Scotland located in areas exposed to a 1:75 or greater annual chance of flooding from the sea under a trajectory of a 4ºC rise in global mean temperature by the end of the century

Receptor	% change
Electricity generation sites	No change
Electricity transmission and distribution substations (>5,000 customers)	+90%
Strategic road network	+129%
Rail network	+164%
Rail stations	+27%
Mobile phone masts	+203%

Notes: Assumes no additional adaptation beyond current plans.

Adaptation

The Scottish Government is responsible for flood and coastal erosion risk management policy and action is being delivered in accordance with the Flood Risk Management (Scotland) Act 2009. Funds for flood and coastal defence works are included in the General Capital Grant to local authorities (see In2).

Local authorities are designated as coast protection authorities under the Coast Protection Act (1949) and have permissive powers to carry out work to protect land in their area. Whilst coastal erosion is an acknowledged issue at a national level and within those local authorities that have a coastal erosion policy, the Scottish Government and the Convention of Scottish Local Authorities (COSLA) have agreed that the flood and coast protection component of the General Capital Grant given to local authorities will continue to be exclusively targeted on flood protection schemes and flood risk management and not on coastal protection. Nevertheless, the Scottish Government consider that councils already have the flexibility to use their General Capital Grant allocation for coast protection if they consider it to be justifiable as a local priority.

Shoreline Management Plans are in place for some sections of the Scottish coastline where dynamic coastal processes are occurring (i.e. erosion and accretion) and this has been identified as a local priority. 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.

CCRA1 noted the absence of coastal change analysis between historical mapping and modern datasets in Scotland. This analysis is being undertaken as part of the National Coastal Change Assessment and will be complete by late 2016. It will provide the historical context and anticipated future erosion for all soft coasts in Scotland, thereby supporting adaptation planning within Shoreline Management Plans, Local Development Plans, Scottish Planning Policy, Flood Risk Management Plans and Marine Plans. To better understand the rate of erosion affecting the rail network, Scotrail has completed a study to assess the impact and available options. Proposals are being developed to increase the resilience of the coastal railway line at Saltcoats.

Specific sea level rise assessments have been conducted for major ports in Scotland. Port operators cite some benefits from higher sea levels, including reducing the potential need to dredge harbours and channels. However, there is also evidence of increased sedimentation rates within the navigation channels on multiple North Sea ports in the UK and Netherlands. The causal mechanisms have not yet been identified. To date, no port authorities in Scotland have submitted reports under the second round of the Adaptation Reporting Power.

Urgency score

Research priority - there is a need to assess whether current policies and approaches to coastal management are realistic in the context of climate change as well as value for money and affordability constraints, and to identify infrastructure assets at risk if holding current defence lines is economically unrealistic. Improved understanding is required of the impacts of climate change on existing flood and coastal erosion risk management infrastructure.

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 flooding due to heavy rainfall

Current and future risk

Widespread flooding in 2007 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 priority adaptation to the risk of increased sewer flooding is to reduce the amount of surface water allowed to enter the sewer network. Reducing surface water in sewers can be done 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 'traditional' drainage techniques.

Scottish Water is responsible for the management of Scotland's public sewerage system. The investments that Scottish Water is required to make are set out by Scottish Ministers. They have required Scottish Water undertake catchment studies together with Local Authorities so that there is a better understanding of flows of surface water in urban areas. This information will be used to inform future measures necessary to better manage the surface water and therefore prevent flooding in a changing climate. SUDs must play a significant role in managing surface water. However, there are a number of barriers to water companies across the UK implementing SUDS including:

- Reducing surface water in sewers is a long-term action that can only be achieved gradually. Further work is required to ensure that funding and regulatory arrangements favour reducing surface water rather than building storage tanks and larger sewers.
- Uncertainties in implementing SuDS compared to traditional drainage, including of the costs, effectiveness and timescales of when benefits will be realised. Further work is required to understand flows and volumes of surface water in urban areas and the ability of green infrastructure to manage these flows.
- Capacity and resources in water companies to appraise, design, build and maintain 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.
- Concerns over the long term maintenance of SUDS, as many SUDs in new developments are not being vested with Scottish Water or local highways authorities.

Current permitted development rights for the construction of hard surfaces between a dwelling and a road extend only to porous materials or where runoff is directed to a porous area within the curtilage of a dwelling. This provision was introduced to mitigate the cumulative impact of small increases in hard surfacing leading to increased run off into road drains that ultimately flow into watercourses or sewage treatment works. While sales of porous paving materials comprise a small percentage of residential paving sales, there is no evidence as to the extent to which permitted development rights are being enforced by local planning authorities.

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. The Water Environment (Controlled Activities) (Scotland) Regulations (CAR) 2005 require all surface water from new development to be treated by SuDS before it is discharged into the water environment, except for single houses, where the discharge will be into coastal water or when discharging to the combined sewer. Although the CAR requirement is to protect water quality, SUDS systems can provide flood alleviation benefits through their water retention ability if designed to appropriate standards. The separation of foul from surface water is a standard requirement for all new developments where this can be achieved.

The National Planning Framework 3 is clear that across Scotland water management and flooding are increasingly important and Scottish Planning Policy is clear that avoidance of flooding, including that from surface water sewers and culverts is a key principle. It provides a flood risk framework to guide development. However, these policies are not aligned with the vesting processes and standards for SUDS.

Urgency score

More action needed - There is a need for policies to ensure plans are developed and implemented over the long term to reduce surface water in the sewers. This will require deployment of a range of techniques, including SUDs, into existing built-up areas in order to relieve pressure on the public sewer system. Embedding long term planning in the management of sewer networks will help overcome barriers to reducing 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 flood 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. It has been recognised in England that longer term planning for sewerage / urban drainage services has had less focus than water supply infrastructure and Drainage Strategies are being introduced to address this. There is no equivalent requirement for long term planning of sewer networks in Scotland.

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

Current and future risk

High and fast river flows can cause localised riverbank erosion, undermining structures such as bridges and exposing buried cabling and pipework. Winter precipitation has shown an increase of almost 70% in north Scotland, between1961 and 2004. Between 1961 and 2004 river flows have shown no significant change, but substantial increases in winter flows (Dee, 38%; Kelvin, 69%; Teith, 91%). Peak river flows in Scotland are expected to increase.

High river flows can cause localised riverbank erosion, 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, including to cultural heritage as many road and rail bridges in Scotland are listed buildings.

Across the UK, bridge scour on average causes one bridge failure per year. The most serious recent example of bridge scour was during the Cumbria floods of 2009, when several bridges in the Lake District were lost most notably the Workington Bridge - causing loss of life and severe and lasting disruption to the town.

Only a small proportion of trunk road bridges (4%) and (1%) of rail bridges in Scotland are currently highly susceptible to scour. Over half (57%) of rail bridges currently have medium susceptibility. Network Rail has identified 41 structures classified as high risk. In addition, a further 72 structures have the potential to fall into the high-risk category on the conclusion of more detailed assessment. There has not been any national-level modelling of how risk may increase in the future for Scotland. In England, increases in scour exposure only appear to become significant in the 2080s in a high emission scenario (p90), with 26% of rail and major road bridges moving from a 'low' to a 'medium' exposure category, and 5% moving from 'low' to a 'high' exposure category.

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

In relation to the rail network, bridge scour is not considered as a separate risk in Network Rail's climate change adaptation programme for Scotland. However, a programme of bridge scour protection is underway including physical works (scour protection) and operational instructions. This has mostly centred around embankment stability, coastal defences, and bridge stability. In Scotland, routine helicopter surveys inspect riverbanks for erosion. However it is not known how much adaptation is taking place nationally. Network Rail currently has plans to remediate 20 higher-risk sites between 2015 and 2020.

A systematic evaluation of bridge scour risk has been conducted for all of the strategic road network structures over or adjacent to watercourses. This approach has utilised BA74 (bridges only) and BD97 (bridges, culverts and walls). Transport Scotland also inspect for the effects of scour during general and principal inspections (which mostly entails visual signs of distress with some diving surveys). Bridge scour is noted as a key risk in the Scottish Climate Change Adaptation Programme. Transport Scotland has developed an ongoing programme of scour repair and resilience works based on inspections of known scour issues.

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. There were on average 12 earthwork failures a year across the rail network between 2003/04 and 2013/14 in Scotland.

Landslides affecting the trunk road network are much less frequent than flooding events, with 12 occurring in 2014/15. Almost half (42%) resulted in full road closure and occurred within very remote, rural parts of Scotland, which are particularly vulnerable to loss of road network connectivity.

Modelling shows that across low to high emissions scenarios, soil moisture fluctuations will lead to increased risk of shrink-swell related failures. The impact of climate change on deeper modes of failure is less clear. However, 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 Scotland lists eight sites where landslips and earthwork failures have occurred, with remedial works completed in seven of the locations. Tackling risk of earthworks remains a 'medium' priority, below other weather-related impacts predominantly wind storms and flooding.

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.

A program of detailed research was commenced in Scotland in 2004 under the Scottish Road Network Landslides Study. A landslide plan exists for the trunk road network. Landslides may not tend to create lasting physical damage to roads and assets, and they may be infrequent, but the disruptions to the network from landslides can be catastrophic. For example, at the A83 Rest and be Thankful, mitigation works have included the upgrading of debris flow netting to provide protection from low frequency high impact landslides, and the opening of a local diversion route (called the Old Military Road) adjacent to the A83.

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. 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 risk

Scotland currently has a comfortable 22% (414Ml/d) supply/demand surplus in the public water supply, when considered at a Scotland wide level. However, not all individual Water Resource Zones are in a surplus position. When other users of water are taken into account, one catchment already has insufficient water to meet demands during periods of low flows (the Moray Coastal catchment). This is not used for public water supply but overabstraction (by other users) is a factor which may be leading to environmental damage.

Climate change is expected to restrict the supply of water whilst population growth will add to demand. However these impacts are expected to be relatively modest in Scotland, at least to the 2030s. For example population growth is expected to be offset by reductions in per capita consumption and leakage. Climate change is expected to reduce deployable output by only a single percentage point (14 Ml/d). All but one of the water resource zones in Scotland is expected to remain in surplus through to the 2080s (assuming low population growth, 2oC of climate change, and no additional action). Only a high population growth, high climate change, and no additional action scenario tips Scotland into supply/demand deficit overall by the 2080s, although supply/demand deficits emerge by the 2050s across the central belt of Scotland in this scenario.

Adaptation

Water companies have been actively involved in climate change adaptation and long-term planning since the 1990s. Proposals in water management plans are expected to maintain a healthy supply/demand surplus in Scotland to the 2030s, to retain a 22% (415Ml/d) overall surplus.

Scottish Water has made commitments to ensure that no individual Water Resource Zones are in supply deficit by 2027 through delivery of the investment already planned between 2015 and 2021 and subsequent investment plans. Alongside this work is being done to assess the long term impacts of climate change on water available for public water supply to inform future investment plans, as well as taking into account the needs of the environment through working closely with SEPA and delivering required improvements.

Urgency score

Sustain Current Action - planned levels of future activity are appropriate, but continued implementation of these plans is needed to ensure that the risk is managed in the future. This will require monitoring the delivery of the commitments and outcomes in the current water company business plans and beyond this, ensuring the options in Water Resources Management Plans are effective in managing the risk of future supply/demand deficits.

In the next round of WRMPs from 2019, there may be a case to look further ahead (i.e. 50 years), integrate drought planning with the WRMP process, and stress test both WRMPs and Drought Plans with a wider range of climate change (particularly low flow and drought) scenarios. The WRMPs should start considering the feasibility of implementing further adaptation 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.

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

Current and future risk

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. However, in Scotland high winds are the highest cause of weather–related disruption (£990,000 annualised Schedule 8 costs). 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.

High winds can cause disruption to both road and ferry network operations. High winds can prevent high sided vehicles crossing bridges structures, typically over relatively short periods of time. Extreme high winds can also close mainland road networks, which then required Transport Scotland's operating companies to work with Police Scotland around traffic management and standard diversion routes. Traffic Scotland can provide the travelling public with information via their website, social media and radio broadcasts. Even a short restricted closure to bridges from high winds will lead to impacts on journey time reliability and knock on effects to the economy in terms of disruption to the movement of goods and services. Transport Scotland monitor the impacts of both the Yellow warning and strong winds on transport services for the West and very North of Scotland, with a focus on both planned cancellations and expected disruption to ferry services.

Between a 4% to 36% increase in the numbers of faults due to lightening by the 2080s is projected (for low and high climate scenario respectively) for the electricity transmission and distribution network. There is no statistically significant change in impacts caused by wind or gales, and a decrease in faults due to snow, sleet and blizzard (-70% to -90%) based on the current relationships between weather and faults.

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 lightening 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. The Scotland Route has commenced a proactive strategy to remove high-risk trees which are capable of landing on the track if they fall. A LIDAR (Light Detection and Ranging) survey was undertaken in July 2012 to identify trees that were at risk of falling on to Scotrail’s infrastructure. The results from this survey will be used to target the areas at which the railway appears to be vulnerable. The Scotland Route also has a High Wind Procedure involving live feeds from weather stations and predefined trigger levels for wind gusts of 60mph+ or mean speed of 47mph+. Transport Scotland have had a High Winds Strategy since mid-2000 for the strategic road network.

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 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 / 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.

In12: Risks to offshore infrastructure from storms and high waves

Current and future risks

Several large offshore wind farms have been consented in waters to the east of Scotland. There is good evidence that extreme winds cause large vibrations and loads in wind farm turbines and supporting structures, creating significant fatigue on turbine blades. This fatigue has resulted in some smaller onshore turbines experiencing failure, losing blades which can be thrown vigorously away from the structure. Such blade loss has not occurred in offshore wind farms in Scotland, or elsewhere in the North Sea. However, about 80% of North Sea offshore turbines outside Scottish waters have experienced failure of grouted connections, primarily in monopole foundations. High wind and wave stress in storms have caused North Sea monopile turbines to experience bending movement in the grouted joints between the monopile and the transition piece, resulting in the need for urgent repairs. Current expectations are that monopole foundations will rarely be used in the deeper waters in which wind farms in Scottish waters have been consented. However, it is unclear currently how effectively the generation of offshore turbines currently deployed in the North Sea outside Scottish waters will withstand repeated exposure to extreme winds.

A further risk to turbines arises from scour and erosion of sediment around foundations leading to the potential for engineering failure in the foundations. Extreme weather conditions are likely to increase the frequency of occurrence of unacceptable degrees of scour, particularly around turbines located on sandy seabed. Many existing North Sea offshore turbines are located on potentially mobile seabed sediment. Increases in the prevalence of extreme weather causing stronger tidal and wave-induced currents at the seabed could result in greater mobility of sediment and more scour incidents than expected. Such effects would be expected to be greatest in monopoles in relatively shallow water, and therefore be of less importance in Scottish east coast wind farms than in farms in the southern North Sea.

Further concerns arise from the potential for sediment movement to lead to increased exposure of underwater power transmission cables. In Scottish waters, these will generally be ducted through directional drilling, protected by rock dump or mattresses, or buried in the sea bed. The exposure of buried cable in itself may not cause damage, but exposed cables will be more vulnerable to interactions with fishing gear etc. and rectification will be required for both engineering and safety reasons. Relaying or repairing cables requires highly specialised vessels and personnel, and the global increase in the demand for these vessels for wind farm installations may make access to them at short notice both difficult and costly.

The risks of extreme weather on these developments, including small scale tide and wave, remains largely untested and it will be some time before monitoring data reveals how robust generation equipment including turbines within Scottish waters are to fatigue. Climate projections show significant uncertainty with regard to changes in wind speed and wave height and power.

Adaptation

National Marine Planning policies require off-shore infrastructure to be resilient to climate change, and these policies need to be strongly implemented through the regulatory processes. In all assessments of proposals, the consenting process requires third party certification or verification to ensure turbines and associated plant does not pose a risk to its environs. Where concern remains additional measures are put in place to provide suitable surety to the decision makers, including use of specialist consultants to assess risk, use of tracking equipment in the event of damage, or other mitigation measures. Like all industries the assessment of risk is based on tried and tested formula which includes modelling of extreme storm events based on past, current and future expectations. This package of measures is intended to ensure that risks to the infrastructure minimised.

The designs of modern off-shore turbines require greater account to be taken of the engineering requirements to be able to withstand the force and duration of extreme weather and associated meteorological and oceanographic conditions that may arise with projected levels of climate change. The uncertainties in the predicted consequences of climate change for storminess, wind speed and wave height emphasise the need for adequate design parameters to ensure structural integrity is maintained. New generations of higher capacity and greater size of turbines have provided opportunities to review the apparent inadequate levels of precaution in engineering parameters of earlier turbines that have limited their ability to withstand current weather conditions, and the greater intensity of storms and stronger winds predicted to occur in future years.

Urgency score

Research priority - There is a need to assess whether off-shore wind turbines that have been deployed in recent years, as well as those due to be installed in the next five years, are being designed effectively. This is needed to avoid lock-in to particular technology pathway and will help to create the right conditions to allow further adaptation should structures not show the necessary robustness at some time later in their operating life.

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

Current and future risk

Rail and electricity transmission and distribution networks are the sectors most vulnerable to impacts during periods of high temperatures. Average summer temperatures in Scotland are expected to increase by 1.5-5.7°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.

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 Scotland. The issue is restricted to few locations (e.g. in Waverley station in Edinburgh the track can reach 42 degrees). Heat impacts resulted in near zero Schedule 8 compensation payments to the train operating companies over the eight years to 2013/14.

More extreme temperatures are projected to result in a threefold increase in the number of days where track maintenance cannot be carried out. Overhead power cables also sag in hot weather, increasing frequency of 'dewirement' (i.e. trains becoming disconnected from their power source). The exposure of staff working outdoors to heat stress may also increase.

Changes in temperature are likely to lead to a reduction in the rating of overhead transmission lines of less than 2% in the 2050s and 5% by the 2080s. The impact on distribution networks is expected to be 1.4%-19% in the same period. Higher temperatures also reduce the efficiency of underground cables by 4-5% and 5-7.5% for transformers. This de-rating is particularly significant in the context of a 1.5-2% load increase/annum that has been recorded by some distribution network operators. This could accelerate if demand for electric transport ramps up.

Adaptation

Were it to become necessary in Scotland, 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 Scotland 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 Scotland 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 risk

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 H++ scenario involving slowdown of the gulf stream and low solar activity would reduce average winter temperatures from to around -5°C, with daily temperatures falling to -18°C. 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 across the UK include:

In7: Risks to hydroelectric generation from low or high river flows. Hydroelectric generation is a major component of power capacity in Scotland (1,500 MW, around 12% of installed capacity) with 145 schemes across the country – half in the Highlands and Islands. 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: Risks to subterranean and surface infrastructure from subsidence. 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 electricity 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. Following closures in recent decades, there is now only one major fossil-fuel power stations in operation in Scotland (Peterhead). The remainder of Scotland's electricity is generated by nuclear (two sites, both on the coast), hydroelectric, and increasingly offshore and onshore wind. The location of the remaining nuclear and gas sites on the coast means there should be no shortage of cooling water available. However, other climate-related risks may impact on cooling. For example, Torness nuclear power station had to be temporarily closed down in June 2011 as a result of large quantities of jellyfish blocking its cooling water intake screens. Reports of increased abundance of jellyfish over recent decades have raised concerns over the possible role of climate change in influencing outbreaks.

5. People and the built environment

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

There are several other risks that might be important for Scotland but there is not enough evidence to assess to what extent adaptation action is already underway to manage the risks. Such areas include risks to communities from flooding and sea level rise, extreme weather impacts on the healthcare system, risks to building fabric from moisture, risks to culturally valued buildings, and risks to health from overheating buildings, poor air quality and pathogens. For these risks, more research in Scotland is urgently needed.

Table Sc8: 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. Although the current level of risk is probably small, the current and future risk is unknown for homes, hospitals, care homes, schools, offices and prisons in Scotland. 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	The level of risk thought to be low for Scotland.
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.
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.

Table Sc8: Urgency scores for people and the built environment

					Future spending plans and how these related to the level of risk in Scotland 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 adaptation further steps might be appropriate in Scotland.
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 Scotland relates to the level of risk.
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 Scotland, there are currently around 0.7 excess deaths per 100,000 population (which with a population of 5.4 million equates to 38 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. There is a lack of evidence on current temperature trends in all types of buildings in Scotland.

The frequency that overheating thresholds are 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 1.4°C and 7.5°C for a rise in global mean temperature of 2°C. 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 Scottish population aged over 75 is also projected to increase from 8% to 18% of the population by 2085. .

Heat-related mortality in the 2050s in Scotland is estimated to increase to between 1.3 and 5.2 per 100,000, based on the UKCP09 medium emissions scenario. This would equate to 70 – 281 excess deaths per year, higher if population growth is accounted for (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.

Uptake of air conditioning in housing is currently low in the UK (3% of homes). Although uptake 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.

In Scotland, the Building (Scotland) Act 2003 mandates Building Regulations that are specific to Scotland. The Building Standards System sets out the essential standards to be met when building work or a conversion takes place. The Technical Handbook accompanying Building Regulations has standards related to flood resilience (standard 3.3), moisture penetration from heavy rain (3.10), heating and overheating (3.13), ventilation (3.14), condensation (3.15), and water efficiency (3.27). However, the impact of these regulations on overheating risks is unknown.

Guidance and awareness-raising policies for heatwaves are in force across the UK. Local health boards in Scotland provide guidance for the public on protecting themselves in hot weather. The effectiveness of these plans in reducing health outcomes is difficult to measure. The plans provide guidance but do not encompass plans and policies to change aspects of the built environment to reduce exposure to heat.

There have been some surveys of the effectiveness of these kinds of plans, but it remains unclear how effective these are at changing people's behaviour, so it cannot be assumed that such activities will manage the risk in the future.

Urgency score

Research priority - The future risk to people in Scotland is fairly small (though not trivial), and there is a lack of evidence on the total level of risk and the benefits of acting for all types of buildings. More research is also required to better understand how people react in hot weather and the effectiveness of measures to encourage the public to protect themselves.

PB4: Potential benefits to health and wellbeing from reduced cold

Current and future risks

Cold-related mortality is significant, with the estimated number of cold-related deaths between 35,800 and 49,700 deaths per year across the UK. In Scotland, one study suggests there are around 48 - 72 excess deaths per 100,000 population per year (which with a population of 5.4 million equates to 2,590 – 3,890 excess deaths per year) (high magnitude, low confidence).

Poor quality housing (cold homes) are a major determinant of the burden of cold related mortality and morbidity. There were estimated to be 940,000 fuel poor households in 2013, equivalent to 39% of all households.

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 estimates that that total number of deaths will only decline by around 2% from a baseline of 41,000 deaths across the UK, by the 2050s (medium emissions scenario, includes population growth). The same study projects a reduction in cold-related mortality in the 2050s to between 34 – 54 per 100,000, based on the UKCP09 medium emissions scenario. Assuming no growth in population, this would equate to 1,836 – 2,916 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.

Urgency score

More action needed- Further action is needed to improve the thermal standards of dwellings in Scotland if the number of excess deaths from cold is to diminish significantly even in warmer average winters. Steps are needed to ensure that further insulation of the housing stock does not increase overheating risks 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 countries 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. Large systematic reviews of epidemiological evidences 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 180,000 residential properties at any degree of risk from flooding across Scotland, of which 97,000 (4%) are at 1:75 or greater risk[6]. This equates to 200,000 people at 1:75 or greater risk (medium magnitude, medium confidence). Current expected (direct) annual damage to residential properties is estimated to be £42 million (medium magnitude, medium confidence). SEPA have also collated values for current levels of risk from across the Flood Risk Management Strategies, and estimate that there are approximately 134,000 residential properties at any degree of risk. It also estimates that annual damages – both direct and indirect – are over £113 million for residential properties (communication from SEPA). Box Sc.1 (page 44) provides an explanation and further details on the differences between the CCRA modelling and SEPA statistics.

Assuming no population growth and a continuation of current levels of adaptation, by the 2050s the projected number of people at 1:75 or greater risk in Scotland rises by 10% to 220,000 under a 2 degree scenario and by 21% to 242,000 for a 4 degree scenario. For the 2080s, the projections suggest an increase of 18% to 236,000under a 2 degree scenario and an increase of 43% to 286,000 people under a 4 degree scenario (medium magnitude, medium confidence). Expected annual damage to residential properties is projected to rise in Scotland by between 43 - 99% in the 2050s and 73 - 190% in the 2080s depending on the climate scenario (medium magnitude, medium confidence).

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[6] Note that 1:75 is not the standard return period used for flood risk assessments in Scotland, but has been used in the CCRA to give a consistent set of results for the whole of the UK.

Adaptation

The Flood Risk Management (Scotland) Act 2009 transposed the EU Floods Directive. Part 3 of the Act put in place a framework for the Scottish Environment Protection Agency (SEPA) to prepare a National Flood Risk Assessment (NFRA, first published in 2011) flood hazard and risk maps (first published in 2013) and flood risk management plans to the timescale required by the Directive. The review of flood risk management plans in 2021 must account for the likely impacts of climate change. In 2015, SEPA published 14 new flood risk management strategies for each Local Plan district. These will be transposed into delivery plans called local flood risk management plans in 2016.

The Act also replaces the 1961 Act by giving local authorities a 'general power' to take forward a full range of flood risk management measures. As well as retaining a duty to maintain flood defences, the 2009 Act gives local authorities powers to deliver flood protection schemes that will contribute to the implementation of agreed flood risk management plans and are consistent with requirements laid down by Scottish Ministers.

An analysis of 16 planning authorities (out of 32) has shown that only over half of these authorities have undertaken a Strategic Flood Risk Assessment for their Local Development Plans, despite being requested by SEPA in all but two cases. Local Development Plans were found not satisfactorily applying the SPP principles of precautionary approach to flood risk from all sources, flood avoidance, by safeguarding storage and conveying capacity; and flood reduction through natural and structural management methods. However most of the issues within the LDP where then rectified during the Examination, thus the final plans were deemed satisfactory.

Flood risk management legislation promotes the implementation of a more sustainable and integrated approach to managing surface water (drainage and flooding), which includes a significant change away from more traditional hard engineering (e.g. underground storage) to managing water on the surface and reducing water in sewers using 'green and blue' infrastructure (including sustainable urban drainage systems, SuDS), both in existing areas and in new developments. According to SEPA, coordination between the drainage and flooding authorities is happening in localised areas but needs to be improved. Under the Water Environment (Controlled Activities) (Scotland) Regulations 2011, it is a general requirement for SuDS to be installed where new developments have surface water that drains into the water environment in order to protect water quality. Where legally required, SuDS should manage surface water drainage up to a1 in 30 year rainfall event and protect water quality. Not all SuDS are required to manage surface water flooding (up to the 1 in 200 year rainfall event in Scotland). Surface water drainage in Scotland falls under water company and road authority responsibility for sewers and roads respectively, while surface water flooding falls under the responsibility of flood authorities.

According to SEPA, Scottish Planning Policy sets out a framework to ensure new development is not at risk of flooding. In general most development (e.g. residential, commercial) should not be at risk of river, coastal or surface water flooding in the 1 in 200 year flood event, but more vulnerable types of development may require higher standards. The National Records for Scotland (household projections 2012 based) project that between 2012 and 2037 the number of households in Scotland is projected to increase by 17% to 2.78 million, an average annual increase of about 15,800 households. The land use planning system is essential to ensuring these new homes are not at risk of flooding (communication from SEPA).

Unlike in England and in Wales, there has not been a national assessment of long-term (i.e. out to 2060 and beyond) funding and adaptation needs for flood and coastal risk management in Scotland. This means it is not clear whether the sums being spent on flood and coastal defence will be sufficient to avoid flood risk increasing over the long term. The Flood Risk Management Strategies will inform future spending plans.

Uptake of property-level protection (PLP) is deemed to be low in Scotland, although actual uptake figures are not available (JBA, 2014). The same report estimated that 43,000 properties located in areas at 1 in 25 to 1 in 30 flood risk could benefit from PLP and that uptake would be cost-effective. Some local authorities in Scotland provide subsidy/discount schemes for PLP (for example, Scottish Borders Council) and the potential for PLP has also been identified in the FRM Strategies.

Urgency score

Research priority - More evidence is needed to assess precisely how the current level of action relates to the level of risk in Scotland. 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 surface water 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 gravitational variation across the Earth and a number of oceanographic factors. The current level of risk to the viability of coastal communities is low in Scotland (low magnitude, high confidence).

Some coastal communities especially in the Hebrides, areas of the Solway Firth, Firth of Clyde and the coastline from Moray to Fife (including Aberdeen) might be at risk from increased storminess and wave overtopping, but there are uncertainties over the scale and timing of these risks.

Adaptation

In Scotland, the Flood Risk Management (Scotland) Act 2009 and the Coast Protection Act (1949) provide the primary legal framework for flood and coastal erosion risk management. Scotland is currently undertaking a National Coastal Change Assessment, the findings of which are due in 2016/17.

Where present, Shoreline Management Plans assess 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. There are non-statutory Shoreline Management Plans in place for some locations in Scotland. It is not currently known whether the approaches and actions implied by the plans are being adopted.

These plans also do not consider the likelihood and impact of loss of coastal communities and what measures should be taken to manage this change.

Urgency score

Research priority - There is a need to develop long-term plans – in addition to shoreline management plans - for coastal communities 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 risk

Building fabric can be damaged following a flood through damp and mould and the deposition of salts and sediments from flood water.

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 seasons. This is where when damp walls are heated by solar radiation to the extent that moisture can migrate towards the cooler interior of the building. The Scottish House Condition Survey (2014) states that around 67,000 (2.8%) homes suffer from penetrating damp and 226,000 (9.3%) from condensation.

In many locations across the UK, 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. However, there have been no population-wide studies that link the prevalence of mould in buildings to flooding or other climate risks.

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

Adaptation

There are no national level data in Scotland or elsewhere in the UK about the current and necessary future level of adaptation of buildings to damp, mould, wind and driving rain.

Urgency score

Research priority - Further research is needed to understand:

- The degree of current and future risk of different types of buildings or buildings in different parts of Scotland to driving rain, mould, and damp.
- What adaptations are taking place 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 (flooding, erosion or land instability, wind storms) and longer-term, chronic damage to a building fabric.

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 the UK's historic buildings and grounds from extreme weather and long-term changes to the climate. 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). According to SEPA, 76% of pre-1919 housing is assumed to be in private ownership, on the basis that 76% of housing stock is in private ownership.[7]

Adaptation

Information is collected on the condition of listed and historic buildings in Scotland through the Buildings at Risk Register for Scotland and the Scottish House Condition Survey.[8] 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. In general, overarching plans and appropriate adaptation actions are not yet in place.

Urgency score

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

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[7] Ecofys 2013: Review of Estimates of the Economic Impact of Scotland's Historic Environment, A Report to Historic Scotland, Revised 2013.

[8] http://www.buildingsatrisk.org.uk/

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. According to Sayers et al. 2015, in Scotland at present, no hospitals are located in areas at 1:200 or greater risk of flooding, but there are 84 emergency service stations, 10 GP surgeries and 53 care homes located in areas at 1:200 or greater risk of flooding. SEPA estimate that 3 hospitals are located in areas at 1:200 or greater risk of flooding.

Heatwaves can cause problems with the functionality of hospitals as well as the thermal comfort of patients and staff. Research indicates that that older designs are at less risk of overheating than more modern buildings, though again the level of risk in Scotland is unknown.

The risk of heat-related mortality is larger in care homes than in the general population. Qualitative studies suggest that problems are associated with poorly adapted equipment the structural design of buildings, and current care practices. However, it is not known how big an issue this is for Scotland.

Cold spells and snow storms are very disruptive due to staff not being able to travel to work (as observed for example during the cold winter of 2010-11). Cold weather can also affect healthcare infrastructure and increase demand on health services (see examples in Chapter 5 of the Evidence Report).

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. Under a 4 degree scenario by 2050, the numbers of Scottish assets located in areas at 1-in-200 annual chance of flooding or greater include around 105 emergency service stations (28% increase), 12 GP surgeries (19% increase) and 65 care homes (23% increase). (medium magnitude, low confidence).

Future projections of risk are not available for other hazards.

Adaptation

The Sustainable Development strategy for Scotland (2012) requires each NHS Scotland body to produce a Sustainable development action plan. Each of the health boards in Scotland is in the process of producing climate change plans.

Across the UK as a whole, there is some evidence of inconsistencies in terms of planning for extreme weather in the health and social care sector. 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, but it is not known how important this will be in the future for Scotland.

Urgency score

Research Priority More evidence is needed to assess how current plans in Scotland 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 Scotland 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.

PB10: Risks to health from changes in air quality

Current and future risks

There is no evidence available that is specific to Scotland for this risk. At the UK 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 Euro 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 (NO2), 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 temperatures 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 the climate. 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 oxides 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-relate 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

The need for action to reduce the impacts of climate change alone on air pollution is unclear. There is an obvious need to put in place measures to reduce the effects of emissions on air pollution Current policies are not currently sufficient to control current air quality levels to within EU guided limits, but the justification for further action in the future due to climate change is uncertain. Scotland in 2015 produced the Cleaner Air for Scotland that links the air quality and climate change agendas.

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 data on the number of children and adults living with chronic respiratory conditions 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 Scotland 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. 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. Modelling has been done on capacity of mosquito vectors and tick vectors (*Hyalomma marginatum)* to move north in Europe, indicating that UK unlikely to become habitable for *Aedes albopictus* before mid-century. 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.

The future magnitude of impact is uncertain, but as the current magnitude is thought to be high and the published evidence suggests that the risk will increase, expert judgement is that the future risk will also be high magnitude. This risk has low confidence.

Adaptation

Surveillance and monitoring activities are underway in all four UK countries. Health Protection Scotland (HPS) is the Scottish National Surveillance centre for communicable diseases, and has responsibility for pathogen surveillance. It is not known how effective these 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 should 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 has been an expansion of the geographical ranges of some harmful warmer water phytoplankton species into higher latitudes. The transmission of marine pathogens (through food) is also 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.

Evidence related to the impact of future climate change on gastro-intestinal pathogens in drinking water is also limited. 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. The level of magnitude is unknown and this risk therefore has low confidence.

Adaptation

Policies are in place to deal with future issues arising from risks to water quality. . Drinking Water Quality in Scotland is regulated by the Drinking Water Quality Regulator (DWQR). CEFAS have also developed an early warning and forecasting tool for Vibrio. .

Urgency score

Sustain current action - Policies and mechanisms are sufficient 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 these represent a fairly small percentage of the total 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 nationally rainfall was 59% of the 1981 – 2010 average. Very rarely, there are restrictions on domestic supplies that can affect health and wellbeing, 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. The current magnitude of risk annually is unknown and this risk therefore has low confidence. There is also an unknown risk to households connected to private water supplies. There are around 150,000 people in Scotland that are connected to a private water supply.

Water supply interruptions can also be caused by flooding and cold weather, but the risks for Scotland are not quantified.

The future risks to health from droughts 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 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 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 the 'watching brief' category for Scotland are:

PB2: Risks to passengers from high temperatures on public transport. Higher temperatures have been cited as a risk to the effective functioning of urban transport networks because of risks to commuter comfort and health. In Scotland, the current and future magnitude of this risk on an annual basis is unknown and it therefore has low confidence. This risk is classed as sustain current action at the UK, but given the uncertainty and potentially low magnitude of overheating risks in Scotland this risk has been classed as watching brief.

PB3: Opportunities for increased outdoor activities from higher temperatures. Climate change is increasingly recognized as a factor that may influence the recreational use of outdoor environments. Despite awareness of the pervasive effects of climate change, its effects on outdoor recreation have only recently been studied in detail. 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 near future. 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 Scotland 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. The future level of risk is currently projected to be low, and therefore it is thought unlikely that there would be a significant adaptation shortfall. The relatively high level of regulation regarding food safety from farm to fork provides the UK with a high level of capacity to adapt climate change. As climate change moves the climate into unknown territory this could make current regulations and food monitoring inadequate to deal with future threats, such as emerging disease. Thus, activities such as horizon scanning and ongoing monitoring are needed. Early warning systems or food risk detection systems may also play an important role in mitigating and adapting to climate change induced food threats.

6. Business and industry

Flooding and extreme weather events which damage assets and disrupt business operations pose the greatest risk to Scottish 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 supportive 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 Sc9. Urgency scores for business and industry

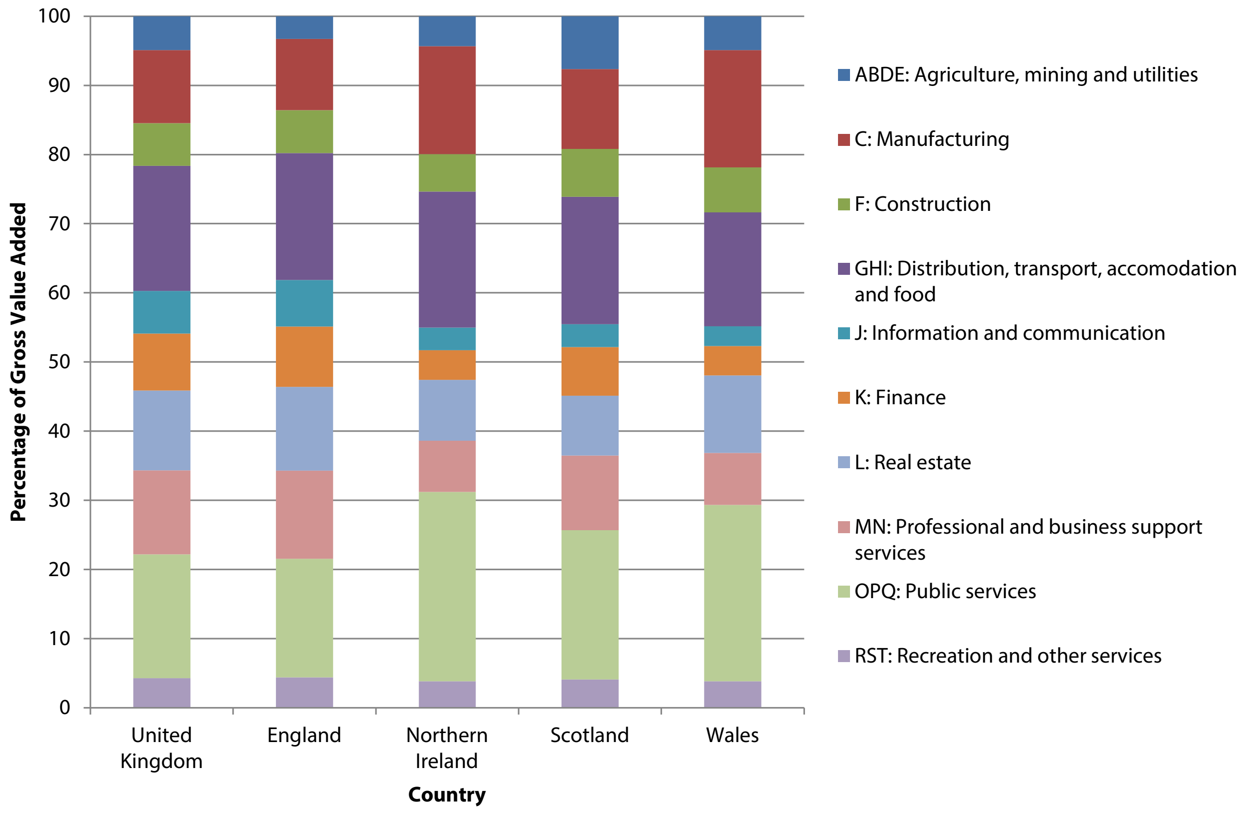
Risk/opportunity (reference to relevant section(s) of CCRA Evidence Report)	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
Bu1: Risks to business sites from flooding (6.2.2, 6.2.3)	England	Northern Ireland, Scotland, Wales			More research is needed in Scotland 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 Sc9. 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 Sc5 compares the distribution of Gross Value Added (GVA) among sectors by UK country for 2014. The relative contributions can differ. For example, 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%). Agriculture, mining and utilities make up a higher proportion of Scotland's GVA (8%) than for the UK as a whole (5%).

Figure Sc5. Distribution of Gross Value Added among sectors by UK country, 2014



Source: ONS (2015).

Table Sc10 compares the distribution of workforce jobs in the UK and Scotland in 2015. Like for Gross Value Added, there are differences in the proportion of workforce jobs accounted for by different industry sectors. For example, mining and quarrying accounts for approximately 39,000 workforce jobs or 1.4% of the total in Scotland, whereas it accounts for 71,000 or 0.2% of the total in the UK. 782,000 or 29% of workforce jobs in Scotland are in Wholesale and Retail Trade; Repair of Vehicles and Human Health and Social Work Activities. In the UK these two industry sectors account for 9 million or 27% of workforce jobs.

Table Sc10. Percentage of workforce jobs by industry section, 2015

Industry	United Kingdom (%)	Scotland (%)
A : Agriculture, Forestry And Fishing	1.2	2.1
B : Mining And Quarrying	0.2	1.4
C : Manufacturing	7.8	7.6
D : Electricity, Gas, Steam And Air Conditioning	0.4	0.7
E : Water Supply; Sewerage, Waste Management	0.6	0.7
F : Construction	6.6	6.9
G : Wholesale And Retail Trade; Repair Of Vehicles	14.7	14.4
H : Transportation And Storage	4.6	4.4
I : Accommodation And Food Service Activities	6.7	7.2
J : Information And Communication	4.0	2.4
K : Financial And Insurance Activities	3.4	3.2
L : Real Estate Activities	1.6	1.3
M : Professional, Scientific And Technical Activities	8.7	6.5
N : Administrative And Support Service Activities	8.4	7.8
O : Public Administration And Defence	4.4	5.7
P : Education	8.7	7.9
Q : Human Health And Social Work Activities	12.4	14.6
R : Arts, Entertainment And Recreation	2.9	3.0
S : Other Service Activities	2.6	1.8
T : Activities Of Households As Employers;...	0.2	0.2
Total (%)	100.0	100.0
Total (Thousands)	33,783	2,697

Source: ONS (2016d) accessed through NOMIS.
Notes: 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 (SIC) 2007.

The proportion of private sector enterprises accounted for by Small and Medium Enterprises (SMEs) is similar in Scotland to the UK as a whole. 99.9% of private sector enterprises in Scotland are SMEs, with the vast majority of these having fewer than 10 employees. SMEs in Scotland account for 43% of private sector employment and 47% of turnover. Table Sc11 sets out these data in full.

Table Sc11. UK and Scotland private sectors

Size of business	UK			Scotland		
	Businesses	Employment (thousands)	Turnover (£, millions)	Businesses	Employment (thousands)	Turnover (£, millions)
Micro	5,146,400 (95.5%)	8,461 (32.7%)	672,815 (18.1%)	322,365 (94.7%)	577 (33.1%)	39,682 (18.9%)
Small	203,525 (3.8%)	3,968 (15.3%)	543,058 (14.6%)	15,095 (4.4%)	291 (16.7%)	26,583 (12.7%)
Medium	32,560 (0.6%)	3,183 (12.3%)	537,996 (14.5%)	2,420 (0.7%)	238 (13.6%)	32,886 (15.7%)
Large	6,965 (0.1%)	10,260 (39.7%)	1,956,409 (52.7%)	490 (0.1%)	638 (36.6%)	110,253 (52.7%)
Total	5,389,450 (100%)	25,871 (100%)	3,710,278 (100%)	340,370 (100%)	1,745 (100%)	209,404 (100%)

Source: BIS (2015a).
Notes: 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 249 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.

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

- For the present day, approximately 42,000 non-residential properties are at any degree of risk (1:1000 year or less) of flooding in Scotland. Of these, 25,000 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 £120 million.
- By the 2050s, the number of non-residential properties at risk of significant flooding in Scotland is projected to increase between 9% and 21%. Expected annual damages are projected to increase between 19% and 60%, equivalent to a £23 million to £72 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 at risk of significant flooding in Scotland is projected to increase between 17% and 38%. Expected annual damages are projected to increase between 40% and 120%, equivalent to a £50 million to £150 million increase. [Scenario: 2°C or 4°C , not including population growth and assuming the continuation of current levels of adaptation].

Analysis by SEPA (2016) finds that for the period 2016 to 2021, approximately 29,000 non-residential properties are at risk of flooding. Annual average damages from all sources of flooding (coastal, fluvial and pluvial) for this period are estimated to be £91 million. Box Sc.1 (page 44) provides an explanation and further details on the differences between the CCRA modelling and SEPA statistics.

Adaptation

SEPA has produced Flood Risk Management Strategies for 14 Local Planning Districts (LPDs) which aim to help individuals, local communities and businesses to understand their local flood risk and its management. Businesses in Scotland can sign up to Floodline to receive Flood Alerts and Warnings. Over 1,900 businesses have registered. This may be an underestimate since business owners or managers may have signed up to the service as individuals but receive flood warnings specifically for their business premises rather than their own personal properties. SEPA has also developed guidance for businesses on creating flood plans and advice on flood insurance.

Research for the UK conducted in 2013 (which included some respondents from Scotland) suggests that the proportion of private sector organisations saying they have a business continuity management (BCM) plan in place increased from 42% to 58% between 2008 and 2013. Other research suggests that in general the smaller the business, the less chance there is that they have a plan in place. Around four-fifths of surveyed businesses report benefits from having a BCM plan in place.

Under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 it is a general requirement for new developments with surface water drainage systems discharging to the water environment to have sustainable urban drainage systems in place. Scottish Planning Policy aims to avoid increased surface water flooding through requirements for SuDS and minimising the area of impermeable surface (Scottish Government, 2016). It also states that proposed arrangements for SuDS should be adequate for the development and appropriate long-term maintenance arrangements should be put in place. There is limited evidence to assess whether the proportion of commercial sector projects which have made use of permeable paving, or other surface water flood mitigation measures, is increasing. The Scottish Government commissioned JBA Consulting (2014) to assess the flood risk benefits of property level protection. JBA Consulting concluded that *"PLP can be an effective approach to managing flood risk in Scotland" but that "take up has been limited"*.

Urgency score

Research priority - More research is needed to understand future spending plans and the uptake and impact of flood protection measures in Scotland, 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 16% (Sayers et al., 2015, for the ASC) or 21% (SEPA,2016) of total expected annual damages to Scotland from flooding, 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 Scotland from sea level rise is thought to be low (low magnitude, high confidence), but the future risk is uncertain. 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 Scotland are at risk from permanent coastal change has not been quantified to date.

Damages from coastal flooding in Scotland are estimated to increase by around 450% by the 2080s, meaning coastal flooding will account for a far higher proportion of flood damage in Scotland than the present day (high magnitude, low confidence). [Scenario: 4°C, not including population growth and assuming a continuation of current levels of adaptation]

Adaptation

There are non-statutory Shoreline Management Plans in place for some locations in Scotland. In some cases private management plans have been developed to protect places of importance to the tourism industry from flooding and coastal erosion, for example West Sands, St. Andrews.

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 may have an impact on businesses located in affected areas. Research is required to understand the level of risk, and 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.

Analysis by HR Wallingford et al. (2015) shows that the current risk of water scarcity for businesses in Scotland is small. The catchments in Scotland with the largest absolute natural available resource (water available for human use once ecological flow requirements are satisfied) during times of low flows are the Rivers Tay and Spey. The catchments in Scotland with the least absolute natural available resource during times of low flows tend to be small, coastal catchments, although there are a few which are larger and more central.

Non-domestic consumption of public water supplies was 410 million litres per day in 2014-2015. SEPA analysis identified the chemicals and food and drink manufacturing sectors as the largest industrial users of water in Scotland. Earlier analysis by CJC Consulting suggested that the major water using sectors in Scotland (comprising abstracted water and mains supply) were fish farming, malt whisky distilling and paper manufacturing. Long-term water scarcity lasting more than a few months, such as that experienced in parts of Tayside during 2003-2004 is extremely rare in Scotland. Typically, water scarcity is a short-term issue occurring mostly in summer. In terms of summer rainfall, while there is some evidence of a decrease in parts of the north of Scotland by as much as 20%, the SEPA conclude that any changes in summer rainfall have so far not resulted in measurable trends in summer water scarcity.

The Scotch Whisky Association commissioned the Scotch Whisky Research Institute to assess climate change risks. Their research noted that low flows in rivers affected a number of sites in recent years and that raised summer temperatures elevated water temperatures making the spirit production less efficient (Scotch Whisky Research Institute (2011) for the Scotch Whisky Association).

In the future, projections suggest that under the most extreme upper bound scenarios for the 2050s and 2080s, considering both climate change and population growth, there is a general pattern of a lack of available resource across central Scotland. Only the northern most catchments of Scotland are projected to maintain a high level of water available under all future scenarios. The same research found that enhanced adaptation is most notable in the west where in a number of catchments the difference between a ‘No additional action’ and ‘Current objectives+’ scenario may make the difference between a projection of surplus or deficit.

SEPA findings of suggest by 2050 that the reduction from current flows in some rivers in Scotland would be more than 25% and reduced rainfall and higher temperatures may lead to more than a doubling in the frequency of low flow events. Less flow means less dilution of the pollutants that make their way into rivers and, combined with the higher temperature, could likely result in a reduction of water quality. This may mean more intensive treatment may be required for raw water supply to business. Low flows may also affect where business sites are able to discharge water and may require new approaches, for example use of tankers.

Adaptation

All abstractors have a duty under Regulation 5 of the Controlled Activities Regulations (CARs) to use water efficiently. The CARs were amended in 2011 to include emergency provisions to allow SEPA, in certain circumstances, to amend existing authorisations or issue new authorisations to cope with prolonged periods of dry weather. SEPA identify catchments under pressure from abstraction in River Basin Management Plans and work with appropriate stakeholders to develop site and sector specific solutions. SEPA is also consulting on a national water scarcity plan.

All non-domestic customers in Scotland are metered unless it is not practicable to do so. In 2014/15 about 80% of Scottish Water connected non-household properties were metered.

There are signs that water is being better managed by some businesses. Non-domestic water consumption in Scotland has fallen from 530 million litres per day in 2002/03 to 410 million litres per day in 2014/15. Resource Efficient Scotland, a free advice and support programme established by Scottish Government, published a guide to improving water efficiency and promote case studies of good practice.

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. 10% of FHC signatories' sites were in Scotland. The Scotch Whisky industry reported in 2015 that net water use was down 14% from 2008 levels.

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 Scotland-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%). Using survey results from those living in flood risk areas in Scotland, Werrity et al. (2007) found that the mean work days lost by those affected ranged between 6.3 and 10.4 days depending on if annual, compassionate or unpaid leave was taken. The mean work days lost per household ranged from 0.7 to 1.4.

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.

Current and future risks – high temperatures

There is no Scotland-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 Scotland) 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 Scotland-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 Scotland's exports increased from £12.6 billion in 2005 to £17.5 billion by 2015. Over the same time period the value of Scotland's imports increased from £9.8 billion to £13billion. 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. Studies have found that share prices can fall by between 7% and 30% on average following failures in the supply chain, relative to benchmark companies. The Scotch Whisky Institute noted in 2011 that heavy snow and ice challenged the integrity of warehouses in the north of Scotland, causing operational and supply chain disruptions.

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. Landslide disruptions have been noted to block roads and cause disruption to business in Scotland. For example, the Stob Coire Sgriodain landslide in June 2012 resulted in a goods train being derailed. The British Geological Survey has also documented landslides in the past 10 years at Glen Ogle, Penicuik and the 'Rest-And-Be-Thankful Pass'. High tides and stormy seas can disrupt ferry services to islands for several weeks each year causing raw material delivery problems, fuel supply issues and difficulty in shipping finished goods.

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 value 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 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 knock-on 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 also tends to be at individual business or sometimes sector level. There is a gap therefore, in assessing international supply chain interruptions, and how the resilience of UK infrastructure affects business' ability to create resilient supply chains and distribution networks. There may be key areas or vulnerable pinch-points which have yet to be identified.

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 Scotland are:

Bu4: Risks to business from reduced access to capital. We do not have any evidence that is specific to Scotland 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 Scotland 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 reserved (shown with a * below). Other areas, such as food supply and safety policies are devolved to the Scottish Government. In any case, cooperation within the UK, as well as with other countries, is key to managing these risks. Table Sc11 sets out the urgency scores for international risks.

Table Sc11. International risks and urgency scores

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 (Section 7.2)	UK				At 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 pro-active 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.

Table Sc11. International risks and urgency scores

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 Scotland, as 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 reserved. As such, the resilience of the Scottish 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 volatility of food prices, but it is unclear how these data are used for strategic, forward planning. Relying of 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.

Urgency score

More action needed - There is no food security strategy at the Scottish 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 the EU and 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 Scotland 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 (Lloyd's); the return period of an outbreak of foot and mouth disease is estimated to be about 1:15 years.

Adaptation

Food Standards Scotland is responsible for food safety (and nutrition) policy in Scotland. Food Safety Policies reflect the EU frameworks, establishing controls on food imported from countries outside the EU. Food control regulations govern the control of food not of animal origin entering the UK from non-EU countries. Food imported from non-EU countries must also comply with the requirements of the EU Food Hygiene Regulations. The duties of port health authorities are key to manage international food safety risk. These duties 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, with food price spikes and supply chain vulnerability, the interconnected nature of food systems makes the scope for effective unilateral UK government 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 an impact assessment of different options.

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 the EU, 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

As for the rest of the UK, Scottish agriculture could gain a comparative advantage in specific products, relative to the other regions of the EU, 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 Scottish 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 very scenario-dependent.

Urgency score

More research needed- (at UK level for global trend, at Scottish level for domestic trends). Scotland 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 Scottish agriculture, especially in terms of water and soils. 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 Scottish Government, and are described in the Urgency Scoring template 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 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 Scotland, 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 relating to natural capital, water security, food security, wellbeing, economic prosperity and global security.

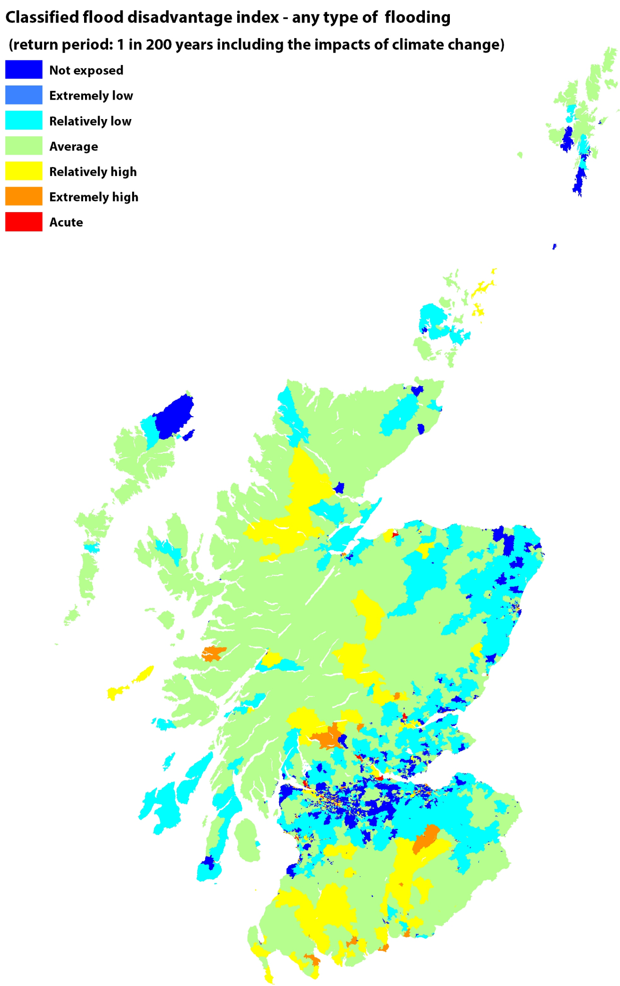
For example, food security in Scotland is likely to be impacted by increasing constraints to agricultural production from a combination of increased soil erosion (Ne3); the continued loss of soil carbon from intensive agricultural practices (Ne4); and sea level rise (Ne11). Wellbeing in Scotland can be affected by risks from flooding, for example through impacts on people's physical and mental health and life expectancy, as well as people's living conditions and disposable income, through direct economic damages to properties (PB5). Flooding also impacts on jobs and income through, for example, employers closing business, being forced to change employment conditions, or leaving an area due to unacceptable flood risks (Bu1).

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. In Scotland, Falkirk, Edinburgh, Aberdeen and the Highlands are prone to future flood disadvantage from at least two out of three sources of flooding (river, coastal and surface flooding).[9] Dumfries and Galloway, West Dunbartonshire and Glasgow are prone to future flood disadvantage from at least one source of flooding (figure Sc6).

[9] Kazmierczak, A., Cavan, G., Connelly, A. and Lindley, S. (2015) Mapping flood disadvantage in Scotland. Scottish Government report.

Figure Sc6. Flood disadvantage index for Scotland



Source: Kazmierczak, A., Cavan, G., Connelly, A. and Lindley, S. (2015) Mapping flood disadvantage in Scotland. Scottish Government report.

Institutional frameworks for adaptation

There is evidence that the institutional framework for adaptation in the UK has the potential to deliver cross- cutting adaptation action. However, there are obstacles to realise this potential, including: unclear or unmeasurable adaptation policy goals across multiple, correlated risks; a large number of partners involved in delivering adaptation; the limited alignment between related policy goals (e.g. flood risk management with housing and planning policies); and capacity (including resource) gaps, particularly at the local level. There are also many examples where cross-cutting policies have been successfully developed or put forward. For example, the Scotland Land-Use Strategy contains policies to encourage the development of regional land-use frameworks and regional partnerships.

Adaptive capacity and research gaps

Addressing risks require the capacity to look at them systemically, as well as knowledge, information, tools and resources to do so. The main research gaps identified by the CCRA for Scotland include:

- Possible future land-use changes, impacts on soil conditions and understanding resilient varieties/species and cropping regimes.
- Improving the understanding of how species and ecosystems will respond to climate change, the uncertainties involved, and what the best options are for conservation taking into account such uncertainty.
- Understanding the scale of the risk to freshwater species from higher water temperatures, and effectiveness of adaptation measures.
- Understanding risks to marine ecosystems.
- Understanding the future risk from overheating in buildings.
- The impacts of future spending plans on flood defences on level of residual risk.
- Characterising the impacts of sea level rise 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 Scottish historic buildings and their surroundings, including historic urban greenspaces and gardens.
- Data on air pollution.
- Disease vector monitoring, and surveillance and research, on those diseases posing the biggest risk in the changing climate.
- Understanding costs and benefits of adaptation options for different coastal areas.
- 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.

Committee on Climate Change
7 Holbein Place
London
SW1W 8NR

www.theccc.org.uk

@theCCCuk