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A climate change risk assessment for Northern Ireland

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Statement of Use

This report presents the findings of an assessment of climate change risks for Northern Ireland, which has been completed as part of the UK Climate Change Risk Assessment (CCRA).

Before reading this report it is important to understand the process of evidence gathering for the CCRA.

The CCRA methodology is novel in that it has compared over 100 risks (prioritised from an initial list of over 700) from a number of disparate sectors based on the magnitude of the consequences and confidence in the evidence base. A key strength of the analysis is the use of a consistent method and set of climate projections to look at current and future threats and opportunities.

The CCRA methodology has been developed through a number of stages involving expert peer review. The approach developed is a tractable, repeatable methodology that is not dependent on changes in long term plans between the 5 year cycles of the CCRA.

The results, with the exception of population growth where this is relevant, do not include societal change in assessing future risks, either from non-climate related change, for example economic growth, or developments in new technologies; or future responses to climate risks such as future Government policies or private adaptation investment plans.

Excluding these factors from the analysis provides a more robust ‘baseline’ against which the effects of different plans and policies can be more easily assessed. However, when utilising the outputs of the CCRA, it is essential to consider that Government and key organisations are already taking action in many areas to minimise climate change risks and these interventions need to be considered when assessing where further action may be best directed or needed.

Initially, eleven 'sectors' were chosen from which to gather evidence: Agriculture, Biodiversity & Ecosystem Services, Built Environment, Business, Industry & Services, Energy, Forestry, Floods and Coastal Erosion, Health, Marine & Fisheries, Transport and Water.

A review was undertaken to identify the range of climate risks within each sector. The review was followed by a selection process that included sector workshops to identify the most important risks (or opportunities) within the sector. Approximately 10% of the total number of risks (or opportunities) across all sectors were selected for more detailed consideration and analysis as part of the UK-wide assessment.

The risk assessment used UKCP09 climate projections to assess future changes to these selected sector risks. Risks were, in general, analysed using single climate variables, for example temperature.

A final CCRA Evidence Report draws together information from the eleven sectors (as well as other evidence streams) to provide an overview of risks from climate change to the UK.

This report for Northern Ireland provides a similar overview of risks from climate change to Northern Ireland. The most important risks (or opportunities) for the UK were reviewed with Northern Ireland stakeholders to determine which were important for Northern Ireland. This resulted in some risks being dropped from the list and others being added. Where risks have been added, these have not been analysed in detail,
but are discussed within the broader context of risks from climate change to Northern Ireland.

Neither this report nor the CCRA Evidence Report aims to provide an in depth, quantitative analysis of risk within any particular ‘sector’. Where detailed analysis is presented using large national or regional datasets, the objective is solely to build a consistent picture of risk for the UK, including Northern Ireland, and allow for some comparison between disparate risks and regional/national differences. The results presented here should not be used for re-analysis or interpretation at a local or site-specific scale.

In addition, as most risks were analysed using single climate variables, the analysis may be over-simplified in cases where the consequence of climate change is caused by more than one climate variable (for example, higher summer temperatures combined with reduced summer precipitation).
Executive summary

This climate change risk assessment for Northern Ireland has been produced as part of the UK Climate Change Risk Assessment (CCRA). The CCRA is required under Section 56 of the Climate Change Act 2008, and will be laid before Parliament in January 2012.

This report presents a national assessment of potential risks (and opportunities) from climate change facing Northern Ireland for the period to 2100. Its findings will inform the development of adaptation work in Northern Ireland.

The assessment draws together and presents evidence from individual CCRA UK sector reports and recent research literature. The findings are presented for a range of possible future scenarios and include an indication of confidence in the results and areas where there are evidence gaps.

Northern Ireland’s current climate is one of relatively mild winters and cool summers, although within the natural variability of its climate, Northern Ireland can experience periods of more extreme cold, wet, windy and hot weather.

The CCRA is based on the UK Climate Projections, which were published in 2009 (UKCP09). This provides projections of climate change for the 2020s, 2050s and 2080s compared with the period 1961-90. For each epoch, a range of climate change scenarios have been considered. For example, changes under the 2050s Medium emissions scenario (central estimate) indicate:

- An increase in mean winter temperatures of 1.7°C (range 0.6 to 3.0°C)\(^1\)
- An increase in mean summer temperatures of 2.2°C (range 0.9 to 3.9°C)
- An increase in mean winter precipitation of 9% (range 2% decrease to 20% increase)
- An decrease in mean summer precipitation of 13% (range 25% decrease to 5% increase)

In addition, sea level rise is projected to increase by between about 0.11 m and 0.19 m by 2050.

These changes have been used to derive projections of changes in bio-physical systems, for example changes in river flows, aridity and water availability. These have then been used together with the climate change projections to assess the potential magnitude of consequences for Northern Ireland.

A list of the most important climate change impacts and consequences for Northern Ireland was developed through a process of consultation with stakeholders. This takes account of the impacts that were considered to be most important for the UK as a whole, together with particular features and issues relevant to Northern Ireland.

It is these most important impacts for Northern Ireland that form the basis of this report. Discussion of these impacts builds on the results from the analysis undertaken for the UK with additional information specifically for Northern Ireland.

Specific features that distinguish Northern Ireland from the UK as a whole and, hence, may increase Northern Ireland’s vulnerability to certain consequences of climate change include:

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\(^1\) The range provided in brackets represents the plausible range in projections for the scenarios selected (i.e. ranging from the Low emissions scenario, low estimate (p10) to the High emissions scenario, high estimate (p90). This is explained more fully in Section 2.4.
With increased urban development in recent years, the fragmented and very varied landscape is under conflicting pressures related to land use and landscape. Climate change is anticipated to add to these pressures.

Northern Ireland shares a land border with the Republic of Ireland. Therefore, many of the potential threats that face Northern Ireland would also affect the Republic of Ireland. Adaptation strategies need to reflect this.

The vast majority of private businesses in Northern Ireland are very small and their vulnerability and adaptive capacity is a major concern for Northern Ireland.

Northern Ireland has a relatively isolated geographical location, which means it often has longer supply routes that, by their very nature, make them more vulnerable to disruption.

Northern Ireland has relatively high levels of social deprivation, with the highest level of fuel poverty in the UK. Many of the socially deprived areas of Northern Ireland are also areas at greatest risk from extreme weather events.

The natural water environment is highly valued and is a significant feature of the landscape in Northern Ireland, but species and habitats are already under threat.

For its size, Northern Ireland has a very interesting and diverse geology supporting important historic features and artefacts that are already under threat.

For each impact, an assessment has been made of the potential consequences that may occur in the future. The results are presented in terms of the magnitude of the consequences by the 2020s, 2050s and 2080s. The projections are, however, highly uncertain, as they depend on (a) the UKCP09 projections; (b) the assumptions made regarding socio-economic change (and in some sectors the degree of adaptation); and (c) the method adopted for the assessment. All of which are highly uncertain.

Therefore, whilst the assessment provides projections of a range of possible changes in risk, the results must not be considered to be predictions of change. The interpretation and use of the results should be as follows:

1. The results provide a guide to the possibility of a risk occurring, its order of magnitude, direction of change and potential timing.
2. The supporting evidence on specific risks illustrates possible future changes.
3. Adaptation actions should recognise the likely direction of change and the high degree of uncertainty.
4. For the impacts of greatest concern, gaps in evidence should be addressed including the establishment of monitoring and further research where appropriate.

This report does not attempt to provide a comprehensive discussion of all potential impacts for Northern Ireland, nor does it attempt to identify potential adaptation measures or associated policy for Northern Ireland. In addition, there is a need to continue to update the climate projections for the UK for future cycles of the CCRA.
Summary of findings

Extreme weather is still predominant among potential risks related to climate change but that other risks, such as water scarcity and species being able to track climate space, are becoming increasingly important.

From the results of this assessment, the potentially most significant threats for Northern Ireland from climate change appear to be:

- Reduced river flows and water quality during the summer.
- Reduced water availability during the summer, particularly for domestic use.
- Reduced soil moisture and increased erosion affecting biodiversity and ecosystem services, including carbon storage.
- Increased flooding and coastal erosion affecting people, properties (including built heritage) and infrastructure.
- Increased coastal squeeze and coastal evolution affecting beaches, intertidal areas, grazing marshes, etc.
- Increased risk of wildfires resulting in biodiversity loss.
- A decline in native species and changes in migration patterns, coupled with increased pests, diseases, non-native and invasive non-native species, in particular in the freshwater and marine environments.

Many of the threats listed above are closely linked and also relate to other threats, such as the impact of flooding on properties, agriculture, finance and supply chains, described throughout this report. Therefore, these should not be considered in isolation or, for example, only by the sector most affected. Instead, an integrated approach to mitigate and/or adapt to these threats is required.

Potentially opportunities that have been identified for Northern Ireland from climate change include:

- Increased grass yields, allowing grazing seasons for livestock to be extended.
- Increased yields for Sitka spruce, which may improve forest productivity.
- Increased tourist numbers and tourist seasons.
- Opportunities for trade and shipping routes.
- Reduced demand for heating due to milder winters, reducing energy bills.
- Decline in premature deaths and hospital admissions in winter.

It is important to note that these threats and opportunities have been identified as significant at the Northern Ireland scale, but this does not mean that other threats or opportunities are not significant at a more local scale.

In addition, the confidence in the magnitude and timing of many of these threats and opportunities is variable and often low, as these have been assessed based on analysis using very simple relationships and limited datasets and, in some cases, based on analysis for other parts of the UK.
Results by theme

The results of the assessment are presented in the following five themes: natural environment; agriculture and forestry; business; buildings and infrastructure; health and wellbeing. The main potential threats and opportunities are summarised below by theme.

Natural Environment

The main potential threats facing the terrestrial natural environment in Northern Ireland relate to the following:

- Increased soil moisture deficits and drying, with consequences for species, habitats and soil organic carbon;
- Species unable to track climate space, with generalist species being more able to adapt than specialist species;
- Increased risks from pests, diseases and invasive non-native species;
- Changes in species migration patterns with consequences for the conservation network and cultural ecosystem services;
- Increased risk of wildfires; and
- The potential environmental impacts of climate mitigation measures (principally onshore wind), if not planned for adequately.

The main bio-physical impacts facing the freshwater environment in Northern Ireland relate to the following:

- Lower flows in summer;
- Higher water temperatures and increased stratification of water bodies; and
- Reduced water quality, due to pollution from point and diffuse sources.

These bio-physical impacts pose the following potential threats to native freshwater species, habitats and ecosystem services:

- Increased risk to native species from pests, diseases and invasive non-native species; and
- Changes in species migration patterns and reproductive ability.

The main bio-physical impacts facing the coastal and marine environments in Northern Ireland relate to the following:

- Tidal flooding and coastal erosion;
- Higher water temperatures and increased stratification of coastal loughs; and
- Reduced water quality, due to pollution from point and diffuse sources.

These bio-physical impacts pose the following potential threats to native coastal and marine species, habitats and ecosystem services:

- Coastal evolution impacts on intertidal, grazing marshes, etc.;
- Changes in coastal species migration patterns;
• Increased risk to native coastal and marine species from pests, diseases and invasive non-native species; and

• Shifting of marine species, with consequences for ecosystem services.

Agriculture and Forestry
Agriculture in Northern Ireland potentially faces both threats and opportunities due to climate change. The sector is not projected to have severe negative consequences by the end of this century, with the possible exception of increased flood risk. However, there is limited confidence in these projections due to lack of data. Potential opportunities include increases in grass and wheat yields.

If climate change impacts were analysed at a more local scale, it is likely that there would significant variation in which areas would be most affected negatively or positively by climate change, for example due to flooding, waterlogging or crop yield. The results presented in this report should not be considered as representative at a local or site-specific scale.

Forestry in Northern Ireland potentially faces both threats and opportunities due to climate change. The potential increase in yield of Sitka spruce has been identified as an opportunity. However, this may be countered to some degree by a reduction in productivity due to drought. The most significant threat identified is from pests and diseases, with the forest extent affected by red band needle blight being projected as high by the 2050s.

Due to the limitations in the analysis methods and available data, the projections provided in this report should not be used for commercial production forecasting, but give an indication of where early adaptation actions may be beneficial.

Business
Many of the potential risks for businesses in Northern Ireland cannot be assessed with any degree of confidence, because the data is not available or the risks are intrinsically too uncertain. However, based on future projections for rainfall and sea level rise and evidence available for other parts of the UK, flooding may become the greatest single climate change concern for businesses in Northern Ireland. The results of the Preliminary Flood Risk Assessment (PFRA) for Northern Ireland should help to estimate future flood risks for Northern Ireland up to 2030. Further information is provided in Appendix D.

Buildings and Infrastructure
There is potentially a significant opportunity for Northern Ireland related to reduced energy demand for heating, although this may be offset slightly by a projected increased demand for cooling. The other most significant threats that have been identified by this assessment relate to water availability for public water supply and performance of sewerage (indicated by an increase in combined sewer overflow spill frequency).

However, many of the potential risks for buildings and infrastructure in Northern Ireland cannot be assessed at present, because the data is not available or the risks are intrinsically too uncertain. Similarly to business, flooding may become a significant climate change threat for buildings and infrastructure in Northern Ireland. The PFRA should improve understanding regarding the magnitude of this risk.
Health and Wellbeing

There is potentially an opportunity (or benefit) for Northern Ireland related to a decline in the number of premature deaths and hospital admissions in winter due to milder weather. This projected decline is greater than the projected increase in premature deaths and hospital admissions caused by high temperatures in summer.

The most significant threats for which projections have been provided relate to the increase frequency in emergency response required to deal with flooding and other climate events, such as wildfires.

Similarly to business, buildings and infrastructure, flooding may become a significant climate change threat to people’s health and wellbeing in Northern Ireland. Again, the PFRA should improve understanding regarding the magnitude of this risk.

How does Northern Ireland compare to the UK as a whole?

The overall risk profile for Northern Ireland is different from the UK as a whole. This reflects the differences in the current climate and climate projections for different parts of the UK and the vulnerability of Northern Ireland to these climate variables.

For example:

- Heat related threats (such as premature deaths, overheating of buildings, etc.) are not projected to be as severe in Northern Ireland compared to parts of England, especially the South East.

- There are potentially greater opportunities for agriculture and forestry with increased grass and wheat yields and forest productivity, although the latter is based on analysis for Scotland, which shows a significant potential increase in yields for Sitka spruce.

- Future flood risks may be less severe than in England and Wales, but the results of the PFRA will give a much better indication of the increase in flood risks up to 2030.

- Water availability is projected to be a significant threat for Northern Ireland, comparable in magnitude to the projections for parts of England and Wales. For example, the projected change in deployable output is a little under 15% by the 2050s, which is similar to Wales and parts of southern England.

- The types of threats to Northern Ireland’s natural environment (e.g. increased pests and diseases, changes in species migration patterns, species unable to track climate space, etc.) are similar to the rest of the UK. However, the potential consequences vary and are dependent on the types of species, habitats and ecosystems that are found in Northern Ireland.

- It has been assumed that many of the threats and opportunities for businesses would be similar for Northern Ireland as the rest of the UK, but this does not take into account the different socio-economic characteristics of Northern Ireland, and should only be considered as indicative.

- Some of the key issues for Northern Ireland remain unknowns, e.g. reliance of imported fossil fuels, fuel poverty, SMEs and micro-SMEs. Although highlighted as particularly important for Northern Ireland, these are also very relevant issues for the UK as a whole and would benefit from further research.
Gaps in evidence

The most significant gaps in evidence for Northern Ireland relate to future flood risks, which may have significant consequences for coastal environments, agriculture, buildings, infrastructure and the health and wellbeing of people affected.

The PFRA for Northern Ireland that will be published in December 2011 has generated a broad range of flood risk indicators to measure the adverse impact of potential future floods on groups of receptors. The Climate Change Flood Map, produced by the PFRA, only provides the estimated flood plains relevant to the year 2030. To help increase our understanding of the consequences of climate change, remove uncertainties regarding their scale and nature and aid climate change adaption, further research is needed to enable a more detailed analysis of future flood risk for Northern Ireland, similar to that carried out for England and Wales as part of the CCRA. This would require the use of the range of climate scenarios (based on the projections presented in UKCP09 for the 2020s, 2050s and the 2080s) and associated socio-economic scenarios selected for the CCRA analysis.

Further gaps in evidence are discussed in Section 6 of this report.
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1 Introduction

1.1 The CCRA

It is now widely accepted that the world’s climate is being affected by the increasing anthropogenic emissions of greenhouse gases into the atmosphere. Even if efforts to mitigate these emissions are successful, the earth is already committed to significant climatic change. UK governments are committed to actions for both mitigation of and adaption to climate change.

The Climate Change Act 2008 made the UK the first country in the world to set a legally binding framework for reducing emissions, but also set a framework for building the nation’s adaptive capacity.

The Climate Change Act also creates a framework for building the UK’s ability to adapt to climate change. Among other actions, the national governments within the UK are all developing programmes for adaptation. To inform these programmes, the Act requires that an assessment of the climate change risks to the UK is prepared on a five year cycle. The first assessment is due in January 2012 and an updated assessment will be issued every five years.

The objective of the Climate Change Risk Assessment (CCRA) is to inform UK adaptation policy in 2012, by assessing the current and future risks and opportunities posed by the impacts of climate for the UK to the year 2100.

The CCRA has produced the following reports (Figure 1):

**CCRA Evidence Report** – This report presents a synthesis of the evidence of current and future climate change risks for the UK as a whole to 2100, based on the findings in the Sector Reports and other evidence.

**Government Report** – Using the CCRA Evidence Report as the underpinning evidence, along with the output from other ongoing studies, this report presents the main CCRA findings in the context of current policies and future plans for the development of the National Adaptation Programme.

**CCRA Act Report** – The CCRA Evidence Report and the Government Report together form the report to be laid before parliament as required by the Climate Change Act 2008.

**Sector Reports** – The sector reports document the assessment of risks for each of 11 sectors, and these are cited throughout this report. Their purpose is to provide the more detailed data and information that underpins this assessment.

**Sector Summaries** – Key findings from each Sector Report are summarised for senior UK Government and international policy-makers.

**Devolved Administration Reports** – Following on from the UK-wide assessment, assessments were undertaken for Northern Ireland, Scotland and Wales in consultation with stakeholders. These reports present the outputs from the UK-wide assessment from the perspective of each Devolved Administration, supplemented with local case studies.

**Devolved Administration Summaries** – Key findings for each Devolved Administration are summarised for policy-makers.
CCRA Summary Report – Key findings from the CCRA are summarised for policymakers.

CCRA2 Recommendations Report – A report describing the gaps in knowledge and lessons learned during the first CCRA.

1.2 This report

The purpose of this report is to present the findings of the CCRA for Northern Ireland. This report provides the following:

- An overview of the climate change impacts that are currently considered most important for Northern Ireland;
- A discussion of the key issues in Northern Ireland that affect the Province’s vulnerability to climate change; and
- A synthesis of the CCRA analysis work on specific climate change impacts and consequences from the perspective of Northern Ireland.

The main sources of evidence used in this report are the sector reports produced by the CCRA project. These are cited here as, for example, ‘Energy Sector Report’. Full details of each report can be found at the end of this report. Unless stated otherwise, projections for climate change impacts and consequences quoted in this report are those determined as part of the CCRA sector analysis work. All projections need to be treated with caution. The level of confidence that can be placed in the projections is discussed here, but reference should be made to the sector reports in order to understand fully the assumptions made and the level of confidence of specific projections.
This assessment also builds on previous work undertaken in Northern Ireland, most notably by SNIFFER (Arkell et al. 2007). Although the SNIFFER project pre-dates the UKCP09 climate projections as used for the CCRA, most of the climate change impacts described in its final report remain relevant and the report provides a very useful overview of the breadth of climate change impacts that could affect Northern Ireland.

1.3 Overview of Northern Ireland

With a population of less than 1.8 million people, Northern Ireland is the smallest of the Devolved Administrations and is also smaller than any of the English Regions.

Northern Ireland is unique within the UK for a variety of reasons, not least because it is separated from the rest of the UK by the Irish Sea and shares a border with the Republic of Ireland. The landscape of Northern Ireland is very diverse geologically and, with the exception of the Belfast Metropolitan Urban Area and Derry City, is predominantly rural with the majority of land being used for agriculture and mostly privately owned. It is home to a wide variety of species and habitats that not only have an intrinsic importance of their own (including some with international importance), but also have a high public amenity and tourist value. The rivers and loughs systems in Northern Ireland are particularly scenic and valued features, with Lough Neagh being the largest freshwater lake in the British Isles. These and other features are described in more detail in the relevant sections of this report.

Because of these unique characteristics, Northern Ireland’s potential vulnerability to climate change also differs from the rest of the UK and the Province has its own specific set of challenges for adapting to climate change. Some of the key issues in Northern Ireland that might affect its vulnerability are discussed in Section 1.6 below.

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2 Including both freshwater and sea loughs.
1.4 Stakeholder consultation

On 23rd March 2010 the CCRA team meet with Northern Ireland stakeholders in Belfast. This meeting highlighted work undertaken to date within Northern Ireland and discussed the best means of engaging with stakeholders for the CCRA project.

On 29th September 2010 we held a workshop in Hillsborough to give Northern Ireland stakeholders an opportunity to discuss which climate change impacts are important for Northern Ireland and hence which risks they would like to see reflected in the CCRA recording. A workshop record for this event is available (CCRA, 2010).

Other activities have been undertaken remotely as part of the identification of important climate change impacts for Northern Ireland. These are described in the section below.

1.5 Climate change impacts

1.5.1 Selection of UK-wide impacts

Prior to the commencement of the Northern Ireland assessment, the CCRA project had already undertaken a UK-wide sector-based risk assessment. Sector stakeholders from across the UK contributed to this assessment through workshops, which took place in May 2010, or in the case of Forestry and Business/Industry/Services sectors via focused telephone interviews in June 2010.

A list of climate change impacts was developed based on eleven sectors. In addition, impacts that were not covered by the sectors were also added to the list. This list of climate change impacts was referred to as the 'Tier 1 list of impacts'. This list contained over 700 impacts – too many to analyse in detail as part of this first CCRA.

During July and August 2010, the UK-wide assessment produced a consolidated list of the highest priority climate change impacts for this first CCRA (taking into account climate change impacts that had been identified in more than one sector). This was referred to as the ‘Tier 2 list of impacts.

The consolidation exercise included a scoring process, based on estimates of the magnitude of the consequences (economic, environmental and social), likelihood and urgency of each impact; this helped the project team to evaluate the relative importance of impacts and, hence, informed decisions regarding whether an impact was to be included in the Tier 2 list.

It is important to note that the Tier 2 list of impacts was not based on the availability of data; the selection process disregarded how ‘easy’ it was to measure a particular impact. However, once the list of impacts was produced, the next step in the process was to determine whether each impact could be measured (i.e. the identification of risk metrics). The outcome of this process was that approximately half of the impacts were analysed in detail, either fully or semi-quantitatively. The geographical extent of the analysis depended on the availability of suitable data. This varied significantly between England and the Devolved Administrations, with Northern Ireland in general being the least data rich.
1.5.2 Selection of Northern Ireland impacts

The Tier 2 list of impacts described above was for the UK as a whole and, therefore, did not necessarily reflect the specific priorities for Northern Ireland. Hence, a refined version of this list has been developed that reflects the most important climate change impacts for Northern Ireland. This list can be found in Appendix A. It is only these most important impacts for Northern Ireland that form the basis of this report. This report does not attempt to provide a comprehensive discussion of all potential impacts for Northern Ireland.

The Northern Ireland Tier 2 list of impacts was determined via the following steps:

- An online feedback opportunity was provided on the CCRA website http://ccra.defra.gov.uk, where stakeholders were invited to identify which of the UK-wide Tier 2 impacts were particularly high priority for Northern Ireland and whether there were any additional high priority impacts missing from the list.

- Prior to the September 2010 workshop, Sector Contacts in Northern Ireland were invited to review the scoring for the UK-wide Tier 2 impacts for their sector and provide updated scores if required. This was carried out for the following sectors: Biodiversity & Ecosystem Services, Energy, Health, Transport and Water. Scores for the Marine sector were provided after the workshop.

- At the September 2010 workshop, participants were able to review the UK-wide Tier 2 list for their sector, alongside any scores for Northern Ireland, and on the basis of these identify the most important impacts for Northern Ireland, highlighting any important impacts that were missing.

- The feedback from all three activities was reviewed by the CCRA project team and a draft Tier 2 list for Northern Ireland was produced. As part of this process, where an impact had been identified as more important for Northern Ireland but a new score had not been provided, this was undertaken by the project team.

- The draft Tier 2 list for Northern Ireland was circulated to stakeholders for comment and the list was amended where appropriate. The amended draft was then issued to stakeholders for information.

These important impacts for Northern Ireland do not necessarily reflect the full breadth of impacts analysed as part of the CCRA. Information on other impacts can be found in the sector reports and CCRA Evidence Report (CCRA, 2012a).

1.6 Key issues

It is important to take into account the unique social, economic, political, administrative, geographical and environmental starting-point for Northern Ireland. The general view at the September 2010 workshop was that, although the projected climate change for Northern Ireland was not any more severe than for other parts of the UK (and in some instances less severe), the characteristics of the Province are sufficiently different that its vulnerability could be greater. Several key issues were

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3 The Northern Ireland Tier 2 list included in this report may differ slightly from the second draft issued to stakeholders. This is a result of the work undertaken in the intervening time, which may have altered understanding regarding the importance of certain impacts.
highlighted as being potential reasons for greater vulnerability to climate change. These were the following and are described more fully in the sections below.

- Conflicting pressures on land use and landscape
- Cross-border issues with the Republic of Ireland
- Private businesses, in general, are very small
- Reliance on imports and exports
- Social deprivation and social cohesion
- Water pollution and the provision of water services

1.6.1 Landscape and heritage

Northern Ireland has one of the most geologically diverse areas anywhere in the world for a territory of its size. Its landscapes are renowned for their distinctive features, and the management of these landscapes is of primary importance.

(Environment and Heritage Service, 2008)

The fragmented and very varied landscape of Northern Ireland was identified by stakeholders as being a very important consideration in understanding of Northern Ireland’s vulnerability to climate change.

There is concern that the land that is available for wildlife and, in general, the protection of the natural landscape may be put under additional pressures in the future with a changing climate and as Northern Ireland faces conflicting demands for land use. Yet land and landscape management have the greatest visual impact on our environment and our appreciation of it (DOENI, 2011).

- Over 7% of the total land area of Northern Ireland is designated as Areas of Special Scientific Interest (DOENI, 2011).
- Nearly one-fifth of the total area of Northern Ireland falls within a designated Area of Outstanding Natural Beauty, providing these landscapes with special protection.
- Peat soils occupy 15% of the land area in Northern Ireland but contain 42% of the carbon stock (an important ecosystem service) (NEA, 2011)
- Around 75% of the total Northern Ireland land area is used for agriculture, including common rough grazing (DARDNI 2010).
- Only a relatively small amount of land in Northern Ireland is covered by woodland (approximately 6%), much of which consists of non-native conifers (Arkell et al., 2007).
- Whilst agricultural land has not expanded in recent years, the area of land taken up by development has increased. Agricultural intensification and

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4 Equivalent to 1001 km²
5 “The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth. The concept “ecosystem goods and services” is synonymous with ecosystem services.” (NEA, 2011)
6 The Countryside Assessment estimated forest cover at 10%. This figure may include areas of willow coppice, orchards, scrub and young plantings.
7 However, latest statistics show a sharp drop in the number of new dwellings since 2006/07, with housing completions in 2008/09 62% lower than 2006/07 figures. In the same period, housing completions on greenfield sites have decreased by 75% (DOENI 2011).
loss of land to development are recognised as threats to habitats, heritage and landscape in Northern Ireland. How climate change may affect these pressures is discussed in Section 4. Future demands on land use will also depend on many other factors, including future economic growth, international markets and expansion of renewable energy sector.

Coupled with landscape is also the issue of cultural heritage, which can be natural, historic (including archaeological) or built. Cultural heritage is very closely linked to wellbeing (which is discussed in Section 4.6) and tourism and is a very important aspect of Northern Ireland’s cultural identity.

Like landscape and land use, cultural heritage crosses all five themes discussed in this report, but is difficult to assess in a holistic way. However, three types of geographical area have been identified as being especially at risk from climate change from the perspective of their heritage assets:

- Coastal zones - coastal erosion is already a problem for heritage assets around the Northern Ireland coastline and this may be exacerbated in the future.
- Sand dunes systems - sand dunes, and any heritage within them, may be exposed, degraded or lost entirely.
- River valleys – flooding and morphological changes to rivers may potentially expose, destroy, bury or rework archaeological assets.

With Northern Ireland’s long coastline, several off-shore islands and underwater reefs, Northern Ireland’s marine archaeology is also rich with shipwrecks and human artefacts.

1.6.2 Cross-border issues

Northern Ireland is unique within the UK, as it shares a land border with another EU Member State, namely the Republic of Ireland. This means that Northern Ireland’s vulnerability to some climate change impacts has the potential to be greater than in other parts of the UK (if not matched with compatible regulatory regimes in the Republic of Ireland) and strategic approaches to adaptation measures need to reflect this.

Examples of how sharing a border might affect Northern Ireland’s vulnerability to climate change include:

- Agriculture – spread of animal diseases and crop pests
- Biodiversity – spread of non-native species
- Energy – supply route of natural gas and electricity to/from the Republic of Ireland
- Forestry – spread of pests and diseases
- Health – vector-borne diseases and air pollution episodes
- Flooding – risk of flooding of power stations in the Republic of Ireland that supply Northern Ireland
- Marine & fisheries – spread of non-native and invasive non-native species via shipping routes
• Water – the North Western River, Neagh Bann and Shannon\(^8\) International River Basin Districts (IRBDs)

These impacts are discussed in more detail in Section 4.

Northern Ireland shares many characteristics of its natural and built environment with the Republic of Ireland. Therefore, there are significant benefits in looking at climate change impacts and adaptation at the All-Ireland scale. There are a number of cross-border bodies, initiatives and strategies that can play a part in enabling the whole of Ireland to adapt to climate change. These include:

• All-island Animal Health and Welfare Strategy\(^9\) – set up in March 2010 to help reduce and prevent the spread of animal disease.

• All-island Energy Market\(^10\) – creating a single market for natural gas and electricity, which commenced in 2007 with the Single Electricity Market.

• All Ireland Species Action Plans – cross-border working on species conservation between the Environment and Heritage Service in Northern Ireland and the National Parks and Wildlife Service in the Republic of Ireland.

• Loughs Agency\(^11\) – a cross-border body with a statutory remit for conservation, protection and development within the Foyle and Carlingford catchments.

• Regional Strategic Transport Network Plan\(^12\) – includes cross-border transport links (specific projects in INSTANT\(^13\) and STREETWISE\(^14\))

• North-South Ministerial Council – developing consultation, co-operation and action within the island of Ireland\(^15\)

• Tourism Ireland\(^16\) – promoting tourism for the whole island of Ireland.

• Waterways Ireland\(^17\) – responsible for the management, maintenance, development and restoration of inland navigable waterways across the whole of Ireland.

1.6.3 Small businesses

SMEs are at the very centre of the Northern Ireland economy accounting for 98% of the business environment and employing over half a million people. With this in mind it is of the utmost importance that we do not lose sight of the vital role they have to play in supporting the entire economy.

John Friel, Regional Chair of the Federation of Small Businesses.\(^18\)

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\(^8\) Only a small portion of the Shannon IRBD lies within Northern Ireland.


\(^10\) [http://www.allislandproject.org/](http://www.allislandproject.org/)

\(^11\) [http://www.loughs-agency.org/site/](http://www.loughs-agency.org/site/)


\(^13\) Partnership project between Roads Service (Northern Ireland) and the National Roads Authority (Republic of Ireland).

\(^14\) A Euro Regional project involving the National Road Authorities of England, Scotland, Wales, Northern Ireland and the Republic of Ireland.

\(^15\) [http://www.northsouthministerialcouncil.org/index.htm](http://www.northsouthministerialcouncil.org/index.htm)

\(^16\) [http://www.tourismireland.com/](http://www.tourismireland.com/)

\(^17\) [http://www.waterwaysireland.org/index.cfm](http://www.waterwaysireland.org/index.cfm)

The degree to which individual businesses are affected by climate change will depend on their level of vulnerability and adaptive capacity.

The vast majority of businesses in Northern Ireland are small and medium enterprises (SMEs) or micro-SMEs. Micro-SMEs are independent firms employing up to 9 staff (95% of SMEs in Northern Ireland fall into this category19). Small enterprises are firms employing between 10-99 staff and medium denotes firms employing between 100-499 staff. Many of these SMEs are agricultural businesses; there were 54,471 farms in Northern Ireland in 2010 with an average size of 40 ha (DARNI, 2011).

The vulnerability and adaptive capacity of SMEs were considered as being a particularly important concern for Northern Ireland. How climate change may affect SMEs in Northern Ireland is discussed in Section 4.4.3.

1.6.4 Reliance on imports and exports

Northern Ireland has a relatively isolated geographical location compared to the majority of the UK, which means that it often has a longer supply route (for example Northern Ireland receives its supplies of natural gas via Scotland and the Republic of Ireland). Therefore, the protection of these supply routes is highly important. This is discussed in Section 4.4.

Northern Ireland’s sea ports are considered as a particularly important link in the Province’s commercial and industrial supply chains. Port operational downtime is discussed in Section 4.5.5.

1.6.5 Social deprivation and social cohesion

Relatively high levels of social deprivation and the different experience in Northern Ireland compared to the rest of the UK of civil unrest/political instability and integration of people from other ethnic and cultural backgrounds were considered as significant by stakeholders at the September 2010 workshop.

Many of the socially deprived areas of Northern Ireland are also areas at greater risk from extreme events (both with the current climate and in the future). The communities and individuals within these areas are also amongst the least able to deal with the consequences.

Social vulnerability

In June 2009 it was estimated there were 1.789 million people living in Northern Ireland and it was projected that this figure would reach 1.8 million by 201120. Children under the age of 16 accounted for 21.4% of the population in 2009 and 16.9% of the population were of state pension age.21 These groups, especially if also suffering from social deprivation, are likely to be particularly vulnerable to extreme weather events.

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19 http://www.bitc.org.uk/northern_ireland/what_we_do/in_the_economy/sme_support/index.html
20 2011 census data was not available at time of writing.
due to physical frailty and financial hardship, and climate change impacts in general, as they tend to be less able to take adaptation measures.

Fuel poverty was highlighted by stakeholders as being an issue of particular concern for Northern Ireland, as it has the highest rate of fuel poverty in the UK (Northern Ireland Assembly, 2009)\textsuperscript{22}. The 2009 House Condition Survey indicated that 44% of the population in Northern Ireland suffer from fuel poverty, an increase from 34% identified by the same survey in 2006 (DSDNI, 2011).

For a variety of socio-economic reasons this problem may become worse in the future. How levels of fuel poverty might be affected by climate change is discussed in Section 4.6.9.

\textit{Civil unrest and political instability}

The civil unrest and political instability experienced in Northern Ireland over the last 40 years is also a unique issue facing the Province. This has had a significant impact on the economy of Northern Ireland including:

- A deterrence for private investors (particularly from overseas), for example service sector firms\textsuperscript{23};
- An increase in public expenditure to act as an economic stabiliser resulting in state economic dominance;
- A private sector economy based on agriculture and manufacturing (neither of which lead to high productivity or high incomes); and
- A reduced tourism industry (In 2006, it is estimated that this was only a third of its potential, when compared with Scotland or the Republic of Ireland (Committee on the Preparation for Government 2006)).

These factors contributed to Northern Ireland suffering from a productivity and income gap compared with the rest of the UK (only Wales and the North East of England have a lower GVA per head of population than Northern Ireland\textsuperscript{24}). This has had the consequence of higher than average levels of social deprivation.

With increased political stability in recent years there has been socio-economic growth. However, this has led to housing and development pressures leading to loss of landscape character and biodiversity and loss of valuable historic and cultural heritage (EHS 2008).

\textsuperscript{22} The average wage in Northern Ireland is approximately 90% of the average UK wage (NI Executive, 2009) and fuel prices are reportedly 40% more in Northern Ireland compared with the rest of the UK (BBC Watchdog, 2011).

\textsuperscript{23} Northern Ireland was not able to take advantage of the boom in call centres until the ceasefires, which were able to reduce the risk of disruption to operations through bomb damage or bomb scares.

\textsuperscript{24} http://www.statistics.gov.uk/downloads/theme_economy/CRC2008ALL.pdf
Box 1: Areas of deprivation within Northern Ireland

The Northern Ireland Statistics and Research Agency (NISRA) released results from the Northern Ireland Multiple Deprivation 2010 study in March 2010. These results are based on 52 indicators mostly relating to the period 2007-2009. The indicators are grouped into seven types or 'domains' of deprivation weighted as follows:

- Income Deprivation 25%
- Employment Deprivation 25%
- Health Deprivation and Disability 15%
- Education, Skills and Training Deprivation 15%
- Proximity to Services 10%
- Living Environment 5%
- Crime and Disorder 5%

The areas with highest relative deprivation were found to be in the Belfast Local Government District, with areas within Strabane, Lisburn and Derry also featuring in the top 30 deprived areas. However, rural districts were not without their own areas of deprivation.

These results showed a positive correlation between six out of the seven domains (i.e. an area deprived in one domain is likely to be deprived in other domains, particularly income, employment, health & disability, education skills & training).

![Map of Northern Ireland Multiple Deprivation Measure](image-url)
1.6.6 Water supply and quality

Water quality

According to the Northern Ireland Environmental Statistics Report 2011 (DOENI, 2011):

- A quarter of monitored river waterbodies are of at least a good status. The level of compliance for rivers designated as salmonid under the EC Freshwater Fish Directive (2006/44/EC) has increased in recent years, whereas the level has decreased for the relatively small length of cyprinid designated rivers.
- There are 21 sea and freshwater loughs currently monitored in Northern Ireland, of which only five achieved a good status in 2009.
- Groundwater is currently of high quality.
- Industrial discharge quality and water utility discharge quality have improved in recent years, although there was a slight drop in water utility discharge quality in 2009.
- Drinking water quality is at the highest level recorded since 2004.

Eutrophication is probably the most widespread threat to good water quality in Northern Ireland. A considerable number of rivers in Northern Ireland are showing signs of eutrophication. One of the causes of this, and an area of concern raised by stakeholders, is diffuse pollution from runoff from agricultural land, in the form of fertilisers and animal wastes. Another factor is sewage and other discharges from urban areas (point sources). Due to the percentage of land used for agriculture, the impact of this sector on water pollution and subsequent supply is greater than elsewhere in the UK. Eutrophication of water supply source due to agriculture runoff (as well as other sources) is an increasing risk when assessing climate change projections.

How climate change may affect water quality is discussed in Section 4.2.

Water charges

In April 2007, Northern Ireland Water Limited (NIW) was created and became a Government Owned Company (Go-Co)\(^\text{25}\). It is the sole provider of water and sewerage services in Northern Ireland.

Charges for domestic customers for water and sewerage services were due to be introduced firstly in 2007/08 and then in 2009/10, but both dates were deferred by the devolved government. Since 2007 the Northern Ireland Executive has replaced the revenue funding for NIW that would have been collected through charges.

At the present time only non-domestic customers pay for water, sewerage and trade effluent discharges. These include farms, businesses, industrial users, voluntary organisation and charities, public bodies, churches and any other non-household use properties.

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\(^{25}\) This is a statutory trading body owned by central government but operating under company legislation, with substantial independence from government.
1.7 Policy context

The Northern Ireland Executive is responsible for adaptation to climate change in all transferred policy areas under the Northern Ireland Act 1998.

The UK Climate Change Act 2008 requires Northern Ireland Departments to prepare an adaptation programme to address the climate change risks to Northern Ireland and to review them no later then every five years. Reports on the adaptation programme and subsequent progress are required to be made to the Northern Ireland Assembly.

A Cross Departmental Working Group on Climate Change (CDWG CC) has been established by the Northern Ireland Executive to support work on climate change. An Adaptation Sub Group has also been convened with responsibility to:

- Support the preparation of an assessment of the risks to the United Kingdom of the current and predicted impact of climate change;
- Support the preparation of an adaptation economic assessment on the key climate change risks to the United Kingdom;
- Evaluate the climate change risks and opportunities for Northern Ireland and prepare and deliver a cross-departmental adaptation programme on climate change;
- Review cross-departmental action on adaptation on an annual basis and report to the CDWG CC on progress; and
- Make recommendations and/or decisions on wider climate change adaptation issues as appropriate.
2 Climate variability and change in Northern Ireland

2.1 Current climate

Northern Ireland’s climate is one of relatively mild winters and cool summers, a consequence of the moderating effects of the Atlantic Ocean. However, the indented shape of the coastline and the extensive areas of high ground introduce differences in temperature, cloud and precipitation.

Some of the main characteristics of Northern Ireland’s climate and how these compare with other parts of the UK are summarised below:

- **Mean annual temperatures** - At low altitudes in Northern Ireland these vary between 8.5°C and 9.5°C. The UK as a whole varies between 7°C in the Shetlands and 11°C in Cornwall and the Channel Islands. As with uplands in other parts of the UK, the mean annual temperature decreases by approximately 0.5°C for each 100 m increase in height.

- **Maximum temperatures** - July is usually the warmest month with a mean daily maximum temperature of between 17°C in upland areas and along the north coast to almost 20°C in low lying areas south of Lough Neagh and in Fermanagh. In the UK, the highest mean daily maxima for July is in the London area at 22.5°C and the lowest is in the Shetlands at 15°C. The highest recorded temperature in Northern Ireland was 30.8°C in 1976 (County Fermanagh) and 1983 (Belfast). By comparison, the summer of 2006 had a highest temperature of 30.0°C at Castlederg, County Tyrone.

- **Minimum temperatures** - January and February are the coldest months, with the mean daily minimum temperatures varying between 0.5°C in upland areas to 2°C on the coast, the warmest area being County Down. This is in general fairly comparable with North West England, although some of the highest ground in the Lake District has mean of below 0°C. December 2010 was the coldest on record for Northern Ireland, with a new lowest recorded temperature of -18.7°C set at Castlederg on 23 December 2010.26 The previous record was -17.5°C in 1979 in County Down.

- **Frost** - The number of days of frost varies widely in Northern Ireland. There are fewer than 25 days of air frosts a year along the coast, compared to over 55 days in upland areas. Ground frosts occur on average less than 80 days each year on the coast to over 115 days in the uplands. These ranges are similar to those experienced in Wales. The range is wider in Scotland.

- **Mean annual precipitation** - This is strongly related to the local topography and varies between 1600mm in the upland areas (about half of that of the English Lake District, Snowdonia and the Western Highlands of Scotland) to less than 800mm in the driest lowland areas. The wettest part of Northern Ireland is the extreme west of County Tyrone with an annual average of 1950mm.

- **Extreme rainfall** - Heavy rainfall events (rainfall depth greater than 25mm) are infrequent due to the relatively low topography and limited severe summer convectional activity compared to other parts of the UK (SNIFFER, 2002).

- **Wind** - Northern Ireland is one of the windiest parts of the UK (western and northern parts of Northern Scotland are on average the windiest). The windiest areas are over the highest ground and along the coasts of Antrim and Down, where on average they have about 15 days of gales each year.

- **Sunshine** - In general, Northern Ireland is cloudier than England, because of its topography and proximity to the Atlantic. Despite this the coastal strip of County Down has an annual average of over 1400 hours of sunshine, which compares favourably with many coastal areas of England and Wales (with the exception of the south coast of England and the Channel Islands). The dullest parts of Northern Ireland are the upland areas of the north and west, with an annual average of less than 1100 hours (similar to the mountains of Scotland and the Shetlands).

More detailed information about Northern Ireland’s current climate can be found in Arkell et al. (2007) and on the Met Office website.27

### 2.2 Recent climate trends

The following is a summary of the climate trends apparent in the climate records from the Armagh Observatory.

- **Mean annual temperature** – Following a low towards the end of the 19th century, there has been a fairly steady increase in mean annual temperature. The 1990s saw the mean annual temperature rise to its highest level since records began in 1844 to nearly 10°C compared to just over 9.5°C in the middle of the 20th century (EHS 2004).

- **Mean annual minimum temperature** – Recorded mean annual minimum temperatures follow a similar trend as mean annual temperatures, with a low towards the end of the 19th century, followed by a steady increase. Since 1990, the 10-year moving average mean annual temperature has steadily risen to around 6.5°C by 2009, which is its highest level since records began in 1844, compared to below 5°C at the end of the 19th century (DOENI, 2011).

- **Mean annual maximum temperature** – Recorded mean annual maximum temperatures again follow a similar trend, with a steady increase since the end of the 19th century. The mean annual maximum temperature by 2009 was over 13.5°C, compared to 12°C at the end of the 19th century (DOENI, 2011).

- **Extreme temperatures** – The number of hot days (mean daily temperature is greater than 18°C) appear to have increased slightly in recent years to an average of around 10 days compared to 8 days in the middle of the 20th century. In the 1990s there was a dip in the number of cold days (mean daily temperature is less than 0°C), but overall there is no clear trend. The cold winters in recent years are likely to provide a further fluctuation in this indicator (EHS 2004).

27 [http://www.metoffice.gov.uk/climate/uk/ni/]
- **Annual precipitation** – There is no long-term trend observed in annual precipitation since the records began (EHS 2004).

- **Winter precipitation** – The 10-year moving average for the percentage of annual rainfall in winter has fluctuated between 25% and 30% since the start of the 20th century. Between 1999 and 2009 the average winter rainfall percentage has fallen from 28% to 23% (DOENI, 2011).

- **Summer precipitation** - The 10-year moving average for the percentage of annual rainfall in summer has fluctuated between 20% and 35% since the start of the 20th century. Overall there has been a slight downward trend, but between 1999 and 2009 there has been an increase from 21% to 27%, with the highest level recorded in 2007 when 45% of the year’s rainfall fell in the summer months (DOENI, 2011).

- **Sea level** - Sea levels for Northern Ireland measured between 1918 and 2002 indicate a very slight fall due to the post-glacial rebound (isostatic uplift) exceeding the global rise in sea levels (EHS 2004).

Recent trends in sea levels for Northern Ireland have been assessed from records of monthly means for the Proudman Oceanographic Laboratory (POL) Class A tide gauges at Bangor and Portrush. Based on this assessment of the 16 years of available records at Bangor (November 1994 to November 2010), relative trends in sea levels are estimated to have increased by 3.2 mm/year. For Portrush, for 15 years of available records (July 1995 to November 2010) the estimated relative trend is 1.3 mm/year. However, it should be noted that these trends are based on small duration data sets, which do not cover the 18.6 year natural tidal variation that peaked at the end of the last century. Error bands on these estimates would therefore be expected to be large (including a potential negative trend) and should therefore be treated with caution.

### 2.3 Climate vulnerability

Northern Ireland is vulnerable to its current climate, as evident from some of its recent extreme events. Here are a few examples and their associated consequences:

- **May 2011** - After an unusual and prolonged warm, dry spell of weather, there were hundreds of heath land and gorse fires across Northern Ireland during the first week in May.

- **December 2010** – Thousands of homes and businesses were without water for several days due to domestic and mains bursts across Northern Ireland as pipes thawed after a prolonged period of freezing weather. NIW had to input an additional 40% of water into the network in an attempt to meet demand, despite this it still became necessary to rotate supply to some customers as reservoirs were drained down.

- **November 2009** – Flooding in Fermanagh from the Erne system caused disruption to rural and urban communities throughout the county for many days.

- **August 2009** – Surface water flooding throughout Belfast, including Lower Ravenhill, Ormeau Embankment and Rosetta areas.

- **January 2009** - Severe weather including gales and heavy rain, led to widespread power cuts.
August 2008 – The Greater Belfast area was affected by flooding: the M2 motorway out of Belfast was closed because of landslides; the M1 underpass filled with nearly 5 metres of water; and 347 homes were flooded (British Red Cross, 2010).

June 2007 – Extensive flooding in East Belfast with 609 homes affected.

January 2007 - Severe weather including gales and heavy rain, led to widespread power cuts.

September 2006 - Winds of up to 70mph hit Northern Ireland as the remnants of Hurricane Gordon passed over the British Isles. Tens of thousands of households were left without electricity, the main cause being branches falling on overhead power lines.

Box 2: Belfast Flooding

For three consecutive years between 2007 and 2009 Belfast has experienced pluvial and flash flooding.

Belfast is vulnerable to pluvial, sewer and tidal flooding. Belfast City Council commissioned RPS Consulting to undertake a study to map flooding hot spots across the city, and to identify possible underlying causes and potential short and long term solutions. This work has been completed and is now held by the Rivers Agency. Currently 10,000 properties in Belfast are at risk of coastal or river flooding (British Red Cross, 2010).

Belfast has an outdated sewerage system with much of the infrastructure more than 100 years old. Similar to most urban sewerage systems, the city has a combined system, which has difficulty coping in periods of heavy rainfall. NI Water has now undertaken a £160 million stormwater management project, the Belfast Sewers Project (2010)28, which aims to improve water quality in both the River Lagan and Blackstaff River and reduce the risk of flooding within the inner city.

The flashy nature of the watercourse catchments surrounding the Belfast urban area, combined with the restrictions to flow from the culverted network and the aging sewers, has resulted in frequent localised flooding, as well as the occasional widespread flooding event when multiple watercourses have overlapped. For the three consecutive years between 2007 and 2009 Belfast has experienced damaging floods. However, it is the threat of tidal flooding in central Belfast that may pose the greatest risk to the city.

The flood risk in Belfast is being managed in accordance with the requirements of the European Directive on the Assessment of Management of Flood Risks, which has been transposed through the Water Environment (Floods Directive) Regulations (Northern Ireland) 2009. The Directive requires Member States to undertake a preliminary flood risk assessment (PFRA) for their territory by December 2011 and, on the basis of this, a strategic assessment to identify areas of potential significant flood risk (APSFR). For all areas that are determined to be APSFR, the Directive requires detailed flood hazard and risk maps to be produced by December 2013 and the publication of flood risk management plans by December 2015. The Rivers Agency has completed the PFRA for Northern Ireland and as Belfast has been determined to be an APSFR, detailed flood hazard and risk maps that take account of the impacts of climate change are currently under development.

Further information about how people were affected in Belfast can be found in Section 4.6.1.

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28 http://www.niwater.com/belfastsewersproject.asp
2.4 Climate projections

The CCRA analysis of climate change impacts is presented in eleven sector reports, covering agriculture, biodiversity, built environment, business and services, energy, floods, forestry, health, marine, transport and water respectively. Full references can be found at the end of this report.

The analysis provides projections of change for a range of consequences of climate change, based mainly on the climate projections for a range of presented in UKCP09. The following UKCP09 variables were used in the analysis:

- Change in mean summer, winter and annual temperature, and maximum annual temperature (degrees Celsius).
- Change in annual average summer, winter and annual precipitation (%).

For both variables, projections from three thirty year time periods: 2010 to 2039, 2040 to 2069 and 2070 to 2099 were considered. For simplicity, these periods are referred to by their central decade: the 2020s, 2050s and 2080s respectively.

Future UKCP09 projections are available for three emissions scenarios: low, medium and high (which correspond to the IPCC B1, A1B and A1FI emission scenarios). In the 2020s only the medium scenario is used since the projections are relatively insensitive to the choice of emissions scenario (due to the inertia of the climate system), but in the 2050s and 2080s projections from all three scenarios are analysed.

As the projections are probabilistic, outputs from UKCP09 estimate the probabilities of changes in climate being more or less than specific probability levels. Specific probability levels of 10%, 50% and 90% where provided (labelled p10, p50 and p90), and these have been used in the CCRA to provide a range of plausible future projections. Interpretation of these probability levels is provided for temperature and precipitation change in Table 2.1 and Table 2.2 respectively.

<table>
<thead>
<tr>
<th>UKCP09 probability level</th>
<th>Interpretation</th>
<th>CCRA probability level</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>10% chance of warming being less than this</td>
<td>p10</td>
</tr>
<tr>
<td></td>
<td>90% chance of warming being more than this</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>Warming equally likely to be either greater or less than this</td>
<td>p50</td>
</tr>
<tr>
<td>90%</td>
<td>90% chance of warming being less than this</td>
<td>p90</td>
</tr>
<tr>
<td></td>
<td>10% chance of warming being more than this</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1 Interpretation and naming convention for probability levels for temperature change

http://ukclimateprojections-ui.defra.gov.uk
Table 2.2 Interpretation and naming convention for probability levels for precipitation change

<table>
<thead>
<tr>
<th>UKCP09 probability level</th>
<th>Interpretation</th>
<th>CCRA probability level</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>This is the “drier” end of the range of possibilities.</td>
<td>p10 (dry)</td>
</tr>
<tr>
<td></td>
<td><em>If precipitation decreasing:</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10% chance of decrease being greater than this</td>
<td></td>
</tr>
<tr>
<td></td>
<td>90% chance of decrease being less than this</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>If precipitation increasing:</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10% chance of increase being less than this</td>
<td></td>
</tr>
<tr>
<td></td>
<td>90% chance of increase being greater than this</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>Precipitation change equally likely to be drier or wetter than this</td>
<td>p50</td>
</tr>
<tr>
<td>90%</td>
<td>This is the “wetter” end of the range of possibilities.</td>
<td>p90 (wet)</td>
</tr>
<tr>
<td></td>
<td><em>If precipitation decreasing:</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10% chance of decrease being less than this</td>
<td></td>
</tr>
<tr>
<td></td>
<td>90% chance of decrease being greater than this</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>If precipitation increasing:</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10% chance of increase being greater than this</td>
<td></td>
</tr>
<tr>
<td></td>
<td>90% chance of increase being less than this</td>
<td></td>
</tr>
</tbody>
</table>

Taking into consideration all of these possible choices of projections, as a minimum the following thirteen selected climate scenarios were applied:

- 2020s: p10 Medium, p50 Medium, p90 Medium
- 2050s: p10 Low, p50 Low, p50 Medium, p50 High, p90 High
- 2080s: p10 Low, p50 Low, p50 Medium, p50 High, p90 High.

The main climate change effects are summarised in this section. In addition to temperature and precipitation change, projections of rise in sea level are also included together with discussion of other climate variables. The colours in the tables reflect the increasing magnitude of change (yellow/orange/red for hotter/drier; shades of blue for increases in rainfall and sea level).

Results from the analysis are presented in subsequent sections of this report, where the following definitions apply:

- ‘Medium’ is the p50 Medium climate change scenario referred to above, applied for the 2020s, 2050s and the 2080s.
- ‘Low’ is the p10 Low climate change scenario referred to above, applied for the 2050s and the 2080s.
- ‘High’ is the p90 High climate change scenario referred to above, applied for the 2050s and the 2080s.

The main climate change effects are summarised in this section. In addition to temperature and precipitation change, projections of rise in sea level are also included together with discussion of other climate variables. The colours in the tables reflect the
increasing magnitude of change (yellow/orange/red for hotter/drier; shades of blue for increases in rainfall and sea level).

Where socio-economic change (particularly population change) has been included in the projections, the definitions are enhanced as follows:

- ‘Medium’ is the Medium climate change scenario defined above plus the medium (or ‘Principal’) population increase projection.
- ‘Low’ is the Low climate change scenario defined above plus the low population increase projection.
- ‘High’ is the High climate change scenario defined above plus the high population increase projection.

The population projections were those provided by the Office of National Statistics as shown in Table 2.3.

**Table 2.3  Population projections for Northern Ireland**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>People (thousands)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2025</td>
<td>2055</td>
<td>2085</td>
</tr>
<tr>
<td>Low projection</td>
<td>1,828</td>
<td>1,592</td>
<td>1,143</td>
</tr>
<tr>
<td>‘Principal’ projection</td>
<td>1,963</td>
<td>2,076</td>
<td>2,044</td>
</tr>
<tr>
<td>High projection</td>
<td>2,101</td>
<td>2,596</td>
<td>3,107</td>
</tr>
</tbody>
</table>

Based on the UKCP09 projections\(^{30}\), the future climate in Northern Ireland would result in:

- Higher temperatures in summer and winter
- Increased winter rainfall, but a decrease in summer rainfall
- More heavy rainfall days (i.e. depth greater than 25mm/day) in summer and winter
- Rise in sea level

Other potential changes in the climate for which there is a greater degree of uncertainty include:

- More frequent and more intense extreme rainfall events\(^{31}\)
- More extreme events (flood, heat and cold) and a greater magnitude of extremes
- Increases in sunlight and UV radiation
- Negligible change in frequency or intensity of winter storms\(^{32}\)
- Negligible change in summer or winter wind speeds or number of windy days

The tables presented in the sections below show the UKCP09 projections for Northern Ireland that have been used for the CCRA analysis.

\(^{30}\) Using the central estimates for the medium emissions scenario.
\(^{31}\) Although increased rainfall is projected with reasonable certainty (including more heavy rainfall days), it is less certain whether the extreme events with particularly intense periods of rain will occur more frequently and/or with greater intensity.
\(^{32}\) Depressions (cyclones) or low pressure areas, not thunderstorms.
Whilst the climate change projections indicate future trends in mean values, they do not take account of climate variability. The weather varies year by year and decade by decade. Short term changes in the UK weather may indicate different trends compared with UKCP09. It is however the long term trends (i.e. climate) that are being considered here, particularly increases in temperature and seasonal rainfall, based on baseline data from 1961-1990.

2.4.1 Projected changes in temperature

Temperatures are projected to increase for Northern Ireland.

- The Medium emissions climate change projections (p10 to p90) show increases in mean annual temperature of between 1.3°C and 3.0°C by the 2050s and between 1.9°C and 4.2°C by the 2080s.
- Both winter and summer temperatures are projected to increase, with higher increases projected for the summer months (with summer increases of 1.0°C to 3.5°C by the 2050s and 1.7°C to 5.0°C for the 2080s).
- Maximum annual temperatures are projected to rise by between 1.2°C and 3.8°C by the 2050s and by between 1.7°C and 5.4°C by the 2080s under the Medium emissions climate change projection (p10 to p90).

Projections for temperature change are given in the following tables, which are based on a 1961-90 baseline.

### Table 2.4 Temperature change: Mean annual temperature rise (°C)

<table>
<thead>
<tr>
<th>Emissions scenario</th>
<th>2020s (p10)</th>
<th>2020s (p50)</th>
<th>2020s (p90)</th>
<th>2050s (p10)</th>
<th>2050s (p50)</th>
<th>2050s (p90)</th>
<th>2080s (p10)</th>
<th>2080s (p50)</th>
<th>2080s (p90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1.1</td>
<td>1.8</td>
<td>2.6</td>
<td>1.4</td>
<td>2.3</td>
<td>3.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>0.7</td>
<td>1.2</td>
<td>1.8</td>
<td>1.3</td>
<td>2.1</td>
<td>3.0</td>
<td>1.9</td>
<td>2.9</td>
<td>4.2</td>
</tr>
<tr>
<td>High</td>
<td>1.5</td>
<td>2.3</td>
<td>3.3</td>
<td>2.4</td>
<td>3.6</td>
<td>5.1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2.5 Temperature change: Mean Winter (DJF) temperature rise (°C)

<table>
<thead>
<tr>
<th>Emissions scenario</th>
<th>2020s (p10)</th>
<th>2020s (p50)</th>
<th>2020s (p90)</th>
<th>2050s (p10)</th>
<th>2050s (p50)</th>
<th>2050s (p90)</th>
<th>2080s (p10)</th>
<th>2080s (p50)</th>
<th>2080s (p90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>0.6</td>
<td>1.5</td>
<td>2.5</td>
<td>1.0</td>
<td>2.0</td>
<td>3.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>0.4</td>
<td>1.1</td>
<td>1.8</td>
<td>0.8</td>
<td>1.7</td>
<td>2.8</td>
<td>1.1</td>
<td>2.3</td>
<td>3.7</td>
</tr>
<tr>
<td>High</td>
<td>0.9</td>
<td>1.9</td>
<td>3.0</td>
<td>1.6</td>
<td>2.9</td>
<td>4.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emissions scenario</td>
<td>2020s p10</td>
<td>2050s p10</td>
<td>2080s p10</td>
<td>2020s p50</td>
<td>2050s p50</td>
<td>2080s p50</td>
<td>2020s p90</td>
<td>2050s p90</td>
<td>2080s p90</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Low</td>
<td>0.9</td>
<td>1.9</td>
<td>3.2</td>
<td>1.1</td>
<td>2.4</td>
<td>3.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>0.4</td>
<td>1.3</td>
<td>2.2</td>
<td>1.0</td>
<td>2.2</td>
<td>3.5</td>
<td>1.7</td>
<td>3.2</td>
<td>5.0</td>
</tr>
<tr>
<td>High</td>
<td>1.1</td>
<td>2.4</td>
<td>3.9</td>
<td>2.1</td>
<td>4.0</td>
<td>6.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emissions scenario</th>
<th>2020s p10</th>
<th>2050s p10</th>
<th>2080s p10</th>
<th>2020s p50</th>
<th>2050s p50</th>
<th>2080s p50</th>
<th>2020s p90</th>
<th>2050s p90</th>
<th>2080s p90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1.0</td>
<td>2.1</td>
<td>3.4</td>
<td>1.4</td>
<td>2.7</td>
<td>4.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>0.5</td>
<td>1.4</td>
<td>2.3</td>
<td>1.2</td>
<td>2.4</td>
<td>3.8</td>
<td>1.7</td>
<td>3.3</td>
<td>5.4</td>
</tr>
<tr>
<td>High</td>
<td>1.3</td>
<td>2.7</td>
<td>4.3</td>
<td>2.2</td>
<td>4.2</td>
<td>6.7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.4.2 Projected changes in precipitation

Annual rainfall is not projected to change significantly for Northern Ireland up to the 2080s. However, UKCP09 projects a more significant change in seasonal rainfall.

- Annual mean precipitation, under the Medium emissions climate change projections (p10 to p90), is projected to change by between -4% and +3% by the 2050s. By the 2080s, under the same projection, annual mean precipitation is projected to change by between -5% and +4%.

- Winter is projected to become wetter with a 1% to 19% increase by the 2050s and 0% to 26% increase by the 2080s, under the Medium emissions climate change projection and the p10 to p90 range.

- Autumn is projected to become wetter although the p10 to p90 range for the Medium emissions scenario shows a change of between -5% and +20% for the 2050s and change of between -6% and +28% by the 2080s.

- Summer is projected to become drier although the p10 to p90 range for the Medium emissions scenario shows a change of between -28% and +4%.

- Spring is projected to become wetter although the p10 to p90 range for the Medium emissions scenario is relatively small compared to the other seasons and shows a change of between -5% and +9% for the 2050s and change of between -3% and +9% by the 2080s.
Table 2.8 Precipitation change: Annual mean change (%)

<table>
<thead>
<tr>
<th>Emissions scenario</th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>-4</td>
<td>-1</td>
<td>3</td>
</tr>
<tr>
<td>Medium</td>
<td>-3</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>High</td>
<td>-4</td>
<td>-1</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 2.9 Precipitation change: Mean Winter (DJF) change (%)

<table>
<thead>
<tr>
<th>Emissions scenario</th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>-2</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>Medium</td>
<td>-2</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>High</td>
<td>1</td>
<td>9</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 2.10 Precipitation change: Mean Spring (MAM) change (%)

<table>
<thead>
<tr>
<th>Emissions scenario</th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>-4</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Medium</td>
<td>-4</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>High</td>
<td>-4</td>
<td>2</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 2.11 Precipitation change: Mean Summer (JJA) change (%)

<table>
<thead>
<tr>
<th>Emissions scenario</th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>-25</td>
<td>-10</td>
<td>7</td>
</tr>
<tr>
<td>Medium</td>
<td>-16</td>
<td>-5</td>
<td>7</td>
</tr>
<tr>
<td>High</td>
<td>-28</td>
<td>-12</td>
<td>5</td>
</tr>
</tbody>
</table>
Table 2.12  Precipitation change: Mean Autumn (SON) change (%)

<table>
<thead>
<tr>
<th>Emissions scenario</th>
<th>2020s</th>
<th></th>
<th></th>
<th>2050s</th>
<th></th>
<th></th>
<th>2080s</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
<td>P10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>-7</td>
<td>5</td>
<td>18</td>
<td>-7</td>
<td>5</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>-6</td>
<td>4</td>
<td>15</td>
<td>-5</td>
<td>6</td>
<td>20</td>
<td>-6</td>
<td>9</td>
<td>28</td>
</tr>
<tr>
<td>High</td>
<td>-7</td>
<td>8</td>
<td>26</td>
<td>-10</td>
<td>10</td>
<td>37</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Warmer conditions are expected to lead to a more intense hydrological cycle with an increase in rainfall depths and intensities during winter months. Projections for the wettest day in winter can be used as an indicator of the potential change in characteristics of future rainfall events in Northern Ireland. These show a range of between -2% and 23% for the p10 to p90 Medium emissions projection for the 2050s, although the range is slightly smaller for the Neagh Bann river basin area (-1% to 22%). There is little variation in the projections across the Province.

Table 2.13  Precipitation change: Wettest day in Winter (DJF) change (%) for North Eastern Ireland

<table>
<thead>
<tr>
<th>Emissions scenario</th>
<th>2020s</th>
<th></th>
<th></th>
<th>2050s</th>
<th></th>
<th></th>
<th>2080s</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>-3</td>
<td>7</td>
<td>20</td>
<td>-1</td>
<td>11</td>
<td>27</td>
<td></td>
<td></td>
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<tr>
<td>Medium</td>
<td>-5</td>
<td>4</td>
<td>14</td>
<td>-2</td>
<td>9</td>
<td>23</td>
<td>-1</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>High</td>
<td>-2</td>
<td>10</td>
<td>26</td>
<td>3</td>
<td>20</td>
<td>44</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.14  Precipitation change: Wettest day in Winter (DJF) change (%) for Neagh Bann

<table>
<thead>
<tr>
<th>Emissions scenario</th>
<th>2020s</th>
<th></th>
<th></th>
<th>2050s</th>
<th></th>
<th></th>
<th>2080s</th>
<th></th>
<th></th>
</tr>
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<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
<td>P10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>-3</td>
<td>7</td>
<td>19</td>
<td>0</td>
<td>11</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>-5</td>
<td>4</td>
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<td>22</td>
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<td>10</td>
<td>25</td>
<td>4</td>
<td>20</td>
<td>43</td>
<td></td>
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</tbody>
</table>
Table 2.15 Precipitation change: Wettest day in Winter (DJF) change (%) for North Western Ireland

<table>
<thead>
<tr>
<th>Emissions scenario</th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
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<tr>
<td>Low</td>
<td>-3</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>Medium</td>
<td>-5</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>High</td>
<td>-2</td>
<td>10</td>
<td>25</td>
</tr>
</tbody>
</table>

The UKCP09 projections provide changes in seasonal variables (as illustrated above), but further analysis was carried out as part of the CCRA to develop projections of heavy rainfall. Outputs from the UKCP09 Weather Generator were analysed to estimate the frequency of heavy rainfall events for London, Glasgow, Cardiff and Belfast. This analysis counted the number of rainfall events of different depths up to a total storm depth of 60mm. The short duration events (>10mm in 1 hour, >20 mm in 3 hours) are relevant for combined sewer overflow (CSO) spill frequency, where the capacity of sewers is quickly exceeded (see Section 3.2.10), and the larger events (total rainfall > 40 mm) are relevant for pluvial flooding (i.e. excess surface water runoff that cannot be infiltrated into the ground or drained via existing watercourses and sewers). Higher intensities or depths were not considered due to the limitations of the Weather Generator.

The results showed that the frequency of short intense events was not projected to change markedly for Belfast. The total number of rainfall events above 40mm was projected to increase annually by 50% by the 2080s, as shown in Figure 4. Overall evidence from UKCP09 and the Weather Generator suggests an increase in precipitation in winter months and that this will occur due to a combination of greater rainfall depths and more frequent heavy rainfall events.

![Figure 4 Change in frequency of heavy rainfall events for Belfast](image-url)
2.4.3 Projected sea level rise

Sea level is projected to rise around the coastline of Northern Ireland. The p50 Medium emissions scenario projection shows an increase of 14.5 cm by the 2050s and 25.3 cm by the 2080s.

Table 2.16 Relative sea level rise for Belfast (cm)\(^{33}\)

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
<th>2060</th>
<th>2070</th>
<th>2080</th>
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<tbody>
<tr>
<td>Low</td>
<td>1.3</td>
<td>2.8</td>
<td>4.6</td>
<td>6.6</td>
<td>8.7</td>
<td>11.1</td>
<td>13.7</td>
<td>16.5</td>
<td>19.6</td>
<td>22.8</td>
<td>24.5</td>
</tr>
<tr>
<td>Medium</td>
<td>1.7</td>
<td>3.8</td>
<td>6.0</td>
<td>8.6</td>
<td>11.4</td>
<td>14.5</td>
<td>17.8</td>
<td>21.4</td>
<td>25.3</td>
<td>29.4</td>
<td>31.6</td>
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<tr>
<td>High</td>
<td>2.3</td>
<td>4.9</td>
<td>7.8</td>
<td>11.1</td>
<td>14.7</td>
<td>18.6</td>
<td>22.9</td>
<td>27.4</td>
<td>32.3</td>
<td>37.6</td>
<td>40.3</td>
</tr>
</tbody>
</table>

2.4.4 Extreme events

Extreme weather events are already a characteristic of the present day climate in Northern Ireland and dominate current climate risks. They will also continue to occur in the future, with or without climate change, due to the natural variability of the climate. At present, the influence of these natural variations is far greater than the effect of longer term warming and Northern Ireland would continue to experience cold as well as heat extremes even under warmer conditions.

Extreme events (including heatwaves, cold periods and floods) are represented in the CCRA analysis using the UKCP09 projections, for example:

- Extreme temperature events are represented by adding the temperature changes in Section 2.4.1 to current extreme temperature data. One way in which the results have been used in the CCRA analysis is the number of days that certain threshold temperatures are exceeded.

- Extreme river flood events are represented by using the precipitation data in Section 2.4.2 to predict increases in high river flows. These higher river flows are then used to estimate projected increases in river flooding.

- Extreme tidal flood events are represented by adding the sea level rises in Section 2.4.3 to current extreme sea level predictions. These higher sea levels are then used to estimate projected increases in tidal flooding.

It is projected that extreme cold weather events will become less frequent. The annual number of frost days is also projected to decrease.\(^{34}\) However, there will remain the issue of repeat freezing and thawing. The extent to which this may change in the future is unclear. Probabilistic projections of snowfall rate are not provided in UKCP09 (although these were provided by UKCIP02). In the absence of this data, UKCP09 Briefing Report (Jenkins et al. 2009) refers to typical reductions of 65-80% over mountain areas and 80-95% elsewhere by the 2080s under the Medium emissions scenario.\(^{35}\) It is important to stress that the cold and snowy weather experienced across the UK between 2009 and 2011 is part of normal climate variability and similar conditions could be experienced in future.

\(^{33}\) These are central estimates (p50) of relative sea level changes (i.e. including isostatic adjustment) with respect to 1990 levels.

\(^{34}\) http://ukclimateprojections.defra.gov.uk/content/view/2004/500/ and http://ukclimateprojections.defra.gov.uk/content/view/1810/689/

\(^{35}\) Averaged over the 11 members of the Met Office Hadley Centre RCM ensemble.
There is a concern that extremes may become more extreme in the future (i.e. variations from mean values becoming greater, both positive and negative). However, whilst research into the impacts of climate change on extreme events is ongoing, projections that are suitable for application in the CCRA are not yet available.

Further discussion on extreme events is provided in the CCRA Evidence Report (CCRA 2012).

2.4.5 Projected changes in cloud cover and UV radiation

Levels of cloud cover are projected to change over the current century. Based on UKCP09 projections for the summer, there could be a reduction in cloud cover of between 10% and 20% in the south of the UK by the 2080s, compared to between 0% and 10% in more northern parts of the UK including Northern Ireland.36

Changes in exposure to UV radiation depend on the amount of radiation that will reach the surface of the earth in the future. This is largely determined by the amount absorbed by the stratospheric ozone layer. It is also affected by levels of cloud cover and temperature changes. Increases in UV radiation are therefore projected in the future, although the magnitude of the increase is uncertain.

2.4.6 Wind and storminess

Surface wind speed

The most recent guidance from the Met Office37 states that by the 2050s:

- Projected change in summer wind speed covers both positive and negative changes but is generally skewed towards negative changes in the UK, except for slightly positive changes in Scotland. This is consistent with the poleward shift of the storm track in summer.
- Projected changes in winter wind speed are approximately symmetrical around near-zero change.

On this basis, it has been assumed by the CCRA that it is unlikely that there will be an increase in average or extreme wind speeds in Northern Ireland.

However, this guidance was produced as a result of additional work undertaken subsequent to the main UKCP09 projections. The results (as for all UKCP09 products) are subject to the caveat that the current generation of climate models used to produce them could be missing a key process liable to change the projections. The next set of climate model projections being generated around the world for the IPCC Fifth Assessment Report should improve representation of the effects of the stratosphere on surface climate and assessment of these models will enable modellers to reassess the current results for surface wind speeds (Sexton and Murphy 2010).

Offshore wind and waves

UKCP09 does not provide offshore wind projections. Wave heights around the UK depend on wind and storms both locally and in the wider Atlantic. Direct measurements of wave heights in UK waters (1960s to present) together with

36 These figures are based on p50 projections for the Medium emissions scenario. http://ukclimateprojections.defra.gov.uk/content/view/1330/499/
37 http://ukclimateprojections.defra.gov.uk/content/view/1176/500/
inferences drawn from pressure and tide gauge data (1880s to present) indicate substantial variability in wave height depending on season and location. Although there have not been any clear trends over the twentieth century, the wave climate seems to have roughened appreciably between the 1960s and 1990s. The roughening wave climate is likely to be a consequence of the change in strength of the North Atlantic Oscillation (JERICHO 1999).

**Nearshore waves**

Wave heights around Northern Ireland are dominated by locally generated winds, blowing from the east across the Irish Sea, and from the north blowing from the Scottish Isles. These waves will dominate wave action along the Northern Ireland coast, particularly from the Irish Sea where swell activity is almost exclusively from the south west. In assessing nearshore wave heights for Northern Ireland therefore, the focus is on wind speeds and directions immediately offshore the Northern Ireland coastline rather than wave heights generated in the wider Atlantic.

As wind speeds are projected to show a negligible change, there is likely to be little variation in nearshore wave heights. UKCP09 does not provide wind direction projections. On the assumption that this would not change, nearshore wave heights can be considered purely as a function of changes in sea levels. This would generally result in increased wave heights nearshore, although levels would be variable around the coastline. Nearshore wave directions would also show a slight change, however, this again would be as a result of increases in sea levels affecting the refraction of wave heights nearshore rather than projected changes in wind directions.

**Surge**

Surge, the increase in sea levels above the predicted tide levels are projected to show a small increase over the rest of this century. Current projections indicate a rate of increase of not more than 0.9 mm/year for return period events up to 50 years, indicating that a 50 year surge in the 2080s will increase by less than 7cm. This would be projected to increase extreme sea levels around the Northern Ireland coast.

**2.4.7 CO₂ levels**

The balance between carbon in the atmosphere and in storage (in soils and the oceans) has a significant impact on the consequences of climate change and the mechanisms that are causing it. For example, more carbon in the atmosphere would lead to an increase in plant productivity (affecting agriculture and forestry) but would also contribute to increases in global temperatures and acidification of the oceans.

Whilst no quantified estimates have been made in this report on the climate change impacts of CO₂ levels in the atmosphere and in storage, this is recognised as an important issue. Soil organic carbon in Northern Ireland is discussed in Section 4.2.1

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38 [http://ukclimateprojections.defra.gov.uk/content/view/1855/500/](http://ukclimateprojections.defra.gov.uk/content/view/1855/500/)
3 Impacts on bio-physical systems

3.1 Introduction

Some of the main impacts of climate change on bio-physical systems are summarised below.

1. Rising temperatures, leading to:
   a. Increase in number of growing degree days and longer growing season\textsuperscript{39}
   b. Increase in number of cooling degree days
   c. Decrease in number of heating degree days
   d. Increase in water temperatures

2. Reduced summer rainfall and higher summer temperatures, leading to:
   a. Lower runoff and low river flows in summer
   b. Increase in aridity in summer leading to drying of soils and reduced moisture availability
   c. Increase in frequency and severity of summer droughts
   d. Increase in frequency and severity of wildfires

3. Increased winter rainfall (and intense summer storms), leading to:
   a. Higher runoff and higher river flows in winter
   b. Increase in wetness in winter leading to increased waterlogging
   c. Increase in flooding (including flash flooding in summer)
   d. Increase in erosion of soils and sediment movement in rivers

4. Sea level rise, leading to:
   a. Increase in coastal flooding
   b. Increase in coastal erosion

Estimates are presented below of the likely magnitude of the main bio-physical impacts for Northern Ireland, based on UKCP09 projections and results from the CCRA analysis.

The consequences of these bio-physical impacts for the natural environment; agriculture and forestry; business and services; infrastructure and buildings; and human health and wellbeing are discussed later in Section 4.

\textsuperscript{39} Growing degree days, growing season, cooling degree days and heating degree days are defined in Section 3.2.
3.2 Terrestrial environment

3.2.1 Growing degree days and growing season

Growing degree days (GDD) – the day-by-day sum of the mean number of degrees by which the air temperature is more than 5.5°C, providing an indicator of plant productivity and the timing of biological processes such as bud burst.

For the baseline period of 1961 to 1990, GDDs range from 200 to 500 in Northern Ireland. During the twenty-first century, the GDDs are projected\(^{40}\) to increase by between 100 and 300 by the 2020s, by between 300 and 500 by the 2050s and by between 500 and 700 by the 2080s.

An increase in GDDs would influence the growing season and time to maturity of agricultural crops. In general, it is anticipated that growing seasons would get longer. However, primary production is influenced by a number of other factors too, which are discussed in Section 3.2.6.

3.2.2 Heating and cooling degree days

Cooling degree days (CDD) – the day-by-day sum of the mean number of degrees by which the air temperature is more than 22°C.

For the baseline period of 1961 to 1990, the average number of CDDs for Northern Ireland is less than 25. Throughout Northern Ireland the CDDs are projected\(^{41}\) to increase by less than 25 by the 2050s, but the southern half of Northern Ireland will have an increase of between 25 and 50 by the 2080s.

Heating degree days (HDD) – the day-by-day sum of the mean number of degrees by which the air temperature is less than 15.5°C.

For the baseline period of 1961 to 1990, the number of HDDs for Northern Ireland was between 2,000 and 3,000. During the twenty-first century, the HDDs are projected\(^{42}\) to decrease by between 300 and 600 by the 2020s, by between 600 and 900 by the 2050s and by between 900 and 1,200 by the 2080s. This means the Belfast, for example, may experience a 50% decrease in HDDs by the end of this century.

Although in general the confidence in both CDD projections and HDD projections is considered relatively high, the relatively uncertainty in future CDDs may be greater than the uncertainty in HDDs.

3.2.3 Aridity and summer droughts

An increase in temperature and reduction in rainfall during the summer months would cause drying of soils and reduced moisture availability, with consequences for the natural environment, agriculture, forestry and water use.

\(^{40}\) Based on 11 member RCM climate projections; UKCP09 projections are not available. The confidence in these projections is relatively high.

\(^{41}\) Based on 11 member RCM climate projections; UKCP09 projections are not available.

\(^{42}\) Based on 11 member RCM climate projections; UKCP09 projections are not available.
The projected change in relative aridity in Northern Ireland is shown in Figure 5. Relative aridity has been used by the CCRA as an indicator of relative dryness compared to the baseline figures for temperature and rainfall between 1961 and 1990. The relative aridity projections indicate that the average relative aridity could increase to about 1.15 in the 2020s, 2.0 in the 2050s and 2.8 in the 2080s. The projections for a dry high emissions scenario in the 2080s give an average relative aridity of about 5.0 in Northern Ireland. This indicates that future major droughts may be very severe events, far more so than droughts experienced to date.

Projections for the frequency and severity of summer droughts have not been made in the CCRA. However an assessment of the potential increase in drought conditions can be made based on changes in relative aridity.

It should be noted that two of the river basin areas are trans-boundary areas with the Republic of Ireland. The relative aridity projections are based on average aridity for the whole river basin area, including the Republic of Ireland.

![Relative Aridity Projections](image_url)

**Figure 5**  Projected change in relative aridity in Northern Ireland

### 3.2.4 Wildfires

The risk of wildfires could also increase in hotter, drier conditions. It is estimated that the risk of wildfires in Northern Ireland could increase by between 10% and 30% by the 2080s. It should be noted that this is just an increase in the conditions that have the potential for wildfires, but that an event also requires a trigger. Although there are natural causes of wildfires, such as lightning, most wildfires are the result of human actions. Therefore, there is a greater risk of wildfires during periods of the year when there is greatest human activity, such as bank holidays and school holidays.

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43 Aridity is the degree to which a climate lacks moisture and relates to precipitation and evapotranspiration. It is usually measured based on a relationship between precipitation and temperature. Details of the relative aridity score used for the CCRA analysis can be found in the Water Sector Report.

44 These figures are based on the average p50 Medium emissions scenario projections for all three river basin areas.

45 Based on McArthur Forest Fire Danger Fire Index results for the UK using UKCP09 projections.
Wildfires occur mainly during a few months of the year (presently during spring and autumn). It is anticipated that the main period for wildfires would be in the autumn and that the wildfire season may extend later in the year. This would be due to a combination of factors including a preceding dry summer period and plant growth. However, this does not mean that wildfires would not happen at other times of year, especially during periods of increased human activity.

3.2.5 Soil erosion

Increased rainfall intensities may increase soil erosion rates. There are also concerns that increases in summer drought could damage soil structure and also influence erosion rates. In fact, the interaction of many climate, soil, hydrological, landscape and land use factors have the potential to cause greater rates of soil erosion and long-term soil degradation.

In general, current erosion rates in the UK are low compared to other parts of the world, but there can be localised problems in parts of the UK related to specific land uses, for example high grazing densities of livestock (Lilly et al., 2009). Figure 6 shows the modelled estimated annual sediment yields for Northern Ireland for different levels of dwarf shrub cover (a. 100% cover, b. 80% reduction in cover, c. difference attributed to heavy grazing).

![Figure 6 Modelled estimated annual sediment yields in Northern Ireland](image)

Source: Lilly et al. (2009)

‘Rainfall erosivity’ has been used by the CCRA as an indicator of the potential for rainfall to cause soil erosion. The concept is based on the energy in rain drops and it is highly correlated with rainfall intensity. Erosion rates are likely to increase with an
increase in intensity of rainfall events or the number of intense rainfall events in a year. See the CCRA Evidence Report for more details (CCRA, 2012a).

For Northern Ireland rainfall erosivity is projected to increase by 49% for the North East Ireland and North West Ireland river basin areas and by 56% for the Neagh Bann river basin area by the 2080s (see Table 3.1).46

Table 3.1 Estimates of change in rainfall erosivity (%) for Northern Ireland river basins

<table>
<thead>
<tr>
<th></th>
<th>2080s Medium emission scenario(^{47})</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
</tr>
<tr>
<td>Neagh Bann</td>
<td>23</td>
</tr>
<tr>
<td>North East Ireland</td>
<td>8</td>
</tr>
<tr>
<td>North West Ireland</td>
<td>8</td>
</tr>
</tbody>
</table>

3.2.6 Primary production

Primary production (plant growth) is influenced by a number of climatic factors, including levels of carbon dioxide in the atmosphere and changes in temperature, precipitation and solar radiation. Optimum rates of primary production are expected to increase in temperate ecosystems with warmer temperatures and higher levels of atmospheric CO2 concentrations. However, water availability and soil nutrient supplies may limit production, even offsetting favourable conditions.

Projections for grassland productivity have been produced for the CCRA as an indicator of primary production, due to the importance of this crop in areas such as Northern Ireland. Further details can be found in Section 4.3.1.

3.2.7 Thermal humidity

Temperature is only one of the factors that influence thermal comfort; it is a combination of temperature and humidity and, to a lesser extent wind and solar radiation, which have a direct impact on thermal comfort and ‘heat stress’ for animals and plants and human health during extreme heatwaves (see Section 4.6.2).

The thermal heat index (THI) combines temperature with relative humidity to give an index that describes thermal discomfort.

For the baseline period of 1961 to 1990, the maximum monthly average THI values for Northern Ireland are between 50 and 72. The projected values\(^{48}\) for THI for the 2020s, 2050s and 2080s remain between 60 and 72.\(^{49}\)

3.2.8 Water temperatures

It is expected that increases in air temperatures would lead to a rise in water temperatures. The extent of warming, particularly of the entire water column, is highly dependent on a number of other factors too including flow velocity, evaporation rates

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\(^{46}\) These figures are based on p50 projections for the Medium emissions scenario.

\(^{47}\) Probability levels associated with changes in precipitation on the “wettest day of the winter season”.

\(^{48}\) Based on 11 member RCM climate projections; UKCP09 projections are not available. The confidence in these projections is medium.

\(^{49}\) Where the THI range is less than 72 this indicates no stress to cattle.
and depth of the water column. River water temperatures have been found to vary both with region and river type (catchment altitude, geology and size) with the former often having the stronger influence (Hammond and Pryce, 2007). This is a complex area of research that needs to consider hydrological and energy balance processes. There is high confidence that water temperatures will rise, but it is not possible to provide meaningful regional estimates of change without more detailed work.

### 3.2.9 Runoff and low flows in summer

The projected decrease in summer rainfall for Northern Ireland would result in reduced runoff volumes and reduced flows in watercourses.

The CCRA analysis looked at how much flows in watercourses would reduce using Q95 flows, i.e. the flow in the river exceeded for 95% of the time. The analysis showed that the Q95 flows in watercourses in Northern Ireland are projected to reduce in the long-term due to warmer drier summers. In other words, low flows in watercourses are projected to get lower. It is projected that Q95 flows for rivers in Northern Ireland could change by the order of +12% (increase) to -21% (reduction) by the 2020s, and -17% to -41% by the 2080s.\(^5^0\) Figure 7 shows the percentage decrease in Q95 for each of the river basins for the Low, Medium and High projections.

It should be noted that two of the river basin areas are trans-boundary areas with the Republic of Ireland. The Q95 projections are the averages for the whole river basin areas, including the Republic of Ireland.

\(^5^0\) These figures are based on the projections for all three river basin areas and the range between the p10 and p90 projections for the Medium emissions scenario.

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Figure 7  Projected percentage decrease in Q95 in Northern Ireland
3.2.10 Runoff and peak flows in winter

The projected increase in winter rainfall would lead to:

- Greater volumes of runoff and higher river flows
- Increased catchment wetness leading to increased problems of waterlogging
- Increased flooding both from rivers and surface water (this could also be caused by intense summer rainfall events)
- Increased spill frequency and volumes from combined sewer overflows (CSOs)

Changes in peak flows and flood frequency for Northern Ireland have not been estimated for the CCRA as the research required has yet to be undertaken. However for the purposes of the Preliminary Flood Risk Assessment (PFRA), DARD Rivers Agency adopted a factor of 20% extra rainfall/peak flows to assess the potential impacts of climate change. Further information can be found in Appendix D.

Increases in rainfall / peak flows in Northern Ireland are most likely to be similar to West Wales and the North West of England, based solely on fact that these areas are broadly similar in terms of current precipitation patterns and catchment characteristics. On this basis, one would expect the relative increase in peak flows for Northern Ireland to be of the order of 15% for the 2020s, 22% for the 2050s and 27% for the 2080s.\(^5^1\)

Details can be found in the CCRA Evidence Report (CCRA, 2012a).

Projections for CSO spills have been determined and are provided in Figure 8. The percentage change in CSO spill volume ranges from 5% to 7% by the 2050s and 8% to 10% by the 2080s, depending on river basin area. This can be considered as an indicator of future sewerage performance, i.e. when CSOs are discharging the sewers will be operating at (or greater than) design capacity, which will mean that there is increased likelihood of sewer flooding.

![Figure 8 Projected percentage change in CSO spill volume in Northern Ireland](image-url)

\(^{51}\) Medium emissions scenario p50 projections.
3.2.11 Solute and sediment transport

The changing balance of seasonal precipitation is likely to have a direct impact on solute and sediment transport, although understanding the relative impacts of climate versus land use change is difficult without detailed catchment scale monitoring and modelling. Examples of potential changes in processes due to climate include:

- Increases in nitrate leaching in winter months due to increase in precipitation, infiltration in soils and recharge for groundwater;
- Similarly, changes in phosphorus losses from soils through erosion or leaching processes, particularly following heavy rainfall events;
- Changes in pesticide leaching and breakthrough in soils and groundwater systems; and
- Potential for enhanced nutrient loss following drought periods, when plants have failed to make use of nutrients and fertiliser.

In each case the nutrient and pesticide transport will only increase where its availability is not limited. Other factors, such as land use and technology, may be more important than climate in future time periods. The potential consequences of changing patterns of solute transport include changes in water quality at the basin scale, ecological status and the requirements for water treatment (see Section 4.2.2)

3.3 Coastal and marine environments

3.3.1 Coastal flooding and erosion

If the projected increase in sea level is realised, the annual probability of the occurrence of present day high sea levels would increase and there would be a corresponding increase in the potential for coastal flooding and erosion.

The Northern Ireland Strategic Flood Map (SFM) illustrates areas throughout Northern Ireland that are estimated to be prone to flooding from rivers and the sea. The map takes account of projected changes to climatic conditions and sea levels for the year 2030 and provides a general overview of the risk of flooding in Northern Ireland.

The production of the SFM is an important first step in a process that (in line with the EU Floods Directive) will lead to the development of flood risk management plans for all areas across Northern Ireland that are estimated to be at potential significant risk of flooding. However, due to the inherent uncertainties in the flood modelling techniques and data used to produce this national snapshot of flood prone areas, the SFM is not sufficiently accurate to determine the flood risk to individual properties or specific point locations. The second generation flood hazard and risk maps that will be produced for the Areas of Potential Significant Flood Risk shall be much improved with less uncertainty, as these will be derived from predictive models developed in accordance with best practice.

At present, coastal erosion is not perceived to be a major issue in Northern Ireland. However, approximately 20% of the Northern Ireland coastline is currently experiencing coastal erosion (compared to 12% of Scotland, 30% of England and 24% of Wales).\footnote{http://www.mccip.org.uk/annual-report-card/2007-2008/marine-environment/coastal-erosion.aspx}
Climate change, in particular sea level rise, is likely to make coastal erosion a more important issue in the future. The combination of sea level rise and erosion is likely to reduce the area of beaches. Out of the 16 Northern Ireland beaches assessed (41 km total length) it is projected that between 100 and 300 hectares of beach area could be lost by 2080 due solely to rising sea levels (assuming that the beach high water mark is unable to move landwards). The normal evolution and chemical processes associated with coastal systems, such as sand dunes, salt marshes, sedimentation and siltation processes, etc. would also be affected.

Given the current uncertainties in predicting future sea level trends, and the lack of specific robust Northern Ireland data, the analysis undertaken for the climate change risk assessment on coastal flooding and erosion has been based upon the national datasets.

Based upon projected sea level rise, the frequency of coastal flooding events is expected to increase significantly. This is demonstrated in Figure 9 for the two Class A national tide gauges in Northern Ireland at Bangor and Portrush.

![Figure 9](http://ukclimateprojections.defra.gov.uk/content/view/825/500/)

**Figure 9  Change in return period with change in mean sea level**

Figure 9 demonstrates that at Portrush, for example, a sea level with a current return period of 100 years (1% probability) will have a return period of less than 10 years if mean sea levels increase by 0.25m, which is approximately the Medium emissions scenario projection for the 2080s.

### 3.3.2 Ocean hydrography and circulation

The following summarises the main findings of the UKCP09 marine and coastal projections relating to hydrograph and circulation. These are based on one future scenario projection for the 2080s.

53 [http://ukclimateprojections.defra.gov.uk/content/view/825/500/](http://ukclimateprojections.defra.gov.uk/content/view/825/500/)
scenario that might be realised under the Medium emissions scenario. Further details can be found in the CCRA Evidence Report (CCRA, 2012a).

- The seas around the UK are projected to become 1.5°C to 4°C warmer, depending on the location, and approximately 0.2 p.s.u. (practical salinity units\(^54\)) fresher by the end of the 21st century. The change in salinity is particularly dependent on the projected change in the storm tracks owing to the latter's effect on precipitation.

- Seasonal stratification strength is projected to increase but not by as much as the open ocean. This stratification is projected to start approximately 5 days earlier and breakdown 5 to 10 days later each year, hence extending the stratified period.

- Changes in open ocean (especially the circulation) are particularly uncertain due to the proximity of the model boundary.

### 3.3.3 Ocean acidification

Although oceanic pH has varied throughout history, the concern is that reductions in pH observed are occurring much faster than in any time during the last 55 million years. As atmospheric concentrations of CO\(_2\) continue to rise in the future, increased absorption by the oceans may accelerate oceanic acidification. Both modelled and observational data suggests that oceanic absorption of CO\(_2\) has already decreased oceanic pH by 0.1 units since 1750.

The CCRA has assessed ocean acidification in a quantitative manner using the relationship derived between atmospheric loading of CO\(_2\) and oceanic uptake and dissolution resulting in decreased pH. The reduction in pH of the North Sea was predicted to exceed on average 0.1 pH units in the next 50 years, due to inputs of atmospheric CO\(_2\) into the marine system. Based on a worst case scenario, it was estimated that there could be a total decline of 0.5 pH units below pre industrial times by 2100. Further details can be found in the Marine Sector Report. Although the North Sea was used as a case study, this relationship can be extrapolated for other UK waters. However, ocean pH can be affected by localised conditions and in some coastal locations pH can vary as much as 1.0 pH units due to complex riverine mixing and biological input.

### 3.3.4 Arctic Sea Ice

Projections of ice cover for the Arctic provided by the Met Office show that the Northern (Arctic) sea routes may become open in the near future and remain open for longer period during the Arctic summer. The projections suggest that there will be ice free Arctic summers by the 2080s. Results showed that the North East passage could be open for up to 120 days by the 2050s and 180 days by the 2080s, while the North West passage may be open for up to 90 days by the 2050s and 120 days by the 2080s.

### 3.4 How Northern Ireland might change

A summary of the ways in which climate change might impact on the natural and built environment of Northern Ireland is given in this section. The impacts are considered in more detail in Section 4 based on the findings of the CCRA analysis.

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\(^{54}\) Ocean water has a salinity of approximately 35 p.s.u.
3.4.1 Changes to vegetation and species

Warmer drier summers would affect both natural biodiversity and human interventions including agriculture and forestry. Wetter winters would result in wetter soils and increased waterlogging, affecting biodiversity and agriculture.

Marine species may be affected by increases in water temperature and other consequences of climate change, for example increased acidification of seawater.

These impacts are discussed in Sections 4.2 (The Natural Environment) and 4.3 (Agriculture and Forestry).

3.4.2 Changes to the landscape

The landscape would change if summers become warmer and drier. The landscape would become more arid and drought resistant species would be more likely to prevail. Soil erosion would increase as soils dried out in the summer and then eroded by the increasingly intense summer and winter rainfall.

Impacts on the landscape have not specifically been addressed in the CCRA, although inferences on the likely effects can be made from the analysis and discussion presented in Section 4, particularly Sections 4.2 (The Natural Environment) and 4.3 (Agriculture and Forestry). However, it also plays a significant role in cultural heritage, tourism (Section 4.4.4) and associated businesses, as well as in human health and wellbeing (Section 4.6).

3.4.3 Loss of beaches and coastal features

Sea level rise would cause changes to the shoreline including loss of beach and intertidal areas. Beaches and coastal structure are important to tourism, with many of Northern Ireland’s attractions being on the coast. Increasing visitor numbers, expanding coastal infrastructure and the current chain of harbours and marinas along the coast, underlies this importance. More than 1 million people visited National Trust coastal properties in 2009 (DOENI, 2010c).

Coastal erosion would increase as a result of sea level rise, causing an increasing loss of coastal land including intertidal habitats. These impacts are discussed in Section 4.2 (The Natural Environment).

3.4.4 Changes to the built environment and society

Changes to the physical built environment as a result of climate change would mainly consist of adaptation actions to mitigate adverse consequences and take advantage of the opportunities presented, for example, warmer summers.

However, based on current projections, the direct impacts of climate change on society would include increases in heatwaves, droughts and floods. The consequences of these impacts are wide ranging and include health effects on people, damage to businesses and disruption to society.

These impacts are discussed in Section 4.4 (Business and Services), Section 4.5 (Infrastructure and Buildings) and Section 4.6 (Health and Wellbeing).
4 Risk assessment

4.1 Summary of approach

This section describes the main consequences of the bio-physical impacts described in Section 3 and direct consequences of climate effects described in Section 2.

The following sections discuss the climate change impacts and consequences for Northern Ireland under the following themes:

- 4.2 The Natural Environment
- 4.3 Agriculture and Forestry
- 4.4 Business and Services
- 4.5 Infrastructure and Buildings
- 4.6 Health and Wellbeing

This section focuses specifically on the Tier 2 list selected for Northern Ireland following the process described in Section 1.5.2. Further information regarding other impacts and consequences can be found in the sector reports. The Tier 2 list for Northern Ireland is provided in Appendix A.

The climate change impacts and consequences have been assessed based on the results of the CCRA analysis. The approach to risk analysis is described in the CCRA Method Reports (Defra 2010a, 2010b). The analysis is described in the eleven sector reports (full references can be found at the end of this report).

At the end of each section there is a summary table similar to one presented in Figure 10.

The table presents the estimated magnitude of the risks for Northern Ireland (both threats and opportunities) ranging from low to high. By presenting these for the three time slices of the 2020s, 2050s and 2080s, this gives an indication of how the risk may change over time.

Where the magnitude of the risk has been quantified, the scaling is based on the central estimates for the Medium emissions scenario for the 2020s, 2050s and 2080s. These impacts are identified by a Q for quantified. The majority of risks, however, have had to be assessed using informed judgement and these are identified by an IJ.

Some risks are too difficult to assess at the present time, either because the science is not sufficiently well advanced yet to understand the magnitude and timing of the risk or the inherent uncertainty is too great. In addition, some risks were identified on the Tier 2 list for Northern Ireland, but have not been assessed due to time constraints. These are included in the table for completeness, but have a grey bar. This does not mean that the risk is not important or that the risk will not change in the future. Further discussion of these ‘gaps in knowledge’ is provided in Chapter 6.

As discussed earlier, this assessment for Northern Ireland is based on the UK-wide analysis undertaken for the CCRA. As part of this analysis, some risks were assessed at the Northern Ireland scale, but others were assessed at the UK scale. These are identified by ‘NI’ and ‘UK’ respectively in the coverage column. Where UK-wide projections are provided, these are considered a suitable substitute for Northern Ireland. If the UK-wide results are not considered applicable and there is not sufficient
information to modify these results for Northern Ireland, based on informed judgement, the risk is shown as not having been assessed. Details of assumptions made are provided with each table.

It is important to stress that all projections presented in these tables are simply best estimates based on current understanding and some risks are understood better than others. Therefore, there is a further column provided that gives an indication of how much confidence there is in the timing and magnitude of the risk, ranging from low to high. Table 4.1 explains these categories.

**Table 4.1  Confidence categories**

<table>
<thead>
<tr>
<th>Confidence Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Expert view based on limited information, e.g. anecdotal evidence, or very simplistic estimation methods using single climate variable and based on historic data.</td>
</tr>
<tr>
<td>Medium</td>
<td>Estimation of potential impacts of consequences grounded in theory, using accepted methods and with some agreement across the sector. This typically includes estimates that have considered a number of climate variables based on UKCP09 sampled data and others where the risk assessment methods are strong, but the UKCP09 science may be less reliable, e.g. summer precipitation.</td>
</tr>
<tr>
<td>High</td>
<td>Reliable analysis and methods, with a strong theoretical basis, subject to peer review and accepted within a sector as ‘fit for purpose’. This includes analytical methods that have made use of Regional Climate Model data and analysis of potential risks that are very strongly linked with increases in temperature.</td>
</tr>
</tbody>
</table>

Consequences can be considered as high, medium or low magnitude depending on four different criteria, as listed in Table 4.2. The cost per year has been estimated based on a monetisation exercise, which is described in Appendix B. However, this alone does not determine whether the consequence is high or not. If any one of these four criteria scores high, then the consequences are shown as high in the table.

**Table 4.2  Risk assessment criteria for Northern Ireland**

<table>
<thead>
<tr>
<th>Criterion</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>People affected (number)</td>
<td>&gt; 100,000</td>
<td>100,000 – 10,000</td>
<td>&lt;10,000</td>
</tr>
<tr>
<td>Deaths per year (number: increase or decrease)</td>
<td>&gt; 1,000 / year</td>
<td>1,000 – 100</td>
<td>&lt;100</td>
</tr>
<tr>
<td>Cost per year (increase or decrease)</td>
<td>&gt; £100 million</td>
<td>£100 – 10 million</td>
<td>&lt; £10 million</td>
</tr>
<tr>
<td>Environmental impact (positive or negative)</td>
<td>Widespread and potentially large</td>
<td>Locally large; Widespread but not large</td>
<td>Local</td>
</tr>
</tbody>
</table>
### Opportunities

<table>
<thead>
<tr>
<th>Tier 2 impacts for Northern Ireland</th>
<th>Magnitude of consequences for each time slice</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020s</td>
<td>2050s</td>
</tr>
<tr>
<td><strong>MA5b</strong></td>
<td>Opening of Arctic shipping routes due to ice melt</td>
</tr>
<tr>
<td><strong>BU8</strong></td>
<td>An expansion of tourist destinations in Northern Ireland</td>
</tr>
<tr>
<td><strong>NIW</strong></td>
<td>Changes in UK trading patterns</td>
</tr>
</tbody>
</table>

### Threats

<table>
<thead>
<tr>
<th>Tier 2 impacts for Northern Ireland</th>
<th>Magnitude of consequences for each time slice</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020s</td>
<td>2050s</td>
</tr>
<tr>
<td><strong>BU6</strong></td>
<td>Mortgage provision threatened due to increased flood risk</td>
</tr>
<tr>
<td><strong>BU3</strong></td>
<td>Risk of restrictions in water abstraction for industry</td>
</tr>
<tr>
<td><strong>BU2</strong></td>
<td>Monetary losses due to tourist assets at risk from flooding</td>
</tr>
<tr>
<td><strong>BU4</strong></td>
<td>Risks of business disruption due to flooding</td>
</tr>
<tr>
<td><strong>BU20</strong></td>
<td>Loss of staff hours due to high internal building temperatures</td>
</tr>
</tbody>
</table>

### Method

- **i.e.** Whether the assessment is based on:
  - **Q** – quantified analysis
  - **IJ** – informed judgement

### Confidence

- **i.e.** How confident we are that these consequences will occur.

### Coverage

- **i.e.** Whether the assessment is based on:
  - **NI** - analysis specific to Northern Ireland
  - **UK** – analysis that is UK-wide
  - **GB** – Analysis undertaken for Great Britain only

### Key for colour coding:

- **High consequences (positive)**
- **Medium consequences (positive)**
- **Low consequences (positive)**
- **Low consequences (negative)**
- **Medium consequences (negative)**
- **High consequences (negative)**
- **High confidence**
- **Medium confidence**
- **Low confidence**
- **Too uncertain to assess**

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**Figure 10** Understanding the summary tables
4.2 Natural environment

Northern Ireland has a diverse range of species considering its size, and a wide variety of habitats that support them, including heathlands, grasslands, wetlands, freshwater loughs, marine and coastal habitats, limestone pavements and woodlands. The Province has a total of 51 priority habitats.55

- There are substantial areas of ground above 200m in the form of the Sperrin Mountains, the granite Mourne Mountains (including Northern Ireland’s highest peak Slieve Donard at 849 m) and the basalt Antrim Plateau. These upland areas and bogs are known for their plant life and invertebrates such as the predatory ground beetles, *Notiophilus aesthuans* and *Miscodera arctica* and the sawfly (*Pontania crassipes*); Slieve Donard is the only Irish site where these three species are found together.

- The lower reaches of the Lower and Upper River Bann, River Foyle and River Blackwater provide extensive fertile lowlands, with excellent arable land also found in North and East Down.

- Lough Neagh is the largest freshwater lake in the British Isles at 383 km² and is a Ramsar site56, SPA and ASSI57, supporting (amongst other things) over 40 rare or local vascular plants, 12 species of dragonfly, breeding birds and waterfowl, including wintering Bewick’s and whooper swans. The second large freshwater lough system centred on Lower and Upper Lough Erne in Fermanagh has 154 islands. Lough Neagh and Lower Lough Erne are the only two known locations in the UK supporting populations of pollan.

- The five sea loughs have a combined area of 522 km² and drain 40% of the land area of Northern Ireland. All five loughs (Lough Foyle, Lame Lough, Belfast Lough, Strangford Lough and Carlingford Lough) are Ramsar sites of international importance for waterfowl and waders.

Habitats, such as lowland meadows and hedgerows are already in decline, and the species that depend on these habitats are vulnerable. There are currently 481 species on Northern Ireland’s priority species list (i.e. species that require conservation action

56 The Convention on Wetlands of International Importance, especially as waterfowl habitat.
because of their decline, rarity and importance in an all-Ireland as well as UK context), four of these are pictured above.  

Certain physiological and life cycle traits may make species inherently vulnerable or resilient to disturbance, including climate-related disturbance, see Table 4.2. For example, species such as Wood Crane’s-bill (Geranium sylvaticum) has a very restricted range within Northern Ireland and is currently in decline (DOENI, 2005); whereas, bracken (Pteridium aquilinum) produces spores in copious amounts, particularly in wet environments (Conway, 1957), and is increasing in range (Burchett et al., 2009).

Table 4.3  Physiological and life history traits that may make a species more or less vulnerable or resilient to climate-related disturbances (re-drafted from Steffen et al.2009)

<table>
<thead>
<tr>
<th>Species at least risk</th>
<th>Species at most risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological tolerance to broad range of factors such as temperatures, drought and flooding.</td>
<td>Narrow range of physiological tolerance to factors such as temperature, drought and flooding.</td>
</tr>
<tr>
<td>High degree of phenotypic plasticity (ability to change observable characteristic or trait)</td>
<td>Low genetic variability</td>
</tr>
<tr>
<td>High degree of genetic variability</td>
<td>Long generation times and long time to sexual maturity</td>
</tr>
<tr>
<td>Short generation time (i.e. life cycle) and short time to sexual maturity</td>
<td>Specialised requirements for other species (e.g. for a disperser, prey species or pollinator) or for a particular habitat that may itself be restricted (e.g. a particular soil type)</td>
</tr>
<tr>
<td>High fecundity (reproductive ability)</td>
<td>Poor dispersers</td>
</tr>
<tr>
<td>‘Generalist’ requirements for food, nesting sites, etc.</td>
<td>Narrow geographic ranges</td>
</tr>
<tr>
<td>Good dispersal capability</td>
<td></td>
</tr>
<tr>
<td>Broad geographic range</td>
<td></td>
</tr>
</tbody>
</table>

Species interact with one another in the natural environment. These interactions, known as ecological processes, ultimately underpin ecosystem functions and thereby the delivery of ecosystem services (i.e. the benefits that people obtain from ecosystems). This can be both in terms of physical needs, such as food, water, fertile soils, or in terms of non-material significance, such as knowledge systems, social relations, and aesthetic values.

One of the most important groups of species is the primary producers. These species, primarily plants and algae, harness sunlight through photosynthesis in order to create the ‘food’ they need for growth. These form the base of almost all food chains, including providing food for humans. To function effectively, primary producers need a range of associated biodiversity; organisms to maintain soil structure, function and fertility and others for pollination.

As well as being important in their own right, many wild species are also of high economic value. For example, Salmon and sea trout are important for angling; pheasant and partridge are important game birds; and culturally significant species, such as the Red Squirrel, Otter, Small Blue butterfly and the Golden Plover, can encourage tourism in an area.

Figure 11 shows the designated sites in Northern Ireland. In summary, these cover the following areas:

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58 http://www.doeni.gov.uk/inea/northern_ireland_priority_species_list.pdf
59 An intrinsic ecosystem characteristic whereby an ecosystem maintains its integrity. Ecosystem functions (or processes) include decomposition, production, nutrient cycling, and fluxes of nutrients and energy. (NEA, 2011b)
Table 4.4 Areas of Natural Heritage in Northern Ireland

<table>
<thead>
<tr>
<th>Area Description</th>
<th>Number of sites</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areas of Outstanding Natural Beauty (AONBs)</td>
<td>8</td>
<td>3,412</td>
</tr>
<tr>
<td>Special Protection Areas (SPAs)</td>
<td>12</td>
<td>1,146</td>
</tr>
<tr>
<td>Areas of Special Scientific Interest (ASSIs)</td>
<td>224</td>
<td>1,001</td>
</tr>
<tr>
<td>RAMSAR sites</td>
<td>19</td>
<td>777</td>
</tr>
<tr>
<td>Special Areas of Conservation (SACs)</td>
<td>52</td>
<td>673</td>
</tr>
<tr>
<td>National Nature Reserves (NNRs)</td>
<td>49*</td>
<td>49</td>
</tr>
</tbody>
</table>

* Includes one marine nature reserve

Designated sites are of paramount importance for nature conservation and associated ecosystem services, such as the heritage value of the natural environment. They offer refuges for many species, particularly those that require semi-natural habitats. However, in order to maintain successful populations of wild species, particularly given the changes that climate change may bring, it is important that there are enough sites, that they are large enough, connected to each other and well-managed. A study by Lawton *et al.* (2010) for the protected site network in England found that this was not currently the case. It was considered that the site network could be enhanced, not only by creating more and bigger sites, but by improving the connectivity between sites, using corridors and by improving the unprotected land so that it does not create an impenetrable barrier for species movements. Whilst this assessment was not carried out in Northern Ireland, the principles of a successful conservation network can still be applied to enhance the current protected sites in Northern Ireland.

Monitoring of the condition of features within ASSIs, for the 6-year rolling period ending March 2010, indicated that 66% of features were ‘favourable’, 31% were ‘unfavourable’ and 3% were ‘unfavourable but recovering’ (DOENI, 2011). Habitats that are under stress, for whatever reason, are likely to have a reduced ability to adapt to change, such as changes in climate. (This is discussed further in the Biodiversity & Ecosystem Services Sector Report.)

According to the State of the Environment Report for Northern Ireland (EHS 2008), human impacts are the main pressures affecting biodiversity in Northern Ireland, namely agriculture, fisheries, housing and development, tourism and renewable energy. Climate change may exacerbate the effects of these pressures and have serious and far reaching consequences for the natural environment in Northern Ireland.

The most important climate change consequences (as identified by the Northern Ireland stakeholders) are considered in this section, under terrestrial, aquatic (freshwater), coastal and marine headings. These direct consequences would also have indirect consequences for society and the economy and these are discussed in Sections 4.3 to 4.6.

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60 Environment and Heritage Service 2008
61 Common standards monitoring (supported by the Joint Nature Conservation Committee) is carried out on a 6-yearly cycle in Northern Ireland to ensure that the condition and integrity of protected sites is maintained and improved. Site monitoring is undertaken to identify whether conservation objectives are being met or worked towards and the site is then classified based on three categories, “unfavourable”, “unfavourable recovering” or “favourable”.
Figure 11 Designated sites in Northern Ireland
4.2.1 Terrestrial environment

Changes in the terrestrial natural environment have been driven principally by land use change and management practices over the last two centuries. Climate change, however, is anticipated to play a bigger part in driving change in the future, impacting biodiversity and ecosystem services.

Changes in soil moisture and increases in invasive non-native species, pests and diseases are projected to become increasing pressures in the future. Future conditions may favour generalist species, pests, diseases and invasive non-native species, leading to a reduction in biodiversity and disrupting ecosystem services. Additionally, changes in migration patterns and phenological mismatch (which may lead to disruption of food webs) may put species and ecosystem services at further risk. The risk of wildfires is also projected to increase, which could put species at risk and damage soils.

Soil organic carbon

Potentially, one of the most important impacts of climate change is on soil organic carbon. This risk is considered to be particularly important for Northern Ireland given the high proportion of organic and peat soils particularly in the north and west of the Province (see Figure 12).

Figure 12  Significance of organic soils in Northern Ireland
Source: Lilly et al., (2009)
The organic content of soils is a key regulator of plant nutrient cycling and water availability. Soil contains high levels of species biodiversity, particularly microbes, fungi and invertebrates, and forms the basis for both effective ecosystem functioning and associated services (e.g. crop production, water regulation and purification, etc.) (NEA, 2011c). Of particular importance is the storage of organic matter and carbon in soils, particularly the highly organic soils such as peat (defined as organic soil > 0.5m depth). Currently, peat soils in Northern Ireland occupy 15% of the land area and contain 42% of the carbon stock for the Province (NEA, 2011c).

The ability of peatlands (i.e. blanket bog (see Box 3), lowland raised bogs and fen) to store new reserves of carbon has been significantly reduced, due to damage from a number of sources, predominantly land management. Many upland areas are also designated sites and, therefore, there is a legal requirement to avoid practices that damage the interests of the site. However, designations do not reflect carbon storage, which means that it is possible for activities to take place that may impact upon this.

Climate change could cause additional stresses that might affect this habitat (see Species and Habitats below). In general, there is considerable uncertainty surrounding the potential impact of climate change on soil organic carbon, because of the complexity of interactions involved. Whilst these interactions would be modified by climate change, it is not currently possible to state with certainty whether this would result in an increased carbon store or sink.

Box 3: Blanket bog in Northern Ireland

Local extinctions of important species within blanket bogs may occur by the 2050s due to climate change.

Blanket bog makes up 10% of the land area in Northern Ireland (NEA, 2011a). The largest areas of blanket bog in Northern Ireland occur at altitudes over 200m and are concentrated on the Antrim Plateau, the Sperrin Mountains and in County Fermanagh including the 5,000 ha stretch along the border near Cuilcagh mountain (LIFE, 1994). Although most widespread in the north-west, blanket bogs also occur in the eastern upland areas, including the Mourne Mountains, and the largest proportion of blanket bog is found on the Antrim plateau (DOENI, 2004).

Blanket bogs in Northern Ireland include important species such as: Irish lady’s-tresses orchid, marsh clubmoss (Lycopodiella inundata), yellow marsh saxifrage (Saxifraga hirculus), Irish hare (Lepus timidus hibernicus), curlew, (Numenius arquata) hen harriers (Circus cyaneus) and red grouse (Lagopus lagopus scotica). Reservoirs that drain areas of blanket bog on the Garron Plateau, the Sperrin Mountains and Mourne Mountains provide much of the drinking water in Northern Ireland (DOENI, 2004).

Modelling done in the Cuilcagh / Pettigo area by Berry et al. (2005) projected the loss of the rare orchid, lesser twayblade (Listeria cordata) most likely due to seasonal drying by the 2050s. Similarly, other species such as Carabidae may experience local extinction. The reaction of peatlands to climate change is uncertain, however. Whereas increased winter rainfall may be beneficial for current blanket bog vegetation, it is also possible that the new climate may favour wet heath rather than peat bog vegetation (Berry et al., 2005).

Recent research in Northern Ireland and Scotland has modelled soil loss due to grazing and climate change. This is particularly important in both countries as their

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62 Future grazing pressure may increase or decrease due to a combination of climate change and other drivers impacting on agricultural practices.
organic and organo-mineral soils account for approximately 40% of the UK’s soil total carbon. Evidence suggests that erosion of organic surface soils has had significant impact on peat and peaty soil in Northern Ireland, with 14% of blanket bog impacted by erosion. This work concluded that estimates of rate of change of carbon content of Northern Ireland’s soils required further analysis, but it was considered to be greatest within actively eroding peatland systems with existing extensive areas of bare peat exposed to the range of drivers of erosion, including grazing (Lilly et al., 2009).

Where there is damage as a result of fire, carbon stored within the peat can be released back to the atmosphere and the ability of the habitat to act as an effective carbon sink is severely constrained.

Species and habitats

Soil moisture
Most UK habitats and species are adapted to a temperate damp climate with water availability only a problem in extreme dry years. They are, therefore, sensitive to a change in climate towards a state where present-day dry conditions become the norm. This could lead to loss of ecosystem function and key services provided by wetlands and other habitats.

Increased soil moisture deficits and drying could have severe adverse effects on key habitats including, for example, blanket bog. There are about 140,000 ha of blanket bog in Northern Ireland and 1.5 million ha in the UK as a whole, containing an estimated 5.1 billion tonnes of carbon. The CCRRA analysis shows that blanket bog across the UK may become more vulnerable. Areas that are currently vulnerable may become inactive (no longer peat-forming) or disappear altogether.

Projected changes in seasonal rainfall may result in draining and eroding of peatlands, which would make them less able to retain water in the winter or to store it in the summer. This may lead to vegetation shrinkage, peat drying out, decomposing or breaking up and being washed away.

This would have implications for carbon sequestration and emissions, although land management practices have greater influence on the status of this habitat than climate change in the short term. For example, planned heather burns, if not carefully managed, can damage peat-forming bog mosses. Currently heather burning is prohibited from May to August. However, with a change of climate and an earlier onset of spring, these guidelines may need to be reconsidered in future.

Increased winter precipitation is projected to lead to an increase in flooding and waterlogging, which provide both opportunities and threats to biodiversity. Increased winter precipitation was not considered to be a high priority climate effect for biodiversity in Northern Ireland, but waterlogging was identified as important for forestry (see Section 4.3.2).

The Northern Ireland Countryside Survey (NICS) (2000) indicated a significant decrease of 25% of wet bog vegetation through the 1990s, the majority due to sphagnum moss degredation towards wet heath and dry bog (DOENI, 2003).

The NICS (2007) indicated a 9.81% decrease in lowland bog cover and a 0.72% decrease in upland bog cover (p.36). The majority of these changes were a result of wet bog sphagnum areas developing into wet heath areas, and the increase in dry bog

63 Key messages from this study can be found here:-
expanses due to the drying out of wet heath areas. Wet to dry bog, and vice versa, exchanges were balanced. Overall the reduction of the blanket bog extent was acknowledged as being significant (Cooper et al., 2009).

Northern Ireland's wetlands may be put under further pressure, due to increasing temperatures and a shift to drier vegetation types, damaging and changing the habitats. For blanket bogs the wetter and warmer winters projected may benefit bog formation, improving the growing conditions (Arkell et al., 2007; DOENI, 2003). Despite the increase in summer temperatures encouraging the seasonal drying of bogs, the increase in autumn, winter and spring rainfall reduces the impact. However, whilst the climatic conditions may benefit bog formation, climate change could alter the vegetation composition from bog to heath affecting the blanket bog extent (Arkell et al., 2007).

**Wildfires**

Some key habitats are sensitive to fire including woodlands, grassland, peat soils (including blanket bog) and heathlands. Fires change the balance of plant species and hence the ecology of the area affected, and, therefore, may lead to a significant loss of biodiversity. This can, in turn, have consequences for the natural heritage and landscape value of the area.

The risk of fire would increase if there were an increased prevalence of hotter, drier conditions (see Section 3.2.4). This could potentially result in the local extinction of some species and expand the extent of those that are more fire-tolerant. Wildfires can also increase rates of erosion and have a detrimental effect on water quality. Of particular significance is the damage that fire can cause to areas of peat, which are a significant carbon sink. Once ignited, peat habitats can 'smoulder' for an extended period and are difficult to extinguish.

**Non-native and invasive non-native species**

Non-native species have not been analysed in detail as part of the CCRA. However, after habitat destruction, invasive non-native species are considered the biggest threat to native biodiversity in Northern Ireland and are a problem already. Non-native species that are currently present in Northern Ireland (including those that have been introduced for cultivation) may become invasive, if climate change causes environmental conditions to become more favourable for their survival and expansion of range. Negative impacts of invasive non-native species include: competing with native species for food and shelter, feeding on native species, and interbreeding with native species thus reducing their genetic purity. Some non-native species also carry disease that can infect and kill native species (see Pests and diseases below).

Some non-native species have already become established and invasive throughout Northern Ireland, for example, the New Zealand flatworm (*Arthurdendyus triangulates*), which predate and feed on earthworms greatly reducing their population. There are also non-native species that may soon become established, for example, the Harlequin ladybird (*Harmonia axyridis*), which may lead to a decline in native ladybirds. This species was listed as one of the most unwanted potential invader in the Invasive Species Ireland 2007 risk assessment, although to date it has only been recorded once in Northern Ireland at Lisburn in 2008.

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64 [http://invasivespeciesireland.com/most-unwanted-species/established/terrestrial/?pg=2](http://invasivespeciesireland.com/most-unwanted-species/established/terrestrial/?pg=2)

Pests and diseases

Pests and diseases have been grouped together for the purpose of the CCRA analysis to avoid confusion over terminology and because some of the background information is similar. For the purposes of this analysis:

- Pests represent either native or non-native organisms that cause damage to native species or ecosystems, such as the Varroa mite that affects bee populations and pollination services.

- Diseases are micro-organisms (pathogens such as bacteria, fungi or viruses) that cause harm when transmitted to a particular host, such as Dutch elm disease in trees and seal distemper virus in mammals.

The risks from pests and diseases have the potential to be inter-linked: pests can act as hosts for the transmission of disease, such as ticks spreading Lyme Disease; or invasive grey squirrels (Sciurus carolinensis) transmitting squirrel pox disease to the detriment of native red squirrels (Sciurus vulgaris).

Pests and diseases already present a severe risk to some species. However, more often, it is the pests and diseases that pose a threat to humans, crops and livestock that are measured. For example, Lyme disease is acquired by humans from biting nymphs and occasionally from adult ticks. Ticks are particularly sensitive to humidity levels, preferring moist conditions and their activity level rises with temperature (see Section 3.2.7 on thermal humidity). In livestock, Bluetongue virus is a disease where the spread may be in part mediated by climate change (see Section 4.3.1). The prevalence of pests and diseases is often limited by the UK climate, particularly minimum temperatures in winter. A rise in temperature is likely to lead to an increased survival rate for pest/disease species and/or increased activity in disease vectors. However, each pest or disease has its own characteristics and there is rarely a single variable that will cause an increase in destructive ability. It is, therefore, very difficult to make generalisations about the implications for biodiversity and ecosystem services. For the CCRA example species were used to illustrate the level of risk and type of consequences that may occur.

Pests

The lily beetle, Lilioceris lilii S., is a small, bright red leaf beetle that feeds exclusively on plants belonging to the lily family (Liliaceae) including many garden varieties of lily (Lilium) and can be very destructive. It is native to mainland Europe, but not to the British Isles. Until the 1940s it was only found erratically in south eastern parts of England, but it can now be found in greater Belfast. In the last 20 years a northwards expansion has occurred and the beetle now covers most of central and southern England with scattered outlier populations in northern England, Wales and Northern Ireland. The expansion coincides with recent northwards movements by a variety of other insects, which is thought to be in response to climate warming.

In Northern Ireland, the lily beetle has been spreading across the south and east of Belfast for several years and in 2006 had reached Crossnacreevy in County Down. The adult beetles feed on lilies leading to severe defoliation, under-sized bulbs, reduced flowering in subsequent years and plant death. There are few native wild plants in Northern Ireland that are thought to be affected by this pest; however, many horticultural plant species are at risk.

Diseases

In the CCRA analysis, this risk was investigated for Phytophthora ramorum, a fungus-like pathogen that causes damage to trees including Japanese larch (Larix kaempferi), European larch (Larix decidua), beech (Fagus sylvatica) and a wide range of woody
species, especially ornamentals such as *Rhododendron* and *Viburnum* species. There have been a number of recent outbreaks along the east coast of Northern Ireland. The recent spread to larch in the UK means it is becoming more difficult to contain, as the pathogen can reproduce abundantly on this particular host.

There have also been confirmed cases of this pathogen on the heathland bilberry (*Vaccinium myrtillus*), which would pose a serious threat to upland ecosystems if it were to spread widely. In December 2008, *P. ramorum* was confirmed to be present on bilberry in the wild in woodland in Cornwall and has since been found in a number of other locations in the wild. Laboratory tests have shown that some species of heather (including *Erica* species and *Calluna vulgaris*) are also susceptible to the pathogen (FERA, 2011b). A similar species, *Phytophthora kernoviae* has also been found on bilberry in the UK (FERA, 2011a).

Studies into the sensitivity of *P. ramorum* to temperature, humidity and water potential have identified optimal levels for growth at different stages of the organism’s life cycle. The findings suggest that the UK is a very suitable area climatically for *P. ramorum* survival. The areas at highest risk are in the moister west of the UK, especially in the South-West of England and Wales. However, compounding factors as mentioned previously mean that even experts in the field are not certain about the future of *P. ramorum* in relation to climate change.

In terms of ecosystem services, the greatest impacts from invasive species, pests and disease are likely to be where provisioning ecosystem services, such as food or fibre provision, are affected. As a result, most of the information available on the level of risk is focussed on pests and pathogens that affect agriculture, forestry and human health, such as *Phytophthora ramorum*, Lyme disease (*Lyme borreliosis*) or the veroa mite that impacts on bee populations and pollination services. This does not mean that regulating services (e.g. flow regulation) or cultural services (e.g. amenity value) would not also be affected when a large-scale outbreak or infestation occurs, but much less information is available for the wider impacts on biodiversity and ecosystem function. However, there is growing awareness of the role of biodiversity in providing an ecosystem service by mediating the spread of pests and diseases, particularly vector-borne diseases. Ecosystems with greater biodiversity are more able to suppress the spread of pests, diseases and invasive species (This is discussed further in the *Biodiversity & Ecosystem Services Sector Report*).

**Tracking changing climate space**

Species may not able to track changing climate space for a number of reasons including ability to disperse, lack of suitable habitats and fragmentation of habitats. In addition, some species may be unable to find a suitable microclimate, for example those with habitats at high altitude.

A review of the MONARCH (Walmsley et al., 2007) and BRANCH (BRANCH Partnership, 2007) projects was undertaken (Berry, 2007). This showed that (a) many species are at risk of being unable to adapt to their changing climate space and (b) many other species would gain additional suitable climate space. The analysis includes example of species in both categories, although other factors will have a major impact on survival in the future, such as habitat loss and fragmentation.

In addition, new species may be able to survive in the UK in the future. Some new species may be of benefit and have little impact of existing ecosystems. However it is also possible the non-native species could be very detrimental to current native species and habitats.

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66 [http://www.forestresearch.gov.uk/website/forestry.nsf/byunique/infd-86ajqa](http://www.forestresearch.gov.uk/website/forestry.nsf/byunique/infd-86ajqa)
There is a concern that if a keystone species in the ecosystem is placed at increased risk there could be consequences for the integrity of the whole ecosystem.

A major barrier to the tracking of climate space is the current fragmentation of habitats. This will affect the long-term sustainability of current biodiversity in the UK in the face of climate change. Although Northern Ireland is largely rural, fragmentation of habitats is a significant concern. The rural landscape is dominated by improved grassland, which has a lower natural adaptive potential than semi-natural habitats, and the semi-natural habitats in Northern Ireland are very fragmented.

Detailed analysis of changes in climate space across a range of species was carried out by the MONARCH project for the UK as a whole. MONARCH3 produced simulated climate space maps for current and future species distributions using the UKCIP02 scenarios (Walmsley et al., 2007). From this analysis, 32 UK BAP priority species are highlighted in Table 4.5 using four categories; Gain, Loss, No Change and Shift. The results need to be interpreted with caution; they are indicative of the changing climate space rather than actual species distributions. However, they provide a useful summary of general trends.

As part of an earlier MONARCH project, MONARCH2, the Cuilcagh/Pettigo case study area was selected as a cross-border site that was considered sensitive to climate change. Blanket bog habitat was the focus of the study. The species modelled were a bog moss (*Sphagnum cuspidatum*), hare’s-tail cotton grass (*Eriophorum vaginatum*), deergrass (*Trichophorum cespitosum*), white beak-sedge (*Rhynchospora alba*) and crowberry (*Empetrum nigrum*), lesser twayblade (*Listera cordata*), golden plover (*Pluvialis apricaria*), downy birch (*Betula pubescens*) and bracken (*Pteridium aquilinum*). The model results indicated that Ireland would become less suitable for all of these species except for white beak-sedge and bracken.

Differential shifts in species’ ranges would result in changes to species interactions and community composition. This dynamism is an essential component of ecosystem resilience allowing adaptation to change. However, if a species that is integral to ecosystem integrity and functioning is lost, then the system becomes vulnerable to major disruption or loss. This has implications for ecosystem services, including any provisioning or culture value that an individual species may have supplied in the affected area (Biodiversity & Ecosystem Services Sector Report).
<table>
<thead>
<tr>
<th>Category</th>
<th>GAIN</th>
<th>LOSS</th>
<th>NO CHANGE</th>
<th>SHIFT</th>
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<tbody>
<tr>
<td><strong>Definition of</strong></td>
<td>Species that gain substantial, potentially suitable climate space and</td>
<td>Species that show significant loss of potentially suitable climate space and</td>
<td>Species that show no significant gain or loss of climate space</td>
<td>Species that show a shift in potentially suitable climate space</td>
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<tr>
<td><strong>category</strong></td>
<td>show no significant loss.</td>
<td>show no significant gain or loss of climate space and no significant gains.</td>
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<tr>
<td><strong>No. of species</strong></td>
<td>15</td>
<td>8</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td><strong>Names of species</strong></td>
<td>birds: stone-curlew, corn bunting, turtle dove;</td>
<td>Birds: skylark, common scoter, black grouse, capercaillie, song thrush;</td>
<td>Birds: tree sparrow, linnet;</td>
<td>Invertebrate: stag beetle;</td>
</tr>
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<td></td>
<td>butterflies: pearl-bordered fritillary, marsh fritillary,</td>
<td>Plants: Norwegian mugwort, twinflower, oblong woodsia.</td>
<td></td>
<td>Mammal: barbastelle bat;</td>
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<td></td>
<td>silver-spotted skipper, heath fritillary, adonis blue;</td>
<td></td>
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<td>Plants: tower mustard, cornflower, cut-grass, floating water plantain.</td>
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<tr>
<td></td>
<td>mammals: greater horseshoe bat, lesser horseshoe bat;</td>
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<td>plants: stinking hawk's-beard, red-tipped cudweed, broad-leaved</td>
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<tr>
<td>Description</td>
<td>All 15 species have a southern distribution in Britain and Ireland</td>
<td>Six have predominantly northern distributions within Britain and Ireland.</td>
<td>These species show no significant change because their present climate space covers most of Britain and Ireland; they are also widespread within Europe.</td>
<td>These species all show a northward shift in potentially suitable climate space within Britain and Ireland.</td>
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<tr>
<td></td>
<td>at present and at the northern edge of their ranges.</td>
<td>Within the UK, their strongholds are Scotland or upland habitats. Five of these species are at risk of losing all climate space and becoming extinct within Britain and Ireland.</td>
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</table>

Source: MONARCH phase 3 synthesis report

**Species migration patterns**
Migration patterns are likely to change increasingly in the future, particularly due to changes in seasonal temperatures both in the UK and other locations on migration paths. This presents both risks and opportunities, with some species using new sites or new species arriving in the UK, taking advantage of milder winters. Long distance migrants such as cuckoos (*Cuculus canorus*) are particularly at risk.
Given the complex relationships that exist between species behaviour, climate variables and other factors, the overall outcome of this risk for biodiversity cannot be predicted at this stage. For example, where migratory species arrive earlier in the year, the receiving habitat may become less able to support the population. This could occur, for example, if plants and invertebrates are not at the right point in their own life cycle to provide food to the arriving migrants.

The CCRA analysis has identified changes in the migration patterns for specific species\(^\text{67}\) using recent data, both in terms of timing (where migratory species arrive earlier in the UK in warmer years) and location (where overwintering migratory species go to different locations in the UK during warmer years).

Changes in migration patterns would have important implications for biodiversity, particularly the designated site network, which might not cover the new migration sites. It also has implications for the cultural benefits that society gains from migratory species as they often have important associations with the annual cycle of seasons, local landscape identity and sense of place.

The arrival and departure of particular species represent important cultural symbols and signals of the changing seasons. Any notable changes in these seasonal events can, therefore, have implications for the relationship between cultural and natural heritage at particular locations, which has often acted to define key features of the local landscape (Biodiversity & Ecosystem Services Sector Report).

**Species breeding cycle and food supply**

The timing of seasonal events is changing (e.g. earlier flowering, leaf-growth, egg-laying, earlier arrival of migrants, etc). This is an important risk factor for some species, although it has not been analysed in the CCRA.

Data from 1954 to the end of the century have shown that there has been a trend since the 1980s of swallows arriving earlier in Northern Ireland each year. This may be linked to milder springs. Data since 1978 have also shown that first sightings of the Large White butterfly have also become earlier, which may be linked to mean winter temperatures (EHS 2004).

These natural adaptive responses may lead to ecological disruption, for example when food supply and breeding cycles become asynchronous. They may also lead to competitive advantages and changing niches for some species with implications not only for community ecology, but also for humans (for example reports of tick bites have increased in recent years, linked with increased survival in warmer winters).

Disruption of these ecosystem relationships could cause major shifts in key functions that they maintain. However, finding evidence for or against disrupted relationships and their demographic effects is difficult, because the necessary detailed observational data are rare or provide only a partial picture. It can also be difficult to judge the extent to which mismatches would have a serious impact and where behavioural changes and natural selection would restore synchronicity over time. Furthermore, different interactions in the food web will not necessarily be affected at the same rate, adding another layer of complexity (Biodiversity & Ecosystem Services Sector Report).

The rate of climate change is likely to be the key variable here, with the likelihood of asynchronous events increasing as the rate of change increases, and hence leading to an increased possibility of major ecosystem disruption and by implication, important consequences for ecosystem services (Biodiversity & Ecosystem Services Sector Report).

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\(^{67}\) Swallow, Sanderling, Ringed Plover, plus wintering waterbirds including Dunlin and Curlew and the Black-tailed godwit (see Biodiversity and Ecosystem Services Sector Report)
Climate mitigation measures

Climate mitigation measures were highlighted as important for Northern Ireland. Northern Ireland has a target of 40% renewable energy by 2020. Wind power will play a significant part in this (both off-shore and on-shore). Bird and bat strikes are a particular cause for concern. It was not possible to analyse this in detail as part of the CCRA, due to a combination of unknowns, in particular lack of a spatial strategy for future renewable energy expansion and uncertainty of the distribution of future biodiversity.

Bioenergy sources, such as the growth of biomass crops, are an important ecosystem service, whereas other sources of renewable energy such as wind, tidal and hydro all have important indirect interactions with the natural environment. This clearly indicates the need to adopt a systems-approach in considering the sustainable supply and demand for renewable energy sources, relative to the local environment (Biodiversity & Ecosystem Services Sector Report).

The Read Report (Read et al., 2009) provides up to date and extensive scientific analysis of the potential of UK forestry to increase the rate at which forestry can contribute to the removal of GHGs. Woodlands planted since 1990, coupled to an enhanced woodland creation programme of 23,000 ha per year over the next 40 years with a contribution of an additional 700 hectares form Northern Ireland, could, by the 2050s, be delivering emissions abatement equivalent to 10% of total GHG emissions annually. Such a programme would represent a 4% change in land cover and would bring UK forest area to 16% which would still be well below the European average. Doubling area of woodland in NI has the potential to increase net carbon sink from 0.54 to 1.09 Mega tonnes of CO₂ or offset up to 12% CO₂ emissions from agriculture.

Generalists favoured over specialists

For many biological systems adaptation will occur naturally over time (although this varies with species longevity, etc.); but the more rapid changes suggested by UKCP09 climate projections are more likely to favour species that can survive under a wide range of conditions (i.e. generalists) or with short life cycles and a lot of genetic diversity (such as viruses and bacteria).

Species that are more ‘generalist’ in their behaviour (i.e. those that can exploit a wide range of environmental conditions, habitats or food types) have a tendency by their very nature to be more adaptable than species that have more ‘specialist’ requirements. The specificity shown by specialist species can make them more vulnerable to environmental changes, especially if compounded by the restricted area or fragmented nature of the habitats they typically depend on. In contrast, generalist species have a greater capacity to respond to a changing climate, although studies on British butterflies suggest that even these species can take decades to adjust to new climate conditions, depending on the magnitude and rate of change.

A reduction in biodiversity through a less varied assemblage of species, which may come about as a result of this, and changes to community structure could result in a simplified and less resilient ecosystem, which in turn could lead to greater impacts and damage from invasive non-native species.

Relatively few studies have examined differences in the effects of climate change on generalist species compared with specialist species. For many UK species there is limited data on historic population size and distribution that could be used to develop models, with the notable exceptions of birds and butterfly species.

A decline in specialist species reduces the species richness of ecosystems and is believed to reduce overall ecosystem resilience to change. The most visible manifestation of this is provided by impacts on pollinators where climate change
already appears to be interacting with a range of other stresses to cause Colony Collapse Disorder and other negative consequences, with knock-on effects for pollination services. A reduction in overall system resilience can also reduce the resistance to invasive species and diseases, which has implications for both biodiversity and human welfare (Biodiversity & Ecosystem Services Sector Report).

Summary of results for the terrestrial environment

The main potential threats facing the terrestrial natural environment in Northern Ireland relate to the following:

- Increased soil moisture deficits and drying, with consequences for species, habitats and soil organic carbon;
- Species unable to track climate space, with generalist species being more able to adapt than specialist species;
- Increased risks from pests, diseases and invasive non-native species;
- Changes in species migration patterns with consequences for the conservation network and cultural ecosystem services;
- Increased risk of wildfires; and
- The potential environmental impacts of climate mitigation measures (principally onshore wind), if not planned for adequately.

The results of the analysis are summarised in Table 4.6.

We have relatively high confidence that the threats facing the terrestrial natural environment with respect to species tracking climate space (BD5) and species migration patterns (BD9) will take place as indicated in Table 4.6, with potentially high consequences by the 2080s. Many other threats have also been projected to have potentially high consequences by the 2080s, but we have less confidence in the magnitude and timing of these, due to limited evidence being available.

The risks that are projected to have medium consequences by the 2020s and 2050s and high consequences by the 2080s (all except for BD1 and BD12) are predominantly resulting from projected temperatures, although other factors may also influence future risk.

The risk to species and habitats due to drier soils (BD1) has a low consequence by the 2020s, but with increasing consequences by the 2050s and 2080s. This is predominantly resulting from projected changes in rainfall patterns, although, again, other factors such as projected temperatures also influence future risk.

With the exception of wildfires (BD12), these projections are based on the UK-wide analysis and have not been reassessed for Northern Ireland, as data at the regional scale is not readily available. This means that the projections for some of the risks (those with low confidence) may slightly overestimate the severity of the consequences for Northern Ireland, but there is not sufficient evidence to justify different projections for the region.
Table 4.6  Climate change consequences for the terrestrial natural environment

<table>
<thead>
<tr>
<th>Threats</th>
<th>Species unable to track changing 'climate space'</th>
<th>Changes in species migration patterns</th>
<th>Risk of pests (inc. invasive non-native species) to biodiversity</th>
<th>Risk of diseases to biodiversity</th>
<th>Changes in soil organic carbon</th>
<th>Generalist species more able to adapt than specialists</th>
<th>Risks to species and habitats due to drier soils</th>
<th>Wildfires due to warmer and drier conditions</th>
<th>Environmental effects of climate mitigation measures</th>
<th>Asynchrony between species breeding cycle and food supply</th>
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*Coverage of analysis

<table>
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<tr>
<th>NI</th>
<th>Analysis undertaken for Northern Ireland only</th>
<th>Ij</th>
<th>Informed judgement</th>
</tr>
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<tbody>
<tr>
<td>UK</td>
<td>Analysis undertaken for the UK</td>
<td>Q</td>
<td>Quantitative</td>
</tr>
</tbody>
</table>
4.2.2 Freshwater environment

The freshwater environment is a particular feature of Northern Ireland. Therefore, future water availability, temperature and quality are very important considerations, not only for species and habitats, but also for associated ecosystem services (including water supply, aquaculture and tourism).

The projected changes in rainfall patterns and higher temperatures may affect water levels, flow rates and the water quality in Northern Ireland’s rivers, loughs and wetlands, which in turn would have negative consequences for native species and habitats. Native species may also be at greater risk in the future from pests, diseases and invasive non-native species that may find future conditions more favourable.

Figure 13 River topography of Northern Ireland
© Crown Copyright

Current water quality

In order to understand how water quality may change in the future, it is first useful to understand the current situation in Northern Ireland; the most significant issues for water quality in Northern Ireland currently are pollution and eutrophication, which are discussed here.

Over 95% of water for public supply comes from surface water sources and sewage is also discharged into these sources. Lough Neagh, for example, provides 50% of the
raw water for Northern Ireland, yet it is a designated sensitive water body due to eutrophication. Algal growth is a big issue in Northern Ireland due to 95% of raw water coming from surface water sources. This is a result of the combined effects of low flows, higher river temperatures and pollution.

**Point and diffuse sources of pollution**

Water quality in Northern Ireland is affected by pollutants from both diffuse and point sources. Point sources can include combined sewer overflows (CSOs) during heavy rainfall events, and discharges of effluent from industry and wastewater treatment works which have been a major source of nutrients to waters in Northern Ireland. Discharges are controlled by the Department of the Environment under the Water (NI) Order 1999 and the Pollution Prevention and Control Regulations (NI) 2003, and according to the Northern Ireland Environmental Statistics Report 2011 (DOENI, 2011), discharge quality from industrial sources and water utilities continues to improve (although there was a slight dip in industrial discharge quality in 2009). Whilst compliance levels decreased from 81% in 2000 to 58% in 2001 (as the number of waste water and water treatment works (WTW) sites increased from 160 to 268 between 2000 and 2001), this has since recovered to a level of 88% in 2008 and 2009 (DOENI, 2011). There has also been a fall in the total number of substantiated incidents (those that impact on the water quality of the receiving watercourse) of water pollution since 2001 – 2003, with a total of 1,248 incidents reported in 2009 (DOENI, 2011).

Whilst diffuse pollution can include runoff from urban areas and atmospheric deposition of nutrients and pollutants, in Northern Ireland runoff from the surrounding agricultural land is the most significant diffuse source of both nitrogen and phosphorus to watercourses (EHS, 2005). These excess nutrients come from a number of agricultural processes including the excess use of chemical fertilisers and animal feed supplements (Bunting et al., 2007). Diffuse contributions of nutrients from agriculture have been identified as the primary cause of eutrophication in Northern Ireland, an issue which affects both rivers and loughs68 (EHS, 2000a).

**Eutrophication and algae growth**

Eutrophication is considered to be the most widespread threat to good water quality in Northern Ireland (EHS, 2008). Eutrophication is defined by the EC Urban Waste Water Treatment (UWWT) Directive (91/271/EEC) as “the enrichment of water by nutrients, especially by compounds of nitrogen and phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable balance of organisms present in the water concerned”.

As stated earlier, both point and diffuse sources of pollution contribute to the enrichment of water by inorganic nutrients in Northern Ireland, in particular phosphorus (mainly an issue in freshwater) and nitrogen (mainly an issue in coastal waters). The resulting growth of plants such as algae can affect the transparency of water, as well as the levels of dissolved oxygen concentrations and pH, causing ecological disruption and potentially affecting nationally and internationally important habitats and species (EHS, 2008). This is not the only impact; a eutrophic watercourse can also have detrimental effects on the aesthetic appeal of water, and the increased growth of toxic blooms of blue-green algae can have serious implications for livestock and other animals as well as health and safety issues affecting recreational activities. In cases where it is abstracted for use in water supply there may be a need to intensify and improve water treatment processes. However, the focus should be on reducing and preventing agricultural runoff and industrial discharge in the first instance. NI Water is

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68 Sea loughs as well as freshwater loughs.
currently authorised to abstract 773 million litres per day (ML/d) for public water supply from rivers, reservoirs and freshwater loughs, amounting to roughly 95% of water for public supply (NIW, 2010).

As part of the Sensitive Area Review 2005, several catchments in Northern Ireland were found to be eutrophic (designated as Sensitive Areas) or likely to become eutrophic if protective measures were not taken (EHS, 2005). These catchments include the Foyle, Roe, Faughan, Lagan and Bann and Lough Neagh catchments. A number of chemical and biological parameters provide an indication of whether a water body may be identified as ‘sensitive’ under the UWWT Directive and/or ‘polluted’ under the Nitrates Directive (91/676/EEC), including (EHS, 2005):

- Phosphorus concentrations;
- Effects on microflora, including chlorophyll a concentrations and the occurrence of toxic algal blooms;
- Changes in macrophyte communities;
- Saturation levels of dissolved oxygen;
- Changes in invertebrate communities and fish.

There are now a number of regulations in place with the aim of reducing inputs of nitrogen and phosphorus to watercourses.

**Current classifications**

Classification schemes developed under the Water Framework Directive (WFD) have been used to assess Northern Ireland’s waters since 2007, replacing the old rivers General Quality Assessment (GQA) classification system. These classifications have now been further updated to report on overall river quality (based on a combination of biological, chemical and hydromorphological quality elements including macroinvertebrates, pH and ammonia). In 2009, 25% of river waterbodies were classified as ‘high’ or ‘good’ overall status (DOENI, 2011).

Chemical river quality is also assessed in terms of compliance with the Freshwater Fish Directive (2006/44/EC), based on the suitability of waters for salmonids and cyprinids. In 2009, out of a total length of 4,154km of salmonid river, 7.7% failed to meet the standards of the Directive. Out of a total length of 126km of cyprinid river, 12.7% failed to meet the standards of the Directive (DOENI, 2011).

Water quality in freshwater loughs is now also given an overall rating (as opposed to providing a breakdown of the three main parameters). There are 21 monitored lough waterbodies\textsuperscript{69} in Northern Ireland with an area greater than 50ha. Overall ecological status is based on a number of parameters including total phosphorus, dissolved oxygen and chlorophyll, macrophytes, phytoplankton and phytobenthos. In 2009, five of the lough waterbodies were classified as ‘good’ status, the remaining 16 lough waterbodies being of either ‘moderate’ (7), ‘poor’ (3) or ‘bad’ (6) status (DOENI, 2011).

Currently the main issues concern levels of total phosphorus. High amounts of phosphorus indicate excessive nutrient conditions and eutrophication in freshwaters. Unlike rivers, concentrations of phosphorus can build up over time in loughs due to their mostly static nature (DOENI, 2009). A lough is classed as being eutrophic once levels of phosphorus exceed 35 micrograms per litre (LNAC, 2002; DOENI, 2009). Three freshwater loughs in Northern Ireland have been assessed to be hyper eutrophic, meaning that they have excessive algal growth (DOENI, 2010). One of these

\textsuperscript{69} Sea and freshwater.
is Lough Neagh, which supplies around 50% of NI Water’s available treated water supplies (NIW, 2010).

Whilst groundwater sources supply only a small percentage of the water used for public supply, numerous surface water bodies in Northern Ireland are dependent on these sources to maintain their water levels and the biodiversity they support (EHS, 2008). Groundwater in Northern Ireland is generally of a high quality; in 2009 65 out of 67 groundwater bodies were at ‘good’ status following WFD classification (DOENI, 2011).

**Projected changes in water quality**

The water quality of rivers and loughs is influenced in particular by low flows, intense rainfall events and water temperature. These are discussed below.

**Low flows**

A decrease in flow levels due to changes in both air temperature and rainfall can affect the dilution and dispersion of contaminants. This could mean that downstream of point sources there are higher concentrations of contaminants during periods of low flow, affecting the quality of the receiving water body (Whitehead *et al.*, 2009b). This could in turn have implications for ecological status and therefore meeting WFD objectives. In loughs and estuaries, a reduction in flushing due to low flows might increase residence times of pollutants, potentially exacerbating existing issues such as eutrophication. The settling rate of sediments could also be enhanced through increased residence times in loughs, reducing turbidity and enhancing the conditions for algal growth through improved light penetration (Whitehead *et al.*, 2009b).

A recent study has modelled the links between a reduction in summer flows due to climate change and water quality through the use of a model sensitivity analysis (Conlan *et al.*, 2007). It was found that levels of phosphorus and Biochemical Oxygen Demand (BOD) would increase under reduced flows in summer; whilst nitrate concentrations also increased due to higher nitrification rates, potentially leading to enhanced growth of algal blooms.

This projected decrease in flow levels due to climate change and the associated impact on water quality could have implications for water treatment and the discharge of effluents to receiving waters. It might also place restrictions on certain abstractions. This issue of low flows is already a concern at the Derg WTW, where NI Water are authorised to abstract 26.6 Ml/d from either the River Derg, the River Strule or both (NIW, 2010). The river has protected status as a Special Area of Conservation for Atlantic salmon and hands-off profiles have been developed to ensure compliance under the WFD. As a result, normal drought planning procedures would need to be followed during times of very low flow in order to maintain the output from the Derg WTW (NIW, 2010b). This may become more of an issue in the future with climate change.

**Water temperature**

The temperature of rivers and loughs influences the rate of bacteriological processes and chemical reactions that occur within them. In addition, the growth rates of macrophytes, epiphytes and phytoplankton and certain behavioural aspects of aquatic organisms including the timing of emergence of insect populations and migration of fish are also controlled or influenced by water temperatures (Whitehead *et al.*, 2009b).

These increased reactions at higher temperatures could subsequently influence water quality. For example, increased temperatures can improve conditions for algal growth as well as reducing saturation levels for oxygen concentrations, and this can
particularly be an issue for shallow loughs where residence times\textsuperscript{70} can be long during the summer (Whitehead \textit{et al.}, 2009b). A number of Northern Ireland’s loughs are relatively shallow, including Lough Neagh.

\textbf{Intense rainfall events}
An increase in winter rainfall and the frequency of intense rainfall events may lead to a rise in pollution loading from both point and diffuse sources.

Although an increase in rainfall may result in higher river flows improving dilution of pollutants (Whitehead \textit{et al.}, 2009b), water quality would deteriorate if the pollution is discharged more frequently or following dry periods when river flows are low and the receiving watercourse would be less able to dilute the pollutants.

\textit{Point sources} - There might be an increase in pollution from storm sewage due to more frequent occurrences of CSO spills, particularly during the summer months when receiving waters have inadequate capacity for dilution (Arkell \textit{et al.}, 2007).

A legacy of underinvestment has meant that a number of sewerage systems in Northern Ireland contain CSOs that are unsatisfactory (LNAC, 2002). Recent investment in sewerage systems has aimed to improve unsatisfactory CSOs. Additionally, a history of poor enforcement of planning requirements for sewage treatment systems before developments were built and occupied has also exacerbated the problem (NIEA, 2009). NIW has started a programme of monitoring 290 high risk CSOs to identify those that spill in dry weather and is also planning a number of Drainage Area Plans to determine the causes of spills (NIW, 2010a).

\textit{Diffuse sources} - Agricultural contaminants are likely to be leached from surrounding land into rivers, loughs and groundwater. When these periods of intense rainfall occur during the summer months following a period of dry weather, the resultant pollutant loads could be high. Moreover, levels of soil erosion could increase, resulting in greater loads of suspended solids within waters and a reduction in water clarity. This increase in pollution has the potential to exacerbate the existing problem of eutrophication as well as elevate levels of pathogenic bacteria in surface water sources.

\textbf{Species and habitats}

\textbf{Water temperature}

The ecological consequences of increases in water temperature remain uncertain because of the complexity of aquatic ecosystems and confounding factors such as water pollution. Nevertheless, there is good evidence of changes in fish and invertebrate populations linked to changes in temperature. These are manifest through changes in food supply, fish growth and invertebrate life cycles. A reduction in oxygen concentrations, for example, will affect fish survival rates and possibly change the ecosystem over time.

Decline of native freshwater fish species (that are valuable to Northern Ireland’s freshwater ecosystems and fisheries) could be coupled by the increased success for non-native freshwater fish species due to water temperature changes. According to the Fisheries department of the Agri Food Bioscience Institute\textsuperscript{71}, some native species (pollan, \textit{Coregonus autumnalis}, and Arctic char, \textit{Salvelinus alpinus}) are approaching their temperature upper limit and some non-native species (carp, \textit{Cyprinus carpio} L. and tench, \textit{Tinca tinca}) are just below the temperature range at which they reproduce.

\textsuperscript{70} Residence time describes the length of time pollutants or nutrients remain within the water body. This is important as pollutants and nutrients stored can then support algal blooms when the conditions become favourable. Increased water temperatures encourage algal growth and also act to reduce oxygen content, reducing the water quality.

\textsuperscript{71} Information received via direct communication.
really successfully (the lower temperatures are currently keeping them in check). It is important to remember that temperature is by no means the only variable that impacts upon fish distributions, but the changes in temperature and the known tolerances of different species allow different levels of pressure or opportunity, from temperature, to be highlighted.

The growth rates of the pollan, found in both Lough Neagh and Lower Lough Erne, has been found to be influenced by higher summer temperatures (EHS and NPWS, 2005). In Lough Neagh, this can be partly attributed to the occurrence of bottom layer deoxygenation due to high temperatures coupled with the eutrophic conditions, resulting in a decline in the quality of any deep cool summer refuge available to pollan (EHS and NPWS, 2005).

Carp can only breed in Ireland when the temperature exceeds 18°C (Ferguson, n.d.). Their feeding patterns are not dissimilar to that of pollan and Arctic char, and so they may become much more suited to the niche these species currently hold if temperatures increase (see Box 4).
Box 4: Native freshwater fish species

Native freshwater fish species are under threat due to climate change.

The pollan (Coregonus autumnalis) is the only member of the whitefish family found in Ireland (Northern Ireland and the Republic of Ireland). Lough Neagh has the only remaining abundant population of pollan, and still supports a small scale commercial fishery. There has been a reduction in the size of spawning individuals and the Shannon lough populations are down to 1% or less of total fish biomass from known former levels. The pollan is a regulated commercial species in Northern Ireland and is subject to a closed season in the Republic of Ireland. It is listed on Annex V of the EU Habitats Directive (92/43/EEC) and is listed in the Irish Red Data Book as Endangered (EHS 2005b).

The Arctic char (Salvelinus alpines) is related to trout and salmon and has similar ecology. It is the most temperature-sensitive of the salmonids (EHS, 2007), preferring a water temperature range of 4-16°C. It has a circumpolar distribution and occurs in Ireland at the southern limit of its geographic range where it is generally confined to deep mountain loughs in which the water temperature remains cool enough for its survival. Any significant rise in temperature could therefore have potentially serious implications for the survival of the species (EHS 2007). Throughout all of Ireland approximately one third of over 70 known Arctic char populations are now believed to be extinct. The Arctic char is listed in the Irish Red Data Book as Vulnerable, but is not protected under the Wildlife (Northern Ireland) Order 1985. This species is important to Ireland’s biodiversity as it is considered to be genetically distinct from other populations of the species. This species is very sensitive to environmental change and is hence vulnerable to a number of factors (EHS 2007).

Pollan and Arctic char are both sensitive to eutrophication; introduced species such as roach which compete with them for food or possibly Zebra Mussels, that may or may not be a threat to the populations but could potentially compete for food and spawning space. Climate change may provide additional stresses on the populations. High summer temperatures already have an effect on the growth of Lough Neagh pollan. The upper thermal limits for pollan are variably estimated at around 20-22°C and increases in winter temperature could conceivably interfere with pollan spawning behaviour (EHS 2005b).

The decline in eel (Anguilla anguilla) populations in Northern Ireland is also an area of particular concern (Department of Culture Arts and Leisure 2010). Various factors have been suggested as contributing to the decline, including climate change, ocean currents, habitat loss, predation and parasites.

The European eel stock has been in rapid decline since about 1980 and shows no sign of recovery. Scientific advice issued by the International Council for the Exploration of the Sea (ICES) indicates that European stock is now outside safe limits. Eels spawn in the Sargasso Sea and then migrate to north Africa, the Baltic and northern Norway; they arrive as glass eels in Northern Ireland from November to March. Many elver and bootlace eels migrate into freshwater between May and September. Although there has been no co-ordinated approach to the management of the European eel stock, individual member states have introduced measures to protect stocks. However, the decline has continued. Commercial eel fishing is only allowed in the Lough Neagh Basin. The other eel fisheries have ceased fishing under local regulations. Lough Neagh now only produces 300 to 400 tonnes of European eel per year, compared to a peak of over 1,000 tonnes in 1979. Local stocks of juvenile eel are being augmented from fisheries elsewhere, as local recruitment in Lough Neagh from the River Bann has declined (Gibson 2011).

73 http://www.niassembly.gov.uk/record/committees2009/CAL/100422_Eelfishingregulations.htm
Invasive non-native species

Some non-native species in waterbodies can lead to competition with native species, and in many situations lead to disruption to certain habitats i.e. they become invasive non-native species. In certain cases, invasive non-native species can also affect water quality and species important for provisioning ecosystem services e.g. Brown trout, salmon and duck and swan mussels. As each species has its own characteristics and reacts differently to different environmental parameters, it is very difficult to make generalisations about the implications for biodiversity and ecosystem services. Therefore, example species are used to illustrate type of consequences that may occur.

Perhaps one of the most well known invasive non-native species in Northern Ireland is the zebra mussel (*Dreissena polymorpha*), see Box 5, that may be more competitively advantaged under climate change than some native species for example, the freshwater pearl mussel, *Margaritifera margaritifera* L., see Box 6. The zebra mussel affects water quality by filtering as much as one litre of water a day through its gills when it feeds (EHS, 2000b). This process often removes phytoplankton and concentrations of suspended solids, clarifying the water and leading to increased macrophyte growth. This improvement in water clarity and reduction in abundance of phytoplankton has been found to impact numbers of certain fish populations. For example, the conditions now favour perch (*Perca fluviatilis*) over roach (*Rutilus rutilus*), which has resulted in a decline in roach recruitment.74

![Freshwater pearl mussels (native species) *Margaritifera margaritifera* L.](image)

![Zebra mussels (non-native species) *Dreissena polymorpha*](image)

There are a number of other invasive non-native freshwater species that have been found in Northern Ireland including aquatic plants that deoxygenate water affecting other fauna and fish. Examples include Floating Pennywort (*Hydrocotyle ranunculoides*) and Water fern (*Azolla filiculoides*).

Reduced river flows in the summer may result in slower moving or stagnant waters, which are more favourable conditions for some aquatic invasive non-native plant species. Invasive non-native species are also likely to react to changes in water temperature. The tolerance of the zebra mussel to a wide range of temperatures and low levels of dissolved oxygen could put it at an advantage over other species to changing climate conditions, threatening the native pearl mussel (Box 6). Spawning events could also occur earlier in the year due to higher temperatures while an increase in winter rainfall could benefit the zebra mussel particularly in shallow areas of loughs (Box 5) (Maguire and Sykes, 2004).

74 Note that roach is also an introduced non-native species. Roach is currently considered an invasive species, perch is not considered to be as invasive. A change in the climate conditions that favours one species over another indicates that a change in which species are more successful in their environment is possible.
Whilst increased ecological disruption and a decline in certain fish species can have indirect economic implications, the resulting plant growth from improved water clarity can also affect the economy directly, through impeding fishing and boat navigation. In Northern Ireland the net economic impact of the angling sector was £22.5m in 2005. This means that it is currently a relatively small industry. However, this is projected to grow by between 40-200% by 2015. This translates into a significant increase in full time employment as well, from 778 to 2,464 jobs by 2015 (PwC 2007). Thus, the changes within the ecosystem have consequences for the services it can provide: Changes to macrophyte growth and phytoplankton communities have consequences for food chains, affecting species at higher trophic levels. The physical presence of the zebra mussels plus the associated changes in nutrient regimes and phytoplankton communities may lead to disruption of ecosystem services such as water quality provision, nutrient cycling and recreational services (Maguire and Sykes, 2004).

Peak and low flows

In addition to water temperature and non-native species, there are other impacts that also affect fish numbers. Spawning beds in small rivers and minor streams suffer by being damaged by flash floods; alternatively if the water levels in rivers are too low the female salmon cannot get access to spawn. Thus, climate change is likely to have an impact directly on species and also with respect to the management of the fisheries and the economic impact of the salmon fishing sector and angling in general.

Abstraction could also threaten biodiversity accentuating low-flow problems. Abstraction may increase due to reduced rain and a need for greater irrigation and public supply. Pollutant concentrations may increase with less dilution and aquatic ecosystems may suffer.

Changes in flows and water levels, in combination with other impacts on water quality and thermal regime, may modify the functioning of aquatic ecosystems. Resulting changes to supporting services, such as nutrient cycling and oxygenation, would have implications for a range of regulating, provisioning and cultural services that these systems provide. This includes water purification and the regular supply of clean water together with impacts on fish stocks and other aquatic species. The potential drying-up of watercourses could have significant implications for wider landscape amenity and cultural value, including recreational and navigational access.

75 A small proportion of this is also sea angling.
Box 5: The Zebra Mussel

Reproductive ability of Zebra mussels may improve with climate change.

Zebra Mussels (*Dreissena polymorpha*), are native to southeast Russia. They are bivalve molluscs that attach to any hard substrate, including boats, buoys and water intake pipes. They live in tight clusters and reproduce prolifically, especially in warmers waters; their ideal temperature range is 18-20°C (Zaiko and Olenin 2006). They are relatively hardy; prefer brackish habitats, are tolerant of reduced oxygen levels and being out of water over short periods of time.

Zebra Mussels have become invasive in many countries, including the UK. They cause varied and unpredictable ecological impacts: changing nutrient cycles, causing local extinction of native mussel species, changing fish populations through colonisation of spawning grounds, changing habitats and food sources. They also block water pipes, disrupt hydro-electric schemes, block boat engines and damage fishing lines and nets. Zebra Mussels may increase water clarity and plant growth around lough margins, which may be perceived as a positive reduction in pollution, but weed growth can cause significant problems (Maguire and Sykes 2004). However, they do not filter out the nutrients in the water. If nutrient levels are high, potentially toxic Cyanobacteria, could become established. This has implications for water supply and treatment, recreational activities and the food chains (ecological function) within the infested loughs.

Zebra Mussels were first recorded in Lough Erne in 1994 and have since been found in Lough Neagh, Lough Bresk, Lough Carron and Lower Lough MacNean. They have significantly altered fish communities in the lough and hence are a major risk to the future of some freshwater fisheries. The possible decline in income to commercial fisheries and to the recreational tourist industry is of concern. Excessive weed growth in Lough Erne, as a result of Zebra Mussels has caused serious problems for boat users and the tourism trade (Maguire and Sykes 2004). The latest information in 2008 on the number of Zebra Mussels in Lough Erne was calculated to be 2.3 x 1010 (biomass 4,152 tonnes). It has been calculated that the entire lough volume could be filtered by this number in just 16 days (Boon 2008). Zebra Mussels have also been found throughout England, Wales (in particularly great number in Cardiff Bay) and in Scotland, where it is causing damage to salmon fisheries.

Zebra Mussels are able to tolerate a relatively wide spectrum of conditions compared with a number of native species including the freshwater pearl mussel (*Margaritifera margaritifera L.*). They can tolerate a temperature range of between -2°C and 40°C and short spells of very low water levels (Zaiko and Olenin 2006). With increased water temperatures, the threshold that initiates spawning may occur earlier in the year, promoting recruitment. Zebra Mussels may therefore be even more competitively advantaged under climate change conditions than many native UK species (Maguire and Sykes 2004).

Dispersal is mediated by three natural mechanisms (currents, birds and other animals) and twenty human-related mechanisms including those related to waterways, vessels, recreation and fishery activities. There are very few mechanisms for control in the wild, only biological controls, principally predation and plausibly by the introduction of bacterium *Pseudomonas fluorescens*, which is toxic to Zebra Mussels. However, there are a number of effective means for removing Zebra Mussels from boats etc. to reduce the likelihood of further spreading the species (Zaiko and Olenin 2006).

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76 Information received from Northern Ireland stakeholders.
Box 6: The freshwater pearl mussel

The decline of freshwater pearl mussel may be exacerbated by climate change.

The freshwater pearl mussel (*Margaritifera margaritifera* L.) is a long-lived, coldwater bivalve that lives at the bottom of suitable rivers and streams in the arctic and temperate regions of Western Russia, stretching across northern Europe to the eastern seaboard of North America. This mussel has a complex life cycle in which the glochidia (larvae) stage of the reproductive cycle infects the gills of salmonid fish such as brown trout and Atlantic salmon (NIEA 2005).

Conservation Status

This species is listed in the IUCN 1996 Red Data List as 'Endangered'. It is protected under Appendix II of the Bern Convention and listed in Annex II and V of the Habitats & Species Directive (EU Directive 92/43/EEC). It is a Biodiversity Action Plan (BAP) species in the UK. In Northern Ireland, the freshwater pearl mussel is listed in Schedules 5 and 7 of the Wildlife (Northern Ireland) Order 1985, which makes it an offence to sell mussels or their products. Historically, pearl fishing is considered to be a major driver of the decline seen.

Surveys dating back to 1643 suggest that the freshwater pearl mussel should be widespread in Northern Ireland, especially in the west (Skinner et al. 2003). Three candidate Special Areas of Conservation, the Cladagh/Swanlinbar River, the Owenkillew River and the Upper Ballinderry River have identified the species as a selection feature. Counts of mussels in these three rivers in Northern Ireland over the 1990s up to a final count in 2004 suggest that the original populations of 10,000 per river have fallen markedly. Between 2002 and 2004 the Cladagh/Swanlinbar population fell by 55% (NIEA 2005). Of particular importance is that virtually no mussels below 10 years in age have been found and most of the individuals found appear to be in excess of 50 years of age. This skew in the population demographic indicates very low levels of recruitment. Without effective mechanisms for the conservation of existing populations and the establishment of enhancement/reinstatement programmes, the freshwater pearl mussel could disappear completely from Northern Ireland.

Recruitment is an extremely serious issue in order to make the populations sustainable. It is thought that this species is density dependent in terms of successful recruitment. The availability of viable host fish, principally brown trout, sea trout and Atlantic salmon, is also a key component of the successful recruitment of this species. Siltation of river beds by very fine sediment may also negatively impact upon juvenile mussels, reducing their survival. Restoration projects to culture the freshwater pearl mussel are ongoing in Northern Ireland and Scotland.

Climate change impacts

This species is a cold water species and so may be directly impacted by climate change through water temperature increases. Additionally, this species may also be impacted indirectly, through changes in water levels; individuals may be washed out and stranded during floods followed by being stranded in situ when the channel bed becomes exposed during low flow. Low flows may also exacerbate problems of pollution, particularly siltation and eutrophication. The freshwater pearl mussel is also sensitive to reduced water quality. Sedimentation, changes and intensification of agriculture, afforestation in the uplands and to a lesser extent effluent discharges from aquaculture and sewage disposal all contribute to a decrease in water quality in an otherwise viable habitat. Removal of habitat for inappropriately planned flood defence and drainage is also a large contributor to the reduction in suitable habitat available for this species.
Species migration patterns

Many animals, including some aquatic species such as salmon (*Salmo salar*), migrate over long distances to seek favourable climate conditions during the annual cycle of seasons. A change in climate can lead to these migration patterns changing as the factors that trigger them are modified. In evolutionary terms, migration has developed primarily in order to maintain a suitable food supply throughout the year for all stages of the animals’ life.

As with terrestrial migratory species, it is not possible to draw a conclusion that ‘fits’ all species, rather each species must be considered individually, within the context of its particular surroundings and life-cycle requirements. It is also important to note that, species migration patterns are likely to change as a result of climate change elsewhere in the world as well as in the UK.

Salmon hatch in freshwater, in rivers. The juvenile fish will spend one to four years, depending on growth rate, in the river before migrating out to sea. They usually spend a year, but sometimes two or three years feeding in the ocean before migrating back to the river in which they were born to spawn. Salmon are sensitive to low flows and water quality issues and whilst to date these issues tend to be attributed to water abstraction and pollution in the main, climate change may act to exacerbate these effects. Long-term studies on the River Bush in County Antrim indicate that climate parameters may be responsible for higher than average mortality in fish at sea. The higher mortality follows migrations to the sea that occur earlier than usual. Early migrations may be triggered by warm winter freshwater temperatures. The differential between the freshwater and marine temperatures may contribute to the subsequent poor survival at sea (Kennedy and Crozier, 2010).

Changes in the distribution and population size of some key species, such as salmon and eel, could also have implications for local provisioning services, which both provide food stocks (Biodiversity & Ecosystem Services Sector Report).

Climate mitigation measures

Hydro-power (including run-of-river generation systems) can have impacts on aquatic biodiversity and associated activities such as fishing, which can be important for the local economy.

NIEA supports sustainable best practice renewable schemes that comply with environmental and other legislation. Like the Environment Agency in England and Wales and SEPA in Scotland, NIEA bases its assessment of hydrological impacts upon UKTAG condition limits. NIEA, in conjunction with other statutory environmental agencies, aims to balance the managed and sustainable development of hydropower within Northern Ireland through effective and integrated environmental protection and regulation. Hydro schemes must not increase flood risk, damage ecology including fish populations, obstruct fish passage, and must also take account of fisheries including their amenity value.

It was not possible to analyse this in detail as part of the CCRA, due to a combination of unknowns, in particular lack of a spatial strategy for future renewable energy expansion and uncertainty of the distribution of future biodiversity.

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77 UK Technical Advisory Group
Summary of results for the freshwater environment

The main bio-physical impacts facing the freshwater environment in Northern Ireland relate to the following:

- Lower flows in summer;
- Higher water temperatures and increased stratification of water bodies; and
- Reduced water quality, due to pollution from point and diffuse sources.

These bio-physical impacts pose the following potential threats to native species, habitats and ecosystem services:

- Increased risk to native species from pests, diseases and invasive non-native species; and
- Changes in species migration patterns and reproductive ability.

The results of the analysis are summarised in Table 4.7.

We have medium confidence that the threats facing the freshwater natural environment with respect to biodiversity (BD10) and species migration patterns (BD9) will take place as indicated in Table 4.7, with potentially high consequences by the 2080s. The potential decline in freshwater quality due to point source (WA9a) and diffuse pollution (WA9b) is projected to have high consequences by the 2050s, but we have less confidence in the magnitude and timing of these, due to difficulties in being able to estimate future pollution loadings, especially as these depend on many factors other than weather and climate.

The risks that are projected to have medium consequences by the 2020s and 2050s and high consequences by the 2080s (BD3, BD9, BD10 and decline of native freshwater fish species) are predominantly resulting from high projected temperatures, although other factors would add to this effect.

The risks that have a low consequence by the 2020s, but then increase by the 2050s, are predominantly resulting from projected changes in rainfall patterns, although, again, other factors would add to these effects (e.g. projected temperatures with respect to summer river flows (WA2)).

The environmental effects of climate mitigation measures (BD6) have only been assessed for terrestrial measures (principally onshore wind); measures directly affecting the freshwater environment have not been considered.

Algal growth was a risk that was identified by Northern Ireland stakeholders for inclusion on the Northern Ireland Tier 2 list, but projections have not been provided as data is not available. However, eutrophication and algal growth are discussed earlier in this section.
Table 4.7  Climate change consequences for the freshwater environment

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<tr>
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<td>Low consequences (negative)</td>
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<td>Low consequences (negative)</td>
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<td>Medium consequences (negative)</td>
<td>Low consequences (negative)</td>
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<td>Not assessed</td>
<td>Not assessed</td>
<td>NI</td>
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</tbody>
</table>

| Threats | Coverage | Method   | | | | | | | |
|---------|----------|----------| | | | | | | |
| BD3     | NI       | IJ       | | | | | | | |
| BD9     | NI       | IJ       | | | | | | | |
| BD10    | UK       | UK       | | | | | | | |
| NEW     | NI       | Q        | | | | | | | |
| WA9a    | UK       | UK       | | | | | | | |
| WA9b    | UK       | UK       | | | | | | | |
| WA2     | NI       | Q        | | | | | | | |
| BD6     | NI       | NI       | | | | | | | |
| NEW     | NI       | NI       | | | | | | | |

*Coverage of analysis #Method of analysis
NI Analysis undertaken for Northern Ireland only IJ Informed judgement
UK Analysis undertaken for the UK Q Quantitative
4.2.3 Coastal and marine environments

*Climate change may increase the risk of tidal flooding and coastal erosion*, which could have adverse consequences for vulnerable coastal habitats, including Northern Ireland’s sea loughs. *Climate change may also lead to a decline in marine water quality and an increase in invasive non-native marine species.*

*Changes in the coastal and marine environments could have significant consequences for buildings and infrastructure, human health, tourism, fisheries and aquaculture, as well as coastal and marine species and habitats. These pose significant threats to Northern Ireland’s coastal and marine heritage.*

*New fish species, changes in marine community composition and increased levels of human activity present both opportunities and challenges for marine management.*

**Flooding and coastal erosion**

Coastal or tidal flooding is considered a relatively infrequent event in Northern Ireland. However, climate change projections indicate coastal flooding occurrences may increase. As coastal flooding consequences are more severe than those associated with river flooding, an increase in the severity of consequences is likely in the future.

Approximately 20% of the Northern Ireland coastline is currently experiencing coastal erosion (compared to 12% of Scotland, 30% of England and 24% of Wales).\(^7\)

Parts of the Northern Ireland coast are likely to be at greater risk of flooding and erosion as a result of sea level rise (see Section 3.3.1). This can lead to coastal squeeze.\(^7\) Reconfiguration of the coast might also occur during a major storm event.

There would be adverse consequences for vulnerable coastal habitats, including sand dunes, salt marshes, and coastal freshwater and brackish habitats, specially the sea loughs. The potential loss of coastal habitats has not been quantified in the CCRA analysis owing to a lack of suitable data. However the analysis indicates that the changes could be significant.

Loss of coastal habitats and species may also have consequences for ecosystem services, such as buffering against coastal flooding and erosion and providing cultural services that help support the coastal tourism industry. The coastal tourism industry is growing in Northern Ireland and any loss of coastal habitats and, hence, disruption of ecosystem services may hamper this growth, see Section 4.4.4.

An example of the impacts on Northern Ireland’s natural heritage is The Giant’s Causeway, which is discussed in Section 5.2.5

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\(^7\) The reduction in habitat area where the natural landward migration of a habitat under sea level rise is constrained by coastal defences.
**Water quality**

Projected future changes in rainfall could cause greater pollution in the marine environment, as a result of lower dilution of pollutants in summer and an increase in CSO spills in winter or as a result of high intensity summer rainfall events. During the summer months, low flows combined with increasing temperatures could lead to a decline in marine water quality, an increased risk of eutrophication of Northern Ireland’s sea loughs (see Box 7) and an increase in the occurrence of microbial pathogens.

**Box 7: Eutrophication of Northern Ireland’s sea loughs**

*Northern Ireland sea loughs have experienced improvements in water quality, despite being vulnerable to eutrophication. It is unclear to what extent climate change may undermine these improvements, as they depend on a number of competing factors.*

Northern Ireland’s sea loughs are currently vulnerable to eutrophication, due to nitrogen inputs coupled with restricted water movement. According to the EHS (2001a), three water bodies were considered to be eutrophic in Northern Ireland (Inner Belfast Lough, Tidal Lagan Estuary and Quoile Pondage) and two further water bodies had the potential to become eutrophic (the north end of Strangford Lough and Lough Foyle).

A study by Service et al. (1996) looked at the trophic status of two sea loughs in Northern Ireland (Strangford Lough and Belfast Lough) in relation to the requirements of certain European Union Directives. The study found that the two loughs had different nitrogen loads and levels of productivity, attributed to the different land uses in both catchments. Belfast Lough, dominated by urban and industrial land, received a higher concentration of nitrogen that remained constant throughout the year. Smaller and more seasonally variable loads of nitrogen were found in Strangford Lough due to the presence of mainly agricultural land (Service et al., 1996). According to the DOENI, although Inner Belfast Lough has demonstrated all the signs of eutrophication in the past, dramatic reductions in nutrient inputs to the inner lough have resulted in water quality improvements (Gibson, 2011).

As nitrogen is generally the limiting nutrient in coastal waters, Winter Dissolved Inorganic Nitrogen is monitored in 27 waters as part of the WFD classification scheme (LNAC, 2002). The Overall Status of marine water quality in 2008/09 was assessed as ‘Moderate’ for 52.2% of water body area (NIESR, 2010). In the upper reaches of Strangford Lough for instance, almost all the nitrogen is removed in the summer months, due to either algal uptake or denitrification on the mudflats of the Lough (Service et al., 1996).

Northern Ireland has 24 identified coastal bathing waters. In 2010 only two beaches failed to meet the EC Bathing Water Directive mandatory microbial standards, while 16 beaches achieved the higher guideline standards. In 2010, eight beaches and one marina were rewarded with blue flag status (DOENI, 2011). There are many potential bathing areas that are not currently monitored. Use of these may increase in the future, especially if the popular beached become busy or reduce in size (see Section 4.4.4).

Where bathing waters are susceptible to poor water quality this is usually due to discharges from CSOs or increased runoff from agricultural land after heavy rain. It is difficult to make a direct correlation between rainfall and bathing water quality. During the driest summers over 70% of bathing waters met the highest standards, whilst during the wet summers of 2007 and 2008 (and 2009) compliance remained between 40 and 50%. This may have been in part due to the significant investment in coastal
wastewater treatment sites since 2005. Climate change projections show a decrease in summer rainfall based on the Medium emissions scenario central estimate (p50) (see Section 2.4.2), which would suggest that may result in water quality improving further during the bathing season.

There may be an increase in harmful algal blooms which could affect people and wildlife. Whilst this is difficult to predict because of the complexity of the processes, there has been an increase in the occurrence of harmful algal blooms in UK waters in recent years. Northern waters, including those around Northern Ireland, are less likely to experience warming than elsewhere, but where there is increase in stratification harmful algal blooms may occur. Currently this is unlikely to affect Northern Ireland but this may change in the future.\textsuperscript{80}

Under the UKCP09 projections, as UK waters become warmer, there may be an increase in harmful pathogens, such as \textit{V. Vulnificus} and \textit{V. parahaemolyticus} sp. These pathogens can have very severe effects on human health (nausea, cramps, headaches, skin loss) and can be fatal. \textit{V. Vulnificus} has the highest morality rate of any bacterial pathogen. Case studies also show that zooplankton species are vector species for these pathogens and relatively small increases in temperature can expand the range of these species, which in turn may result in increases in pathogens. These effects could be UK wide. The highest risk would be in southern UK waters, but the spread of pathogens would also depend to a large extent on transmission through marine waters, which would mean that the risk may be exacerbated in areas of increased shipping and recreational sailing.

\textit{Impacts on species}

Northern Ireland has a rich marine biodiversity due to its position at a junction of cold northern and warm southern waters. The seas surrounding Northern Ireland support a varied range of marine species, including marine mammals such as harbour seals, whales and dolphins, seabirds, waterfowl and other species that migrate here such as salmon and eels, (both of which are endangered). One of the main natural factors influencing the range of habitats and species are the strong tidal forces along Northern Ireland’s waters.

\textit{Migration patterns of coastal species}

Species migration patterns are likely to change as a result of climate change in the UK and elsewhere in the world. This has potentially serious implications for the designated site network as these are fixed locations. There is already concern that reductions in wintering wildfowl on coastal estuaries across the UK have been caused by climate change. In the last 10 years, the wetland bird population in Northern Ireland has decreased by 17%.\textsuperscript{81} It is likely that the decline is mostly due to loss of habitat through land use changes rather than climate, but recent studies have shown that wintering waterbirds have started to re-distribute themselves as a result of climate change, tending to winter more to the north and east of Britain and Ireland as winters have become milder (Berry et al. 2005). Some winter visitors that were once common in Northern Ireland, like the Bewick’s swan (\textit{Cygnus columbianus}) that comes from breeding grounds in Siberia, are now quite rare (RSPB, 2004).

The CCRA analysis has identified a move of overwintering migratory birds from the South-West of the UK to the east coast during warmer winters. However there may also be opportunities for new species using Northern Ireland as part of their migration pattern in the future.

\textsuperscript{80} Under the UKCP09 projections, UK waters may become more stratified particularly around the coasts of Cornwall, Moray Firth, Firth of Clyde and North East England.
\textsuperscript{81} http://www.nisra.gov.uk/publications/default.asp8.htm
Shifting of marine species

Shifting of marine species is projected to occur as a result of changes in sea temperature. This is more unconstrained for marine environments because of the lesser influence of man-made boundaries. Different marine species would be affected in different ways: those at the southern limit of their range may disappear and those at the northerly limit may increase. These changes may alter the interactions within and between species and subsequently the communities, habitats and ecosystem functions and services.

Based on a North Sea case study for the CCRA, commonly fished species are projected to move between 20 to 150 km from present fishing grounds by the 2080s (see Marine Sector Report). Whilst this would require longer fishing trips for specific species, there will also be opportunities as new species enter existing fishing grounds. Projections might have been different if the case study had been the Irish Sea, but in general terms these results indicate that there would be consequences for the fishing industry UK-wide. Species such as salmon and eel, which have life cycles in both fresh and marine waters, have been shown to be particularly vulnerable to climate change (water temperature and river flow) with impacts on both the freshwater and marine phases. Warming will also impact on the pattern of marine currents, which redistribute warm and cold water, with consequences for the dispersal of fish eggs and larvae. It seems likely that winter and early spring spawners (such as cod and plaice) will experience poor larval survival, whereas warmer-water species (such as sprat) may benefit. In addition, some species of marine mammals such as toothed whales and dolphins are showing shifts in distribution, which may be linked to increasing sea temperatures (Biodiversity & Ecosystem Services Sector Report).

A northward shift in the distribution of many plankton species may lead to significant changes in community composition. A change in latitude of more than 10º has been recorded over the past 50 years. In the North Sea, reductions in the number of the previously dominant cold-water zooplankton species *Calanus finmarchicus* has contributed to the reduction in quality and abundance of species such as sandeels (*Ammodytes marinus*) which provide food for many seabirds and potentially some baleen whale species (Biodiversity & Ecosystem Services Sector Report). These impacts on marine communities whilst measured in the North Sea may have synonymous occurrences’ in the seas around Northern Ireland.

A change in range of zooplankton and phytoplankton due to future warming is also thought to have consequences for marine ecosystem services such as oxygen production, carbon sequestration and nutrient cycling. Immobile species will be disproportionately affected. Habitat forming species such as maerl may decline with associated impacts on the wider ecological community as the platforms they create disappear. Further discussion of the potential impacts on benthic species82 in the waters around Rathlin Island is provided in Section 5.2.6.

A further implication of range shifts is that it increases the risk of biological invasions from non-native species. The introduction of non-native species to a marine ecosystem followed by their subsequent establishment may cause effects ranging from the almost undetectable to the complete domination and displacement of native communities.

Non-native and invasive species

The coastal marine environment could also be seriously affected by non-native species that become invasive species. These could potentially affect the whole coastline of Northern Ireland during the 21st century as sea temperatures increase. Whilst the potential impacts of invasive non-native species have not been assessed in detail, they

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82 Living on the ocean bottom.
could have significant economic and environmental implications particularly where they occupy the same niche as native or commercial species.

Temperature is a key defining factor in the natural range of organisms. However, the introduction of non-native species is through direct and indirect movement by human agency. This is most often linked to shipping, leisure boat and tourism industries, as non-native species are carried through ballast waters and attached to ship hulls. This was considered particularly relevant to Northern Ireland due to trans-boundary shipping risks.

Non-native species can also be introduced via aquaculture. An example of this is the Pacific oyster (*Crassostrea gigas*), currently used as an aquaculture species on the basis that the relatively cold waters control spawning. With increasing water temperatures, this species may start to spread. Recent work in Strangford Lough suggests that, although outside their previous natural breeding range, feral populations of Pacific oysters are now breeding successfully and are also known to have spawned in Lough Foyle (Gibson, 2011).

The CCRA looked at nine non-native species and results demonstrated that (based on climate change projections for sea water temperatures and tolerance ranges for individual species) each of these species could expand their range to cover the whole of the UK by the 2080s. Those waters within the UK with the highest volumes of shipping or leisure boats would be the first or most affected, with shipping areas in the warmer southern waters being the most at risk (see Marine & Fisheries Sector Report).

**Fish and shellfish stocks**

Currently marine conservation is vital to protect Northern Ireland’s fish stocks. Low indigenous fish stocks negatively impact on Northern Ireland’s fishing business, tourism and the coastal economy. Marine species worldwide are under greater pressure due to mineral extraction, renewable energy generation and leisure sports, although these activities are possible in Northern Ireland waters, they are not currently a significant issue for the natural environment (DOENI, 2010c). Current marine conservation is required to collect data on fish stocks and habitats to advise on fishing policies, promote a sustainable future and to understand marine interactions with the economy (DOENI, undated). Currently fishing directly employs 654 fishermen in Northern Ireland (NIA, 2011) with hundreds more involved in processing and retail.

Much research has been carried out into a number of key fish and shellfish stocks, where future prospects (and profits) of fisheries are highly dependent on year-class-strength. This has shown a strong relationship between recruitment process, fisheries catches and climate variables (Pinnegar et al., 2010).

Studies in the Irish Sea demonstrate a significant negative relationship between seawater temperature and cod recruitment (Planque and Fox, 1998). This would suggest that projected increases in seawater temperatures may have a negative effect on further cod recruitment in the region, whilst another study predicts the extinction of cod from the Irish Sea with a further increase in seawater temperature of 2°C (Drinkwater 2005).

Modelling studies such as the Sustainable Mariculture in Irish Lough Ecosystems (SMILE) project (Ferreira et al. 2007) have identified the effects of both climatic factors

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83 The non-native species considered in the UK Marine assessment were: Chinese Mitten Crab (*Eriocheir sinensis*); Ctenophore (*Mnemiopsis leidyi*); Slipper Limpet (*Crepidula fornicate*); Japanese Wireweed (*Sargassum muticum*); Wakame (*Undaria pinnatifida*); Carpet Sea Squirt (*Didemnum vexillim*); Pacific Oyster (*Crassostrea gigas*); Common cord-grass (*Spartina alterniflora*); American jack knife clam (*Ensis directus*).  
84 Medium emissions scenario  
85 http://www.marineconservationnorthernireland.co.uk/  
86 The Year Class Strength of Fish is defined as the number of juvenile fish of a given age surviving from the annual egg production to be exploited by the fishery.
and indirect factors (such as changes in the plankton) on the shellfish industry. Results from this particular study showed that an increase in water temperature would result in a reduction shellfish production, in particular mussels.

Coastal shell fisheries may be also adversely affected by a number of other climate change effects. For example, sea level rise could potentially reduce the extent of shellfish beds, reducing the overall area and affecting the quality of those that remain. A decline in sea water quality may affect the quality of shellfish and also have implications for human health.

The effects of decreased oceanic pH (discussed in Section 3.3.3) are still not well understood. However, ocean acidification is known to affect the calcification process of shell forming organisms including shellfish (mussels, clams, oysters, etc.) and crustacean species (crabs, lobsters, etc.) These effects would then have knock-on consequences for shellfisheries and aquaculture. It is estimated that 6 to 12% of shellfish aquaculture in the UK could be lost from this cause. However, these losses would not be spread evenly across the UK. Northern Ireland shellfish landings are projected to suffer a relatively small loss compared to other parts of the UK, due to the limited presence of molluscs in Northern Ireland fisheries (see Marine & Fisheries Sector Report).

The fishing and aquaculture industries in Northern Ireland are relatively small (see Box 8). Therefore, a decline in these industries may not be significant for Northern Ireland as a whole, but would have significant consequences for fishing communities and associated processing businesses.

**Coastal Habitat Relocation**

Coastal habitat relocation can be considered at many sites across Northern Ireland. Sea level changes indicate between 11 cm and 19 cm rise by 2050s and a 25 to 40 cm rise by 2080s.

Such rises would act to squeeze coastal environments, especially those bound by sea walls, with major sea defences situated at Lough Foyle and Strangford Lough. The National Trust for Northern Ireland identifies the need for habitat relocation and promotes the use of soft engineering to mitigate sea-level rise. Projections indicate that Strangford Lough requires coastal realignment to preserve areas of tidal flat and to relocate saltmarsh. Currently bounded by transport infrastructure, habitat relocation would be costly and difficult (Orford et al., 2007).

Under current predictions dune habitats are likely to be relocated due to shoreline erosion. The Murlough dunes are likely to become significantly eroded resulting in the Inner Bay becoming more susceptible to marine processes and greater flood levels. Possible saltmarsh losses would be likely on the western shore. However, this may be compensated by saltmarsh relocation on the northern and western shores (Orford et al., 2007).

It is likely that Northern Ireland will provide many areas suitable for habitat relocation, which may act to preserve coastal habitat and shell fisheries. However, under current circumstances this is limited due to the presence of sea walls and infrastructure.

**Climate mitigation measures**

Tidal and wave technologies can have environmental impacts during installation, operation and decommissioning, such as destruction of the sea bed, disturbance of breeding species, danger of strike especially large individual animals (seals, basking

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sharks, etc.) However, by contributing to marine stewardship, these technologies have the potential to enhance marine biodiversity.

It was not possible to analyse the impacts of marine energy generation in general as part of the CCRA. However, the construction of the tidal stream generator, SeaGen, in the Strangford Narrows in 2008 has provided an opportunity for the impacts on the marine environment to be investigated. An environmental monitoring programme has been carried out to assess the interaction between the turbine and the marine environment, primarily looking at benthic fauna, marine mammals and birds. This has enabled the developers and their consultants, in consultation with the NIEA and others, to develop and implement mitigation strategies to minimise adverse impacts.

**Box 8: Northern Ireland’s sea fishing and aquaculture industries**

| The Northern Ireland licensed sea fishing industry is concentrated at the three east coast fishing ports of Ardglass, Kilkeel, and Portavogie. In 2009, the Northern Ireland fishing fleet of 370 vessels comprised 149 vessels over 10m, mainly fishing for Dublin Bay prawns, and 221 vessels 10m and under, mainly fishing inshore waters. This is a comparatively small fleet compared to the rest of the UK: 2,193 vessels in Scotland, 3,169 in England, 481 in Wales, although the Welsh vessels are generally smaller with less capacity than the Northern Ireland vessels (Marine Management Organisation, 2010). The number of fisherman in Northern Ireland in 2009 was 654 (slightly up on the previous year). There are a further 803 jobs in processing, marketing, etc. based on 2008 figures (McCormack, 2009).

The total landings of the Northern Ireland fleet into the UK and abroad was 24,400 tonnes in 2009, which was equivalent to 4% of the total landings for the UK as a whole (Scotland’s fleet landed 65%, England’s fleet landed 29% and Wales’ fleet landed 2%). Fish landings into Northern Ireland in 2009 were 19,600 tonnes, with a value of £19.4 million. Nephrops (mostly Dublin Bay prawns), herring and mackerel are the most common species landed, followed by scallops and crabs (Marine Management Organisation, 2010).

Irish Sea cod is suffering reduced reproductive capacity and is being harvested unsustainably, while sole is also at risk of becoming harvested unsustainably. Plaice and Dublin Bay prawns are both being harvested sustainably and haddock and herring biomass has recently increased (Gibson, 2011).

At present (September 2011) there are 81 licensed fish farms (covering 92 sites), of which 49 are licensed for the cultivation of shellfish (48 marine and 1 land-based) and 32 for the cultivation of finfish (30 inland and 2 marine). In 2010 the aquaculture sector produced over 11,000 tonnes of shellfish valued at £6.2 million and over 1,100 tonnes of finfish valued at £4.6 million. In total the aquaculture sector directly employs 100 full time and 53 part time employees.88

The aquaculture industry in Northern Ireland is developing, but is relatively small compared to Scotland where it has an annual value of £367 million per year.89

The main cultivated shellfish species are mussels (*Mytilus edulis*) and Pacific Oysters (*Crassostrea gigas*) although a small quantity of Native oysters (*Ostrea edulis*) and clams (*Venerupis semi-decussata*) are also grown. The main finfish species cultivated are salmon (*Salmo salar*), rainbow trout (*Oncorhyncus gorbuscha*) and brown trout (*Salmo trutta*).88

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88 Statistics provided directly from DARDNI, October 2011.
89 [http://www.scotland.gov.uk/Topics/marine/Fish-Shellfish](http://www.scotland.gov.uk/Topics/marine/Fish-Shellfish)
Summary of results for the coastal and marine environments

The main bio-physical impacts facing the coastal and marine environments in Northern Ireland relate to the following:

- Tidal flooding and coastal erosion;
- Higher water temperatures and increased stratification of coastal loughs; and
- Reduced water quality, due to pollution from point and diffuse sources.

These bio-physical impacts pose the following potential threats to native species, habitats and ecosystem services:

- Coastal evolution impacts on intertidal, grazing marshes, etc.;
- Changes in coastal species migration patterns;
- Increased risk to native coastal and marine species from pests, diseases and invasive non-native species; and
- Shifting of marine species, with consequences for ecosystem services.

The results of the analysis are summarised in Table 4.8

We have high confidence that the threats facing the coastal and marine environments with respect to species migration patterns (BD9) will take place as indicated in Table 4.8, with potentially high consequences by the 2080s. Many other threats have also been projected to have potentially high consequences by the 2080s, but we have less confidence in the magnitude and timing of these, due to limited evidence being available. There is a particularly high degree of uncertainty regarding the impacts of climate change on the marine environment, owing to the complexity of processes. This proved particularly to be the case for risk of harmful algal blooms (MA1), marine pathogens (MA2b) and eutrophication of sea loughs (NEW).

The environmental effects of climate mitigation measures (BD6) have only been assessed for terrestrial measures (principally onshore wind); measures directly affecting the coastal or marine environments have not been assessed, but are discussed earlier in this section.

There are potential opportunities for the marine environment, as identified by changes in fish catch latitudes (MA4b), but this also presents a threat (MA4a) depending on which fish species are being considered.

Plankton blooms (NEW) have not been assessed separately as part of the CCRA, but are discussed in relation to algal blooms (see Marine & Fisheries Sector Report).
### Table 4.8 Climate change consequences for coastal and marine natural environments

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
<th>Coverage</th>
<th>Confidence</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MA4b</strong></td>
<td>Changes in fish catch latitude/centre of gravity (plaice, sole)</td>
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<td><strong>High</strong></td>
<td><strong>NI</strong></td>
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<tr>
<td><strong>BD9</strong></td>
<td>Changes in species migration patterns</td>
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<td><strong>MA6</strong></td>
<td>Northward spread of invasive non-native species</td>
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<td><strong>Low</strong></td>
<td><strong>Q</strong></td>
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<td><strong>MA2a</strong></td>
<td>Decline in marine water quality due to sewer overflows</td>
<td><strong>NI</strong></td>
<td><strong>Low</strong></td>
<td><strong>NI</strong></td>
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<td><strong>BD2</strong></td>
<td>Risks to species and habitats due to coastal evolution</td>
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<td><strong>BD7</strong></td>
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<td><strong>MA3</strong></td>
<td>Increased ocean acidification</td>
<td><strong>NI</strong></td>
<td><strong>Low</strong></td>
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<tr>
<td><strong>MA4a</strong></td>
<td>Changes in fish catch latitude/centre of gravity (cod, haddock)</td>
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<td><strong>Medium</strong></td>
<td><strong>Q</strong></td>
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<td><strong>MA1</strong></td>
<td>Risk of Harmful Algal Blooms due to changes in ocean stratification</td>
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<td><strong>MA2b</strong></td>
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<th><strong>2020s</strong></th>
<th><strong>2050s</strong></th>
<th><strong>2080s</strong></th>
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<td><strong>High confidence</strong></td>
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<td><strong>Medium consequences (positive)</strong></td>
<td><strong>Medium confidence</strong></td>
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<td><strong>Low confidence</strong></td>
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</tr>
<tr>
<td><strong>Low consequences (negative)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Medium consequences (negative)</strong></td>
<td></td>
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<td></td>
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<tr>
<td><strong>High consequences (negative)</strong></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**NI** Analysis undertaken for Northern Ireland only  
**IJ** Informed judgement  
**UK** Analysis undertake for the UK  
**Q** Quantitative
4.3 Agriculture and forestry

Agriculture and forestry are very closely related to the climate. Any changes in climate are likely to lead to both positive and negative consequences for agriculture and forestry. Potential opportunities include increased crop yields (including grass), new crops and carbon storage. The main potential threats relate to pests and diseases (affecting livestock, crops and trees) and flooding of agricultural land (although at the present time this can not be quantified for Northern Ireland).

4.3.1 Agriculture

According to Northern Ireland Statistics & Research Agency\textsuperscript{90}, in 2008 there were just under 26,000 active farms in Northern Ireland, utilising 1 million hectares of land. In 2010, agriculture accounted for some £1.4 billion in output and around 50,000 people were involved in farming, most working on a part-time basis. Over half of the economic output from farms comes from the dairy sector, even though it accounts for only one farm in every seven.

Table 4.9 gives a summary breakdown of the composition of the agriculture sector in Northern Ireland compared to the UK as a whole. This clearly shows that Northern Ireland farming is predominantly based on livestock (79% compared to 48% for the UK), which makes it more reliant on the purchase of feedstuffs. The noticeable difference in labour expenses may be a result of only 24% of Northern Ireland’s agricultural labour being employed farmhands, with the remaining workforce attributed to self employed family farmers and spouses.\textsuperscript{91}

Table 4.9 Comparison of Northern Ireland and UK Agriculture

<table>
<thead>
<tr>
<th>Gross output (%)</th>
<th>Northern Ireland</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td>Sheep</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Pigs</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Poultry</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Eggs</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Milk</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>Crops</td>
<td>5</td>
<td>23</td>
</tr>
<tr>
<td>Horticulture</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>Others</td>
<td>12</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total expenses (%)</th>
<th>Northern Ireland</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstuffs</td>
<td>37</td>
<td>19</td>
</tr>
<tr>
<td>Fertilisers and lime</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Machinery</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Capital consumption</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>Labour</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>Interest</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Net rent</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Other expenses</td>
<td>24</td>
<td>30</td>
</tr>
</tbody>
</table>

\textsuperscript{90} http://www.nisra.gov.uk/publications/default.asp3.htm
\textsuperscript{91} http://www.dardni.gov.uk/labour-2010.pdf
**Flooding**

The CCRA analysed river and tidal flood risk for arable, horticulture and grassland, but was only able to undertake the analysis for England and Wales. Comparable data was not available for Northern Ireland. However, river flooding in particular can be a problem for some agricultural areas of Northern Ireland and this may be exacerbated by climate change. The flooding of agricultural land seen in Fermanagh in 2009 (see Section 5.2.3) was a result of an extreme event and not attributed to climate change. However, as such events are projected to become more frequent in the future as a result of climate change, the adverse consequences of flooding on agriculture in Northern Ireland may also increase.

The social consequences for land owners of flooding was highlighted by Northern Ireland stakeholders, as being an important issue, as well as direct impacts on crops, livestock, buildings and machinery.

Land that is flooded regularly (particularly from the sea) becomes untenable for crop production, as does land used for grassland and rough grazing. Saline intrusion was considered by the Northern Ireland stakeholders as a potential problem for crop land in areas around Strangford Lough and Lough Foyle. This has not been analysed as part of the CCRA, as suitable data were not available.

DARD Rivers Agency with the co-operation of other government departments, agencies and stakeholders is endeavouring to identify and map the areas at significant risk from coastal flooding (and hence saline intrusion) and produce flood risk management plans that will contain objectives and measures to manage the adverse consequences that significant coastal flooding has on human health, the environment, cultural heritage and economic activity (see Appendix D).

**Crop yields**

Crop yields were not considered a priority impact by Northern Ireland stakeholders, but these were analysed as part of the UK-wide assessment and projections suggest that Northern Ireland may benefit from future changes in climate. Therefore, these results are discussed below. As well as grassland productivity, the analysis has looked at wheat and potato crop yields for Northern Ireland.92

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92 It is important to note that while temperature and CO₂ increase may suggest increases in yield, the actual yields realised also depend upon the availability of other factors, notably water and nutrients.
**Grassland productivity**

The proportion of agricultural land that is grassland or enclosed rough grazing is over 80% in Northern Ireland.

Experimental evidence shows that grass production can increase in response to higher temperatures or CO₂ concentrations or especially in combination, as long as other factors affecting grass growth are not limiting. Projected increases in temperature and elevated levels of CO₂ may lead to increased grass growth, but only under conditions where water and nutrient supply, particularly nitrogen availability, are non-limiting.

The principle risk metric for grassland-based livestock production is herbage dry matter yield. Based on this, grass yields in Northern Ireland have been projected to increase by 19% for the 2020s Medium emissions scenario (range 10% to 28%), 32% for the 2050s Medium emissions scenario (range 17% to 51%) and 45% for the 2080s High emissions scenario (range 22% to 54%). Further details can be found in the Agriculture Sector Report.

Similar changes are expected in Northern Ireland, but increases in yield may exceed those of England as water stress is likely to be less of a limiting factor. Therefore, this is a potential opportunity for livestock agriculture in Northern Ireland, although other factors (such as dietary changes and the suitability of ground conditions for grazing or cutting) need to be taken into consideration.

In Northern Ireland, grassland is the largest agricultural land-use category (844,000 ha, plus a further 140,000 ha of rough grazing). Grassland-based livestock farming predominates in Northern Ireland, dairying (based on grazed grass plus grass silage and concentrate supplements) is undertaken at a smaller scale with only 3,194 of the Northern Irelands 24,471 farms being dairy (DOENI, 2010d), mainly confined to areas where topography, soil and climate conditions are most suitable for sustaining and utilizing high yields of high quality forage production. Beef and sheep production is generally more reliant on grass. Beef cattle are widespread in their distribution, including farms on areas with relatively marginal conditions for forage production engaged in calf rearing by suckler cows, producing weaned calves for sale as store cattle for fattening on lowland farms. Sheep are also widely distributed; in hill and moorland areas they are often the main, or only, livestock, but elsewhere they may be integrated with other ruminant enterprises. Sheep and many beef cattle are kept outdoors for all or most of the year, or housed in the winter months when grazed forage is unavailable or weather conditions present animal welfare or pasture management problems.

Forage yields per hectare vary considerably between sites and between years, therefore productivity increases may differ from those projected due to local climate and geographical conditions. In general, production is greatest in the areas that have the highest mean temperatures. Low temperatures in the spring reduce early season production and, therefore, the total annual production (Agriculture and forestry sector report). In areas most suited to grass growth, soils with a good depth, structure and soil available water capacity, a maximum dry matter production of 10.5 tonnes dry matter per hectare (t DM/ha) is achievable. However, there is the potential for 12.5 t DM/ha under high fertilization. Currently average yields are around 8.0 t DM/ha (Ulster Grassland Society, 2010) indicating the potential for significant increases and these may increase further under climate change conditions, although further research is needed on projections specific to Northern Ireland. In contrast, upland pastures in northern UK, where there is a short growing season due to low temperatures in spring and autumn, with leached and shallow soils on slopes, typically provide around 2-5 t/ha of forage mainly for grazing, sometimes of low feed value.

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93 The term herbage refers principally to grasses of sown and unsown species, together with non-grass forage species of grassland, such as clovers and other legumes as well as any other non-grass species in the sward.
Grassland productivity is a response of many factors including rainfall, temperature soil type, nutrient availability and CO₂ fertilization. Recent research suggests that the effect of CO₂ enrichment on plants can vary between species, with an increase in dry matter accumulation of 10-50% for a doubling of CO₂ concentrations (Fitzgerald et al., 2008).

Fitzgerald et al. (2008) modelled responses of grass productivity in Ireland to projected changes in temperature, precipitation and soil moisture, as well as CO₂ fertilization, based on statistically downscaled daily data from three Global Climate Models, therefore, applying a very different approach from the CCRA analysis. A maximum average increase in productivity of only 34% was projected by the 2080s. Grassland productivity was shown to have an early start for grazing with a seasonal peak occurring in early April. Modelled results showed low productivity mid-summer, due to the effect of water deficits, indicating a potential requirement to house cows indoors to allow the grass to recover for late-season grazing. Therefore, there is evidence to suggest that, for livestock grazing throughout Ireland, climate change may increase production, but increased seasonality may result in low productivity mid summer.

Fitzgerald et al. (2008) suggested that climate change would have the greatest potential positive impact on grazing in north-east Ireland, due to better draining soils that did not impede earlier spring growth due to increased soil moisture.

Wheat

Average wheat yields in the UK have shown very little increase over the past decade. With a national average of around 8 tonnes per hectare (t/ha), they have failed to increase in line with genetic improvement, suggesting that the benefits from plant breeding are being given away elsewhere in the production cycle. This might be related to soil degradation, poorer crop nutrition, or failure to control weeds, pests and diseases, or a combination of these factors.

Based on a baseline yield of 4.36 t/ha for Northern Ireland (1960-1991), wheat yields in Northern Ireland are projected to increase by between 20 and 65% by the 2020s; around 30 and 115% by the 2050s; and around 40 and 180% by the 2080s. However, the central estimate for the Medium emissions scenario is only a yield of 8.6 t/ha by the 2080s (range 6.2 to 12.3 t/ha), which is not dissimilar to the current national average. Even the upper estimate for the High emissions scenario is only a yield of 12.3 t/ha, which can be regularly achieved by some UK growers.

This suggests that these projections are defensible and that improvements in other yield components, especially plant genetics, may well lead to actual yields exceeding these projections. However, it is very important to note that other factors such as water availability are also an important yield component and that this may become a major determinant of final yield in the future. The projections here reflect a potential increase in yield, based upon temperature increases alone.

Recent research (Semenov, 2009) suggests that despite higher temperatures and lower summer precipitation, the impact of drought stress on wheat yield is predicted to be smaller than that at present, because wheat would mature earlier in a warmer climate and avoid severe summer drought. However, the probability of heat stress occurring around flowering which could result in considerable yield losses is predicted to increase significantly. Breeding strategies might thus need to focus on varieties tolerant to high temperature rather than drought (Semenov, 2009).

Rain-fed potato

The CCRA analysis for rain-fed potato yields was based on the sensitivity of yields to summer rainfall, a relationship that has been used as a climate indicator by Defra in previous studies (Defra, 2005). However, potato yields are expected to be particularly sensitive to increases in CO₂ concentrations, for example European studies have
indicated yield increases of 28% due to CO₂ increases alone (Kimball et al., 2002; Wolf and Van Oijen, 2003; Hermans, 2010). Therefore, this analysis was considered alongside more detailed biophysical modelling studies that account for climate, atmospheric carbon, nutrient balance and other factors to estimate future yields.

Future yields have only been analysed for the UK on a whole (see Agriculture Sector Report). The CCRA analysis shows that lower summer precipitation is likely to result in downward pressure on yields of rain-fed potatoes and that the changes in yield are small, within the range of natural variability and less than the effects of CO₂ fertilisation.

Based on Northern Ireland historic rain-fed yields, the analysis suggests future average reductions in maincrop potato yield for the extremely dry scenarios (p10) of approximately 5% by the 2020s, between 8% and 9% for the 2050s, and between 9% and 14% for the 2080s. For the extremely wet scenarios (p90), there is a small increase in yield of 2% by the 2020s, of between 1% and 2% by the 2050s, and between 1% and 2% by the 2080s.

However, these results are not consistent with more detailed biophysical crop modelling studies, which considered the impacts of climate change on crop growth and yield including CO₂ fertilisation effects. For example, Daccache et al. (2011) studied the impacts of climate change on maincrop potatoes (Maris Piper) in England and, assuming crop husbandry factors remained unchanged, farm yields showed marginal increases (3% to 6%) due to climate change by the 2050s, owing to limitations in nitrogen availability. In contrast, future potential yields, without restrictions in water or fertiliser availability, were reported to increase by between 13% and 16%. These increases are principally due to increased radiation and temperature levels and elevated CO₂ concentration effects.

These studies highlight the complexities of projecting future yields that are affected by climate, atmospheric CO₂ and technological changes. A simple metric based on nationally published yield data to estimate future yields indicates a reduction in yield, whereas site specific studies using parameterised crop models suggest marginal increases in yield. Whilst the data from site studies cannot be extrapolated nationally to other potato growing regions, it is preferable and more robust to rely on biophysical modelling approaches to assess potential yield impacts and consequent production risks.

**Plant pests and diseases**

Warmer summers and milder wetter winters could cause an increase in plant pests and diseases as a result of climate change. Warmer, wetter growing seasons would, for example, favour those fungal pathogens more successful in humid conditions or those that rely on moisture to spread. Milder winters could potentially result in higher survival rates, reducing winter kill and increasing inoculum levels in following seasons.

Plant diseases were investigated in the CCRA analysis using a ‘marker’ disease for wheat (yellow rust). Long-term historical data are available for this disease. However, it was not possible to derive any simple robust statistical relationship between climate variables and impacts on crops, based on the data available. It is possible that improvements in crop agronomy coupled with the development and use of agrochemicals has significantly reduced disease expression, which would buffer the effects of inter-annual climate variability on disease prevalence. Other studies, however, have identified a relationship between the incidence of yellow rust and climate variables, principally temperature, but also in some cases, humidity. The optimal temperature for yellow rust is considered to be between 10 and 15°C with high winter temperatures, associated with over-wintering being the most significant factor for yellow rust infections later on in the year (Te Beest et al., 2008).
Potato blight is caused by the fungus *Phytophthora infestans* and constitutes a major risk to UK potato production each year. It favours warm and humid conditions for reproduction and survival, developing spores when conditions exceed 10°C and 75% humidity for two days or more. Potato blight fungus is generally killed by cold weather, although there are some rare resistant crossbred strains that are able to overwinter. Unfortunately, although an industry blight monitoring and eradication programme has been in place for many years, neither suitable data nor the derivation of a suitable metric was possible (Agriculture Sector Report).

The CCRA analysis has also looked at *Phytophthora ramorum*, which can cause damage to trees including Japanese larch (*Larix kaempferi*) and other plant species such as *Rhododendron* and *Viburnum*. This is discussed under Pests and Diseases in Section 4.2.1.

However, recent research shows that many pests and diseases are robust and able to adapt quickly to change. There is, therefore, little doubt that any opportunities resulting from climate change will be exploited by them. However, the interactions between crops, pests and diseases are complex and currently poorly understood in the context of climate change. More mechanistic inclusion of pests and disease effects in crop models would lead to more realistic predictions of crop production at regional scales and assist in the development of robust climate change risk assessments.

**Livestock pests and diseases**

Pests and diseases are one of the factors that affect livestock welfare, product quality and trade markets with other countries and, therefore, considered important in Northern Ireland due to the predominance of livestock farming. The foot and mouth outbreak in the UK and Ireland in 2001 showed just how serious disease in livestock can be.

Livestock pests and diseases are a cross-border issue. The All-Island Animal Health and Welfare Strategy was agreed in March 2010 with the aim of facilitating the free movement of animals within the island of Ireland and is designed to optimise the animal health status of the island.

Livestock farmers face a range of disease risks: both endemic (present in the UK e.g. Bovine TB) and exotic (not usually present in the UK except during outbreaks e.g. Foot and Mouth Disease); and new and emerging disease that have the potential to cause significant economic damage and threat to food production for the UK as a whole, the agriculture sector and individual farms.

Bluetongue is one of a few relatively well studied diseases that suggest a strong link to climatic factors such as temperature. The vectors for this disease show strong correlation with moisture and temperature variables to different extents, depending upon the species (see Box 9).
Box 9: Spread of bluetongue by midges

**Climate change may facilitate the spread of vector borne diseases such as Bluetongue**

Bluetongue is a vector-borne disease that affects ruminants (cattle, sheep etc). It is transmitted by biting midges (Culicoides) and in 1998 it was reported in Europe for the first time in 20 years. The disease was first recorded in Europe 75 years ago and only in areas that also had the vector *Culicoides imicola*. The range of *C. imicola* has extended northwards considerably since then. Other Culicoides species that inhabit more northerly ranges now overlap in range with *C. imicola* and are now also thought to be carriers of the disease. This means that the disease may be able to spread naturally to more northern countries; a spread that may be also facilitated by humans moving infected animals. Between 1998 and 2005, bluetongue was responsible for the death of over 1.5 million sheep in Europe (Bayliss and Githeko 2006). Further outbreaks occurred in Europe in 2006, 2007 and 2008.

The disease was confirmed in a cow in North Antrim that had been imported from the Netherlands (BBC 2008). 23 cows and their calves were culled as a precaution to prevent the spread of the disease. As there was no evidence of virus circulating in the local midge population Northern Ireland’s Bluetongue free status was unaffected. It was estimated that an outbreak in NI, with associated production losses, and disruption of trade would cost the agri-food industry £25million. At the time, DARD and stakeholders including the Ulster Farmers’ Union called for a voluntary ban on importing animals in recognition of the risk to the livestock industries through farmers’ importing from Bluetongue affected countries (Driver 2008).

**Water demand and availability for livestock**

Although water availability in general was not identified as an important consequence for agriculture in Northern Ireland, it was highlighted that future water availability for livestock may be affected by a reduction in water quality (plankton blooms, cryptosporidium, etc) especially in stratified small loughs and ponds. A reduction in river flows during the summer months may also result in a reduction in availability of sustainable abstractions for agriculture at a time when most needed.

Currently water abstraction for direct use by livestock agriculture is predominantly related to watering and washing of livestock and their production systems (e.g. housing). This is anticipated to increase as a result of climate change. However, the difficulty in proportioning water use to livestock directly means that it has not been possible to estimate how this may change in the future. Water abstracted for the irrigation of crops that contribute (wholly or partially) to livestock diets (grass and cereals) and for spray irrigation for potatoes may be more significant.

However, details of the exact use of water in all these circumstances were not available and it has therefore not been possible to provide projections for livestock water use. It is likely that the major water abstraction issue for livestock is the need for access to drinking water for livestock and the potential need to use more water for cooling animals and cooling plant mechanisms (e.g. milking parlours). Abstraction may also be needed for slurry dilution, which has the added risk of increasing diffuse pollution runoff, affecting river habitats and downstream water usage.

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95 http://www.doeni.gov.uk/niea/water-home/water_resources/abstraction/sectors_affected_by_the_regulations.htm
Increase in GHG emissions

For livestock systems, a changing climate may impact on forage yields; feedstuff quality, availability and cost; water availability, thermal stress and related animal welfare issues; disease spread and control; and management of wastes and bi-products. These factors may in turn influence greenhouse gas emissions (GHG) and the effectiveness or viability of certain farming practices that are required to minimise emissions. For example, opportunities for spreading manure may decrease during periods of drought, waterlogging, etc., which in turn would mean that more storage of animal manures would be required.

At present, the agricultural sector accounts for 23% of all GHG emissions in Northern Ireland (DOENI, 2010d). Potential increases in the area of land brought into production in Northern Ireland, combined with intensification of agriculture as global food demands increase, may impact negatively on emissions from farming. However, methane emissions, which account for over two-thirds (68%) of all emissions from agriculture in the UK actually fell by 8% between 1990 and 2003, mainly due to a decline in cattle and sheep numbers, a trend which is likely to continue. On a global scale, livestock numbers are currently estimated to account for approximately 9% of total anthropogenic GHG emissions (Smith et al., 2007b). Taking into account all associated activities, this rises to 18% of all anthropogenic emissions and almost 80% of all agricultural emissions. Although there is some debate on these estimates (Herrero et al., 2008), this does indicate the significant contribution of agriculture, and livestock in particular, to anthropogenic emissions.

Projected reductions in precipitation for Northern Ireland (Tables 2.8 to 2.15) could further exacerbate this problem. For peatlands, drier soils may lead to a reduction in Sphagnum mosses; peat-forming vegetation. The carbon stock on Northern Ireland was estimated at 0.4 billion tonnes, with 42% of this found in peat soils. A further 3.8-4.4 million tonnes of carbon is estimated to be stored in Northern Ireland’s vegetation (Ostle et al., 2009). The areas most vulnerable as a result of climate change are those where the peat has been degraded through loss of vegetation and structure. In reviewing current evidence and model predictions, Smith et al., (2007a) suggest that land use change and management have been the more significant historical drivers of change in soil organic matter while climate change will likely become more significant over time. Losses of peatland and vegetation may result in the release of GHG such as carbon dioxide and methane. However, the processes that surround the flow of carbon between soils and the atmosphere are complex and not fully understood (see Section 4.2.1 Soil organic carbon).

Waterlogging

With rainfall projected to increase significantly in the winter months by the 2080s (see Table 2.9), there is the potential for an increased frequency and extent of waterlogging of high grade agricultural land. Concern was raised by Northern Ireland stakeholders that this could potentially impact negatively on agricultural productivity (Johnson et al., 2009) and undermine the potential opportunities of increased crop and grass yields.

As part of the CCRA analysis, the consequences of waterlogging have been analysed based on a measure of workable days on agricultural land. A summary of the analysis undertaken for Northern Ireland is provided in Appendix C. The analysis indicates that, whilst there may be a very small increase in the number of unworkable days in winter, there would also be an increase in the length of time without disruption from spring through to autumn. Based on limited analysis of two example sites, the average annual number of unworkable days would increase by around 3 to 5 days by the 2050s

96 http://www.sac.ac.uk/mainrep/pdfs/ghgemissionsfromagric.pdf
Agriculture in Northern Ireland potentially faces both threats and opportunities due to climate change. The sector is not projected to have severe negative consequences by the end of this century, with the possible exception of increased flood risk. However, there is limited confidence in these projections due to lack of data. Potential opportunities include increases in grass and wheat yields, but the limitations in the analysis approach regarding these projections need to be borne in mind.

If climate change impacts were analysed at a more local scale, it is likely that there would significant variation in which areas would be most affected negatively or positively by climate change, for example due to flooding, waterlogging or crop yield. The results presented here should not be considered as representative at a local or site-specific scale.

The results of the analysis are summarised in Table 4.10

The main threat facing agriculture in Northern Ireland is anticipated to be flooding of agricultural land (AG2a/FL4b). Projections are provided, based on the assumption that the UK-wide analysis is reasonably indicative of the future risk for Northern Ireland. However, as this cannot as yet be substantiated with data for Northern Ireland, it has been given a low confidence score.

The main opportunity identified for agriculture in Northern Ireland is increased grassland productivity (AG10). This has been given a low confidence, based on the uncertainties associated with UKCP09 rainfall projections and that the analysis was based on sample sites in England and Wales.

We have medium confidence that wheat yields would increase in the future, based on projections of warmer conditions and assuming that water availability and nutrients do not act as limiting factors.

Potato yields are projected to decrease in the future, due to a decrease in summer rainfall. The results presented here are for Northern Ireland. We only have low confidence in these projections, as potato yields are affected by a number of other factors, including CO2 concentrations, which may help to increase yields.

As discussed earlier in this section, the effect of winter waterlogging (NEW) presents a potential threat, but over the spring to autumn period the effects would be reduced.

The impact of pests and diseases on crops (AG3) was looked at as part of the UK-wide CCRA analysis, but the interactions between crops, pests and diseases are complex and currently poorly understood in the context of climate change, as discussed earlier in this section. Future increases in GHG emissions resulting from agriculture (NEW) would be affected by many factors other than climate change and is, therefore, also too complex to assess, but has been discussed earlier in this section.

Water demand for livestock (AG6) could not be assessed at the UK-wide or Northern Ireland scales, as it was not possible to proportion water use to livestock directly meaning that it was not possible to project how it might change in the future.

Saltwater intrusion (NEW) was also not assessed as part of the UK-wide analysis and has not been assessed for Northern Ireland, due to the limited data available regarding the effects of sea level rise and tidal flooding.
Other climate change consequences for the agriculture sector, such as livestock stress factors and livestock yield and quality, were not considered high priority for Northern Ireland and, therefore, are not discussed here. However, more information is available in the Agriculture Sector Report.

Table 4.10  Climate change consequences for agriculture

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Central estimate</th>
<th>Confidence</th>
<th>Coverage</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2020s</td>
<td>2050s</td>
<td>2080s</td>
<td>NI</td>
</tr>
<tr>
<td>AG1b</td>
<td>Changes in wheat yield (due to warmer conditions)</td>
<td>NI</td>
<td>Q</td>
<td></td>
</tr>
<tr>
<td>AG10</td>
<td>Changes in grassland productivity</td>
<td>NI</td>
<td>Q</td>
<td></td>
</tr>
<tr>
<td>AG1c</td>
<td>Changes in potato yield (due to combined climate effects and CO₂)</td>
<td>NI</td>
<td>Q</td>
<td></td>
</tr>
<tr>
<td>NEW</td>
<td>Waterlogging (spring to autumn)</td>
<td>NI</td>
<td>Q</td>
<td></td>
</tr>
<tr>
<td>AG2a/F14b</td>
<td>Flooding of agricultural land</td>
<td>NI</td>
<td>u</td>
<td></td>
</tr>
<tr>
<td>NEW</td>
<td>Livestock pests and diseases</td>
<td>NI</td>
<td>u</td>
<td></td>
</tr>
<tr>
<td>NEW</td>
<td>Waterlogging (winter)</td>
<td>NI</td>
<td>u</td>
<td></td>
</tr>
<tr>
<td>AG3</td>
<td>Risk of crop pests and diseases</td>
<td>Too uncertain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEW</td>
<td>Increase in GHG emissions</td>
<td>Too uncertain</td>
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<tr>
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<td></td>
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<tr>
<td>AG6</td>
<td>Water demand for livestock</td>
<td>Not assessed</td>
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</table>

**Coverage of analysis**
- NI: Analysis undertaken for Northern Ireland only
- UK: Analysis undertaken for the UK

**Method of analysis**
- Q: Quantitative
- IJ: Informed judgement

<table>
<thead>
<tr>
<th>Threats</th>
<th>Central estimate</th>
<th>Confidence</th>
<th>Coverage</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG2a/F14b</td>
<td>Flooding of agricultural land</td>
<td>NI</td>
<td>u</td>
<td></td>
</tr>
<tr>
<td>NEW</td>
<td>Livestock pests and diseases</td>
<td>NI</td>
<td>u</td>
<td></td>
</tr>
<tr>
<td>NEW</td>
<td>Waterlogging (winter)</td>
<td>NI</td>
<td>u</td>
<td></td>
</tr>
<tr>
<td>AG3</td>
<td>Risk of crop pests and diseases</td>
<td>Too uncertain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEW</td>
<td>Increase in GHG emissions</td>
<td>Too uncertain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEW</td>
<td>Saltwater intrusion</td>
<td>Not assessed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AG6</td>
<td>Water demand for livestock</td>
<td>Not assessed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Central estimate**
- High consequences (positive)
- Medium consequences (positive)
- Low consequences (positive)
- Low consequences (negative)
- Medium consequences (negative)
- High consequences (negative)

**Confidence**
- High confidence
- Medium confidence
- Low confidence
- Not assessed/Too uncertain
4.3.2 Forestry

Woodland cover is relatively low in Northern Ireland at 86,000 ha - 6% of total land cover compared to the UK average of 12.5%. Of this, 65,000 ha is coniferous forest and it is estimated that there is 13,000 ha of ancient and semi-natural woodland, including 2,000 ha of designated sites (ASSI). Commercially productive woodland is dominated by Sitka spruce and other important species are lodgepole pine and Norway spruce. The current climate in Northern Ireland is highly amenable for forestry and the mean productivity of conifer species is 20% greater than for Great Britain (Arkell et al., 2007). Woodland creation is a priority, with the Forest Service aiming to double the existing land coverage over the next 50 years.\(^{97}\) An increase in timber production and wood fuel would be part of this process, but recreation, cultural heritage resources and public access is also a priority.

However, there has been a dramatic decrease in larger scale conifer woodland creation in the last ten years, due to a shortage of suitable land at affordable prices. New planting funded under the woodland grant scheme is now generally restricted to smaller scattered areas of the countryside and broadleaves are normally preferred for landscape and environmental reasons (DOENI, 2011).

Forest productivity

Forest productivity has not been analysed in detail for Northern Ireland. However, projections for Scotland and Wales provide an indication of the potential change in productivity that may be expected for Northern Ireland. Overall forest productivity is projected to decrease across most species in the England, Wales and Scotland. However, Sitka spruce productivity is set to increase in both Wales (small increase) and Scotland (significant increase). Due to Northern Ireland’s commercial plantations being predominantly Sitka spruce, productivity overall may increase in Northern Ireland although it is not possible to say with any confidence to what degree. For the majority of deciduous woodland, a reduction in productivity is projected throughout England, Scotland and Wales and, therefore, it is assumed that a similar response would occur in Northern Ireland.

However, by assuming a similar productivity response to that of Scotland, some important regional differences related to climate are being overlooked, for example, differences in projected productivity between the east and the west for species more suited to wetter or drier conditions. Further limitations of the analysis include not taking into account the potential effects of damaging pests and pathogens, windthrow and other effects of extreme events, or future choices of tree species. Therefore, these projections should not be used in commercial production forecasting. This is discussed further in the Forestry Sector Report.

Pests and pathogens

Forest pests and pathogens are posing ever increasing risks to trees, woodlands and forests, mainly due to the introduction of exotic pests and pathogens, most likely as a result of external factors such as international trade. There is evidence that pest/pathogen life cycles are linked to climate conditions. Therefore, climate change might exacerbate the frequency and severity of attack, although the extent to which climate change would have an impact is likely to vary considerably depending on different pests and pathogens.

\(^{97}\) Unfortunately, poor uptake of grant schemes to plant woodlands means that short-term targets have been reduced. The target for the year 2011/2012 is 200 ha of new woodland, compared to 1,650 hectares over the 2008-2011 period (DOENI, 2011).
The CCRA analysis looked at the potential spread of red band needle blight and green spruce aphid across Great Britain. The main trends shown by the results were:

- The impact of climate change is greater for red band needle blight than for green spruce aphid.
- By the 2050s, over half of all pine forests in the Great Britain could be affected by red band needle blight (range of 11% to 100% for the Low emissions scenario p10 to the High emissions scenario p90).
- By the 2080s, all pine forests in the Great Britain could be affected by red band needle blight (range of 12% to 100% for the Low emissions scenario p10 to the High emissions scenario p90).
- By the 2080s, the area of spruce forest in the Great Britain affected by green spruce aphid could more than double from present day area affected (range of 9% to 52% for the Low emissions scenario p10 to the High emissions scenario p90).

In the analysis ‘affected’ was taken to mean that the prevalence of the pest/pathogen is sufficiently severe to cause a reduction in productivity, timber quality and/or a change in forest management practice. The projections above would lead to significantly lower yields, higher tree mortality and reduced timber quality in the tree species affected. Loss of or damage to woodlands from pests and pathogens may also reduce or restrict public access.

The CCRA analysis has also looked at *Phytophthora ramorum*, which can cause damage to trees including Japanese larch (*Larix kaempferi*). This is discussed under Pests and Diseases in Section 4.2.1.

Forestry pests and pathogens are an all-Ireland issue, but this was not been taken into consideration in the analysis.

**Drought and loss of productivity**

Drought could seriously affect tree productivity in warmer drier summers. Existing data for losses in yield experienced due to drought show losses ranging from 14% in South East England to 10% in Wales and Northern Scotland. Projections for loss of yield in Northern Ireland indicate that losses could be in the region of 15% by the 2050s increasing to 18% by the 2080s.\(^98\)

**Wildfire**

The risk of fire would increase, if there is an increased prevalence of hotter, drier conditions (see Section 3.2.4). The start and spread of wildfires are encouraged by low moisture, high temperatures and high wind speeds, as experienced across Northern Ireland in May 2011 where fire crews fought more than 755 gorse and forest fires in four days.\(^99\) Additional influences such as fuel availability and species type can also affect the rate at which wildfire spreads.

Fires have far reaching impacts on the forestry sector. Biodiversity can be seriously affected both directly and indirectly through loss of habitats and food sources. Timber stocks may be damaged affecting prices and quality. Additionally, fire can leave scars in the landscape having an impact on visitor numbers and those using the area for sport and recreation. Irreversible damage caused by wild fires is a concern for the heritage and landscape of Northern Ireland.

\(^{98}\) Medium emissions scenario p50.
**Windthrow and storm damage**

The risk of windthrow may increase if tree root systems are undermined due to other climate change consequences, such as waterlogging. The projected change in frequency of waterlogging (in the form of unworkable days\(^{100}\)) is discussed in Section 4.3.1. Storm damage in general would not increase based on current UKCP09 projections (see Section 2.4.6).

**Snow and frost damage**

Heavy snow fall can damage tree architecture, but frost damage as a result of earlier budburst with higher spring day-time temperatures is considered to be more of a problem based on previous work by Read et al. (2009). Although considered potentially important consequences of climate change, snow and frost damage have not been analysed as part of the CCRA.

**Summary of results for forestry**

| Forestry in Northern Ireland potentially faces both threats and opportunities due to climate change. The potential increase in yield of Sitka spruce has been identified as an opportunity. However, this may be countered to some degree by a reduction in productivity due to drought. The most significant threat identified is from pests and diseases, with the forest extent affected by red band needle blight being projected as high by the 2050s. Due to the limitations in the analysis methods and available data, these projections should not be used for commercial production forecasting, but give an indication of where early adaptation actions may be beneficial. |

The results of the analysis are summarised in Table 4.11.

We have medium confidence that the main threats facing forestry in Northern Ireland relate to pests and pathogens (FO1a and FO1b), with potentially high negative consequences by the 2080s. The analyses for red band needle blight and green spruce aphid were undertaken UK-wide and have been assumed to be equally applicable to Northern Ireland as the rest of the UK.

Loss of forest productivity due to drought (FO2) and wildfires (BD12) have been projected to have medium consequences by the 2080s, based on CCRA analysis results available specifically for Northern Ireland.

There may be significant opportunities by the 2080s related to forest productivity due to a potential increase in yield for Sitka spruce. However, we only have low confidence in this projection as it is based on analysis for Scotland.

The climate projections regarding wind speeds and storms are too uncertain at present to allow an assessment of the risk of windthrow and storm damage (NEW), as discussed above.

Snow and frost damage (NEW) has also not been assessed as part of this first CCRA, due to time constraints.

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\(^{100}\) Unworkable days, although relevant for agriculture, is not a significant issue for forestry. Reference to this is provided only to give an indication of the possible scale of the threat.
Table 4.11 Climate change consequences for forestry

<table>
<thead>
<tr>
<th>Threats</th>
<th>Opportunities</th>
<th>Central estimate</th>
<th>Confidence</th>
<th>Coverage</th>
<th>Method</th>
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</thead>
<tbody>
<tr>
<td>FO1a</td>
<td>Forest extent affected by red band needle blight</td>
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<td>NI</td>
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<tr>
<td>FO1b</td>
<td>Forest extent affected by green spruce aphid</td>
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<td></td>
<td>GB</td>
<td>Q</td>
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<tr>
<td>BD12</td>
<td>Wildfires due to warmer and drier conditions</td>
<td></td>
<td></td>
<td>NI</td>
<td>Q</td>
</tr>
<tr>
<td>NEW</td>
<td>Windthrow and storm damage</td>
<td>Too uncertain</td>
<td></td>
<td>NI</td>
<td>U</td>
</tr>
<tr>
<td>NEW</td>
<td>Snow and frost damage</td>
<td>Not assessed</td>
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</table>
4.4 Business

*Climate change does not necessarily create ‘new’ risks for businesses; climate change typically represents a change to existing risk profiles (i.e. issues that businesses are already facing on a daily basis). Climate change simply represents a potential change in the duration and/or frequency of occurrence of consequences.*

The Northern Ireland economy is the smallest of the four countries in the UK and is also smaller than any of the English regions. Traditionally, Northern Ireland had an industrial economy, most notably in shipbuilding, rope manufacture and textiles, but most of this industry has been replaced by service industries particularly in the public sector (see section 1.6.5).

Climate change consequences for business and services include:

- Damage caused by extreme events, such as flooding,
- Effects of gradual changes (such as temperature increases),
- Losses due to business disruption, and
- Adverse effects on financial investments.

There is a particular concern that many of the smaller businesses are vulnerable to extreme events such as flooding, either because of inadequate insurances or inadequate resources to recover quickly. These businesses are of particular importance to the Northern Irish economy (see Section 1.6.3) as well as their local communities.

As part of the Preliminary Flood Risk Assessment (PFRA) for Northern Ireland, which takes account of flooding from all sources, a broad range of flood risk indicators have been generated to measure the adverse impact of potential future floods on groups of receptors (including those relating to businesses) and these quantitative indicators will be available when the PFRA is published in December 2011. Further information can be found in Appendix D.

4.4.1 Imports and exports

According to HM Revenue & Customs (2010), in 2009 Northern Ireland’s exports had a value of £5,142 million (approximately 2.3% of the UK’s total export value). 59% of these exports are to the EU, which is a higher proportion than for the UK as a whole (55%). After the EU, North America receives the greatest value of exports from Northern Ireland.

In the same year, Northern Ireland’s imports had a value of £5,014 million (approximately 1.6% of the UK’s total import value). 58% of these imports were from the EU, compared to 52% for the UK as a whole. After the EU, Northern Ireland imports the greatest value of goods from Asia & Oceania.

The majority of exports in 2009 were in the category of machinery and transport; if coupled with other manufactured goods and ‘miscellaneous manufactures’, this far outweighs any other types of exports (approximately 65%). Food and live animals follows on behind with 14%. Imports in 2009 mirrored this pattern quite closely.
In general terms, Northern Ireland has a very similar reliance on the export and import markets as the UK as a whole, and therefore it is not likely to be at a significant disadvantage. However, what sets Northern Ireland apart from the rest of the UK is its isolated geographical location, which means that it often has a longer supply route (for example Northern Ireland receives its supplies of natural gas via Scotland and the Republic of Ireland). Therefore, the protection of these supply routes is highly important. This is discussed further in Section 4.4.2.

There is also a potential opportunity for the shipping industry in the UK due to the opening up of the Arctic sea routes (see Section 3.3.4). These routes have the potential to provide large cost savings and open up new markets for the shipping industry in the UK. As ships would be travelling north, the ports with the largest container vessel flows from the Asiatic markets at present (in the South East of England) would possible be most adversely affected, with the more northerly ports benefiting.

This was not considered by stakeholders as a significant opportunity for Northern Ireland, being more relevant for the largest container ports in Great Britain. However, in December 2010 Northern Ireland exported potatoes to Russia for the first time, due to Russia drought destroying harvests. If such events overseas become more frequent in the future, new shipping channels may be greatly beneficial to Northern Ireland trade. The potential of these new trade route depends on infrastructure investment along the new trade path, as well as international agreements on trade and transport, and the need for environmental and coastguard frameworks (Foresight, 2011).

### 4.4.2 Supply Chains

Businesses rely on a range of infrastructure and associated services including energy, water, transport, Information and Communications Technology (ICT) and waste disposal, as well as raw material supplies. Discussion of specific climate change impacts on Northern Ireland’s infrastructure (transport, water, energy and ICT), including consequences for businesses, is provided in Section 4.5.

Climate change is projected to cause shifts in both average conditions and the frequency and severity of extreme climate events. These shifts have the potential to affect every aspect of the business supply chain, often in ways that are gradual, diffuse or indirect. Due to increased globalisation, outsourcing and just-in-time approaches to inventory, businesses already expose themselves to significant climate risks. Previous studies have also shown that businesses do not tend to recover quickly from supply chain disruptions (PwC, 2008).

Understanding business supply chains is complex and it has not been possible to analyse these in detail as part of the CCRA. Therefore, the scale of the consequences for businesses in Northern Ireland is unclear. However, the length of the supply chain is significant: the longer it is the higher the vulnerability to disruption, which is why this is an important issue for Northern Ireland.

As discussed in Section 4.4.1, Northern Ireland is heavily reliant on imported manufactured goods and energy supplies. The scale of the impacts on energy suppliers and manufacturing abroad is even more unclear and will depend on the likelihood of the relevant regions of the world being affected by climate change; the preparedness and resilience of the countries in question and individual businesses; and world markets (Foresight, 2011).

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4.4.3 SMEs

As SMEs have small premises and workforces, the following impacts may often be greater for SMEs than for larger businesses:

- Changing markets (i.e. changing demands in goods and services);
- Disruption of supply chains (e.g. transport and suppliers);
- Disruption of power and water supplies;
- Impacts on production processes (especially those that are climate or temperature sensitive);
- Disruption to service delivery (including damage to premises, equipment and goods);
- Disruption of workforce (e.g. fewer staff absences can have a greater impact on product or service provision);
- Changing financial burden (e.g. insurance premiums, cost of raw materials, etc.)

Any of the above impacts might originate within Northern Ireland, over the border in the Republic of Ireland or overseas in Great Britain and other parts of the world.

The following types of businesses are recommended by UKCIP as being those that would benefit the most from outside support to reduce their vulnerability:

- Companies whose products, service or processes are weather dependent – examples for Northern Ireland include agriculture, tourism and leisure related businesses.
- Companies involved in making decisions with long-term consequences – examples for Northern Ireland include businesses supporting building and infrastructure projects, forestry and some farming practices.
- Companies that are already affected by extreme weather – e.g. businesses located within a flood risk area or heavily reliant on transport links or a utility supply that is vulnerable to extreme weather.
- Sectors highlighted as strategically important to the locality – e.g. areas of NI with a heavy reliance on one particular sector that might fall into one of the categories above.

In addition to the above, businesses with a reliance on affordable energy, water, ICT, etc. may be affected if these utilities became more expensive in the future, due to costs of climate change being passed on to the consumer. Also, businesses that abstract their own water, for example, could be directly affected if the availability or quality of that water is reduced.

Most small businesses, particularly micro-SMEs, do not take major capital decisions, for example, they tend to use rented rather than owned premises. An exception to this, however, are farmers, who make decisions regarding land, storage, drainage, irrigation, etc. that can last decades and cost hundreds of thousands of pounds. These decisions are often very climate sensitive, which makes these businesses particularly vulnerable and in need of support to improve their adaptive capacity.

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Research undertaken by the Centre for Business Research at Cambridge University on behalf of Invest NI (Cosh et al. 2005) found that within the sample set of Northern Ireland SMEs and micro-SMEs that they were able to survey:

- The average business leader in NI firms was younger and less experienced than in Great Britain. The average age and experience of business leaders in Great Britain is about 4 years greater.

- After allowing for size and sector, the NI firms were more likely to engage in business planning than the rest of the UK (50% compared to 40%), but less likely to have monthly management accounts (63% compared to 75%).

- A greater proportion of businesses in Northern Ireland were likely to export and have higher export to sales ratios than their counterparts in Great Britain. In 2004, 56% of NI SMEs and micro-SMEs (combined) exported compared to 29% in Great Britain. The percentage of micro-SMEs exporting was lower than small and medium enterprises, but this was still 43% in NI compared to 20% for equivalent sized firms in Great Britain. The exports to sales ratios for all three sizes of exporting SMEs were similar at around 22% compared to only 11% for Great Britain.

- In each size group of SMEs, NI firms were found to be more ambitious for growth than their counterparts in Great Britain.

- The NI firms had slightly fewer serious competitors (80% of firms had fewer than 10 serious competitors compared to 77% of matched firms in Great Britain), which was thought to be at least a partial contributor to their greater profitability than British SMEs. The median profit margin for all SMEs in 2004 was 12.5% within the sample set for NI, compared to 9.2% in Great Britain.

- Innovation activity was less overall in the sample NI firms compared to Great Britain, but in the micro-SMEs there had been slightly more innovation within the previous 3 years and more planned in the following 3 years compared to the equivalent British firms.

Whether these differences make NI SMEs more or less vulnerable overall to the impacts of climate change compared to the rest of the UK is unclear; but these differences might result in NI SMEs reacting differently from the rest of the UK to particular consequences, perhaps most notably in relation to changing international markets. This need not necessarily be considered as a threat to these businesses; it can be argued that SMEs in general have a greater level of flexibility enabling them to take advantage of changing markets. Therefore, in conclusion SMEs in Northern Ireland may have greater vulnerability to climate change consequences, but also may have greater potential to take advantage of opportunities.

4.4.4 Tourism

The tourism industry in Northern Ireland supports over 40,000 jobs and 3.2 million visitors. The earnings from tourism are forecast to be £536 million for 2010 (Department of Enterprise Trade and Investment 2010).

Coastal tourism is a growing section of the industry, including a chain of harbours and marinas, which for the base for recreational boating. Also, in 2009, 36 cruise ships brought 57,000 visitors to Belfast, worth £16 million to the local economy (Gibson 2011).
Adverse effects caused by climate change would include the loss of beaches and other natural assets and landscape and increased flooding and coastal erosion. Out of the 16 beaches assessed (41km total length) in Northern Ireland, it is projected that up to 100 hectares of beach area could be lost due to sea level rise alone by the 2080s (assuming that the beach high water mark is unable to move landwards).

The number of tourist facilities at risk of flooding is also projected to increase, and floods could become more frequent. Increased fluvial and coastal flooding and coastal erosion are, therefore, likely to cause losses to the tourist industry although the magnitude of losses will depend on how the tourist industry changes in the future.

There are also opportunities for increased tourism and outdoor leisure activities as a result of warmer summers and longer tourist season, which could mean that the overall consequences of climate change could be positive. A further opportunity for the tourist industry is that of changing holiday trends and the potential for new markets as the attractiveness of Northern Ireland as a tourism destination improves compared to other parts of the world.

Previous modelling studies that utilise the “Tourism Comfort Index” (TCI) indicate that future climate change is likely to result in an improvement in the attractiveness of the UK as a tourism destination and furthermore, extend the tourist season. At the same time, the suitability of Mediterranean destinations will decline in summer (although they will become more suitable in autumn and spring).

4.4.5 Financial Services

Financial services represent an important part of the overall UK economy, contributing up to 12% of GDP although much of this activity is based in London. The financial services industry has only a 2.5% share of the total workforce in Northern Ireland and provides less than 5% of Northern Ireland’s GVA.

Climate change can have a major impact on investment performance with severe potential consequences for the financial sector. This would be exacerbated if management processes are inadequate to manage the risk or climate change risks are
underestimated. Whilst it has not been possible in the CCRA to estimate the magnitude of these consequences, it is clear that they could be very important with knock-on effects across business and society.

Increased flooding as a consequence of climate change could adversely affect the mortgage and insurance markets. As flood risk increases, an increasing number of properties may experience an increase in insurance premiums or may even find difficulty in obtaining insurance, resulting in difficulties obtaining mortgages.

The actual number of properties affected will depend on the position taken by the insurance industry on the provision of insurance to properties in flood risk areas.

Increased flooding could lead to increased annual insurance pay out costs. It is estimated that these could increase for the UK by a factor of 2 to 5 by the 2080s. However, this depends on future policies adopted by the insurance industry regarding the provision of flood insurance. Detailed flood maps are required to provide an estimation of those properties that may be affected and the potential monetary impacts (see Appendix D).

It is a standard condition of all mortgages for a property that they are covered by standard buildings insurance, including flood cover, for the full term mortgage, in order to protect the borrower and the lender. Most properties in the UK are insurable on normal terms. Mortgage lenders have a keen interest in this agreement continuing, thereby ensuring that mortgages can be offered in flood risk areas. In order for this situation to continue, Government has committed to capital investment in flood management and to the control of development in flood risk areas through the planning system.

The NI Executive and the Association of British Insurers (ABI) have agreed to work together to provide a long-term solution that will enable flood insurance to continue to be as widely available as possible without distorting the insurance market. A “Statement of Principles” is in place up to the 1st July 2013. Thereafter, it is envisaged that flood insurance will continue to be widely available operating under free market conditions. The “Statement of Principles” does not apply to any property built after 1st January 2009.

### 4.4.6 Summary of results for business

Many of the potential risks for businesses in Northern Ireland cannot be assessed with any degree of confidence, because the data is not available or the risks are intrinsically too uncertain.

However, based on future projections for rainfall and sea level rise and evidence available for other parts of the UK, flooding may become the greatest single climate change concern for businesses in Northern Ireland. The PFRA should help to estimate future flood risks for Northern Ireland (see Appendix D).

The results of the analysis are summarised in Table 4.12.

The main potential opportunities identified for businesses in Northern Ireland are an expansion in tourist destinations (BU8) and the opening of Arctic shipping routes (MA5b). However, the projections presented here are based on UK-wide analysis, rather than Northern Ireland and need to be treated with caution.

The main potential threats identified for businesses in Northern Ireland relate to flooding (BU2, BU4 and BU6) and water abstractions (BU3). The risk of restrictions to water abstractions for industry (BU3) is discussed in Section 4.5.6. The projections
related to flooding reflect the projections for the UK as a whole, due to lack of data for Northern Ireland. It is possible that this is an overestimation of the magnitude of the consequences and for this reason these have been given low confidence. The Rivers Agency has recently completed the preliminary flood risk assessment for Northern Ireland, which included an assessment of the extent of potential flood risk for commercial and business properties. Publication of maps showing areas that have the most significant flood risk is scheduled by December 2011. Further information is provided in Appendix D.

Climate risks to investment funds (BU1) and loss of productivity due to ICT disruption (BU5) were looked at as part of the UK-wide analysis, but were deemed too uncertain to provide projections at either the UK or Northern Ireland scale. The potential risks to SMEs and micro-SMEs (NEW) are also too uncertain, as discussed in Section 4.4.3.

The challenges faced by key workers in getting to work during or after extreme events (NEW) may become greater or more frequent as a result of climate change, but at present projections cannot be provided for this due to lack of data. Monitoring of extreme weather events is needed before analysis could be undertaken.

The other potential threats that have not been assessed due to time constraints.
Table 4.12 Climate change consequences for business

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
<th>Confidence</th>
<th>Coverage</th>
<th>Method</th>
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</thead>
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<td>Opening of Arctic shipping routes due to ice melt</td>
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<tr>
<td>An expansion of tourist destinations in Northern Ireland</td>
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<tr>
<td>Changes in UK trading patterns</td>
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<td>Mortgage provision threatened due to increased flood risk</td>
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<td>Monetary losses due to tourist assets at risk from flooding</td>
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<td>Risks of business disruption due to flooding</td>
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<td>Loss of staff hours due to high internal building temperatures</td>
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*Coverage of analysis: NI = Analysis undertaken for Northern Ireland only, UK = Analysis undertaken for the UK, NEW = Analysis undertaken for new areas

**Method of analysis: IJ = Informed judgement, Q = Quantitative
4.5 Buildings and infrastructure

Buildings and important parts of Northern Ireland’s transport, energy, water and information and communications technology (ICT) systems are vulnerable to flooding, extreme heat and other climate risks, such as landslides and potential water shortages during major droughts.

The main climate change effects on infrastructure and buildings include:

- Increased risk of flooding to property and disruption of key infrastructure;
- Changes in energy demand, with more cooling required in summer but less heating in winter;
- Changes in water availability, particularly reductions in the summer;
- Subsidence and landslip, that affects sections of the transport network and buildings in some areas; and
- Increased summer heat, that particularly affects conditions in buildings and the urban environment, although the ‘Urban Heat Island’ effect is not regarded as a major threat for Northern Ireland (Arkell et al., 2007).

The dispersed nature of rural homes and communities in Northern Ireland means that there may be a disproportionately large amount of infrastructure potentially vulnerable to climate change, for example, power lines, busy country roads, etc.

The impacts of climate change on infrastructure and buildings are covered under the following headings: buildings; urban space; built heritage; transport; water supply; energy supply; and ICT.

However, there are significant interdependencies between different sectors of Northern Ireland’s infrastructure, which mean that these should not be considered in isolation. Examples include (but are not limited to) the following:

- Power stations are reliant on the transport infrastructure to deliver fuel;
- Energy is required to run water treatment plants, pumping stations, wastewater treatment works, etc.;
- Transport is not only reliant on fuel, but also electricity to fuel pumps and to power airports, train stations, etc.;
- Transport, water and energy sectors are reliant on ICT for their monitoring and control systems;
- ICT is reliant on energy to power devices and enabling infrastructure;
- Within Northern Ireland the workforce for all sectors of infrastructure depend primarily on the road network to get to work.

In an extreme event, disruption to the connectivity and interdependence between various infrastructure assets is often a risk, never more so than in an extreme flooding incident where flooding to electricity substations can curtail the performance of other infrastructure assets such as sewerage pumping stations or street lighting/traffic control. Ultimately this connectivity and interdependence can exacerbate the initial problem and can have severe consequences for emergency response and recovery.
Further information on the interdependencies of infrastructure can be found in Infrastructure, Engineering and Climate Change Adaptation – ensuring services in an uncertain future (Engineering the Future, 2011).

As part of the Preliminary Flood Risk Assessment (PFRA) for Northern Ireland, which takes account of flooding from all sources, a broad range of flood risk indicators have been generated to measure the adverse impact of potential future floods on groups of receptors, including those relating to buildings and infrastructure. DARD, Rivers Agency consulted widely with the owner/operators of key services assets to determine the potential level of loss and disruption to essential services. The response to this consultation is reflected within the PFRA and data that is specific to the potential impacts on buildings and infrastructure will be available with the publication of the PFRA in by December 2011. Further information can be found in Appendix D.

4.5.1 Buildings

Climate change consequences that could affect buildings include floods, overheating, rainfall penetration and soil instability.

Flooding

Flooding is a natural phenomenon, but can have devastating consequences for communities (as experienced in Belfast, Section 5.2.1, and Fermanagh, Section 5.2.3). It is estimated that there are 60,000 properties in Northern Ireland at risk from flooding from the river and the sea, based on a 1% (1 in 100 year return period) probability fluvial event and a 0.5% (1 in 200 year return period) probability coastal event, although approximately 50% of these are protected by flood defences. Nearly 14,000 of these properties at risk are within the Greater Belfast Area. The average annual damage from river flooding in Northern Ireland is estimated at £16 million.

Northern Ireland is also susceptible to surface water flooding (i.e. pluvial flooding and sewer flooding), which occurs as a result of high intensity rainfall overwhelming natural or engineered drainage systems. This results in water (often contaminated with sewage) flowing overland and collecting in depressions in the ground. It is difficult to predict and pinpoint potential areas at risk, much more so than for river or coastal flooding. Historically the city of Belfast has suffered from surface water flooding and a large proportion of flood damage in Northern Ireland was attributed to surface water flooding in recent years (84% in 2007 and 60% in 2008).

With increased development and climate change the number of properties at risk from flooding in Northern Ireland is likely to rise particularly in urban coastal areas where rising sea levels will make the discharge of increased fluvial flood flow more difficult. Even if the number of properties does not significantly increase in the future, based on current climate change projections the frequency of flooding of properties already at risk is likely to increase.

Spill volumes from combined sewer overflows (CSOs) are projected to increase, which can be considered as an indicator of sewerage performance, i.e. if the CSOs are discharging the sewers will operating at or greater than design capacity, which will mean that there is increased likelihood of flooding. However the magnitude of the increase is projected to be relatively modest, reaching 10% by the 2080s (see Section 3.2.10).

103 Excess surface water runoff that cannot be infiltrated into the ground or drained via existing watercourses and sewers.
The preliminary flood risk assessment for Northern Ireland has included an assessment of the extent of potential flood risks to buildings, taking into account climate change. This has included the gathering and sharing of flood risk information with other statutory authorities and stakeholders. Further information can be found in Appendix D.

**Overheating in buildings**

The risk of overheating in buildings is already considered a problem in Northern Ireland, according to stakeholders, due to poor design of offices and other commercial premises in the past. Historically within the UK, building design has been driven by the need for indoor thermal comfort in winter and more recently, by a desire for winter energy efficiency. The risk of summer overheating has not been regarded in the past as a problem in the UK.

The risk of overheating varies from building to building. Nevertheless, there is evidence that some types of building, such as highly insulated lightweight buildings and buildings with heavily glazed facades, are already vulnerable to summer overheating. With increasing temperatures and a higher incidence of summer heatwaves, the risks of overheating is projected to increase for all buildings.

An increase in the frequency of mean average daily temperatures exceeding 26°C would increase the risk of overheating in buildings. A ten fold increase in risk between 2020 and 2080 was projected in the case of London (under the p50 Medium emissions climate change scenario). Data was not available to undertake similar analysis for Belfast, but such a large increase in risk would not be expected based on the projected changes in minimum summer air temperatures.

While the precise performance of individual buildings is dependent on a number of factors specific to their design, in broad terms increasing periods of elevated temperatures will increase the risk of impaired productivity. The combination of overheating and warm weather periods has been observed by previous studies to produce two responses in the workforce: increased absenteeism and reduced productivity. It is projected that there would be an average loss of productivity for those days exceeding 26°C of 20% by the 2020s, 24% by the 2050s and 27% by the 2080s.\textsuperscript{104}

There may also be more disruption in the case of schools and difficulties for hospitals in maintaining cooler areas for patients:

- The projected rise in minimum night-time temperatures may particularly affect the performance of hospital buildings; overheating is already a problem for many hospitals, even in new constructions (SHINE 2010). They differ from commercial buildings as they are occupied and staffed 24 hours a day, with wards often being maintained at warmer temperatures than a domestic bedroom overnight. This means that a rapid night purge, such as might be deployed in offices or schools, is not possible. In addition to this, hospitals have very specific requirements regarding air supply and circulation in order to control infection. Because of these unique characteristics, it is not possible to estimate the increase in risk of overheating of hospitals without appropriate hospital specific evidence. This is not available at the present time.

- The risk of overheating of school buildings varies significantly depending on the age and type of building, in a similar way to other types of buildings. The design of a good teaching environment requires a balance between

\textsuperscript{104} These figures are based on central estimates (p50) for the Medium emissions scenario.
good natural light, good acoustics and good indoor air quality and thermal comfort throughout the year. There are potential conflicts between these requirements, e.g. large windows for allowing daylight in could lead to excessive solar gain in summer.

**Subsidence**

Changes to the present shrink swell pattern of clay soils are expected as a result of climate change due to wetter winters and hotter drier summers. Older buildings and buildings with shallow foundations are at greatest risk. Modern buildings (post-1970) have better foundations, but given the low replacement rate a substantial proportion of buildings will remain at risk.

The average increase in the number of houses suffering subsidence in regions with shrink-swell clay soils is projected to be about 17% by the 2050s under a p50 Medium emissions scenario. This ranges from a reduction of about 10% to an increase of about 30% for the range for climate change scenarios used in the analysis.

However, clay soils are relatively rare in Northern Ireland, the largest area being near Lough Neagh. Therefore, although subsidence was identified as an important impact for Northern Ireland, it is much less of a problem than in other parts of the UK.

![Geology of Northern Ireland](http://www.geographyinaction.co.uk/Geology%20files/Geol_index.html)

**Figure 14  Geology of Northern Ireland**

**Rainwater penetration, damp and condensation**

Increased levels of winter rainfall and wind-driven rain could result in an increase in rainwater penetration of buildings. This was highlighted as a concern for Northern Ireland, particularly for heritage buildings as there are a significant number of historic brickwork buildings in Northern Ireland. These types of buildings are more susceptible to water penetration than those constructed of sandstone (Cessar and Hawkins, 2007).

Increases in wind driven rain can raise the severity of expected rain penetration (e.g. from moderate to severe) to a level where a building’s external elements, materials or joints may no longer provide the precipitation resistance needed. This is particularly relevant where external walls do not have a suitable cavity or rain screen. Building...
materials selected for the external fabric of new buildings are designed and constructed for their resistance to potential rain penetration.

As part of the CCRA, an attempt was made to analyse the potential change in rainwater penetration of buildings in Scotland, based on projections for wind driven rain. The very simple analysis undertaken found projected changes to be minimal, although there was slight regional variation. Further information can be found in the Scotland Report (CCRA, 2012c). Wind driven rain for Northern Ireland is generally not as severe as Scotland and projections do not indicate that this would change. Therefore, it is reasonable to assume that rainwater penetration would not increase appreciably in Northern Ireland.

Rainwater and damp related damage to existing buildings is also considered important for Northern Ireland, not only for the damage it can cause to the fabric of the building, but it can also have consequences for respiratory health of the occupants (see Section 4.6.10).

Damp may be caused by cold houses (Wilkinson, 1999) and condensation or by warm, humid environments (Howieson, 2003). The Northern Ireland Housing Condition Survey (2009) indicates that 6% of Northern Ireland Housing Executive (NIHE) houses experience damp and 3% show incidences of rising or penetrating damp (Frey et al., 2011), caused by poor home standards including inadequate heating, poor insulation and ventilation.\textsuperscript{106}

The projected milder, wetter winters may lead to greater condensation and damp, which in turn would increase the risk of algal/fungal growth in buildings. This would not only result in a deterioration of the building fabric and decorations, but could also have health implications, as increased mould spores could exacerbate asthma and other respiratory disease (Trotman et al., 2004) (see Section 4.6.10). For households suffering from fuel poverty, this problem may be further exacerbated due to heating not being used to dry out properties (see Section 4.6.9).

The main climate driver for condensation, damp and mould is increased winter precipitation and subsequent higher humidity levels. Based on projected winter rainfall for Northern Ireland, this may become significant for Northern Ireland by the 2080s, but evidence is not available as yet to support this theory. More research is also needed to determine whether the risks of mould growth are greater in highly energy-efficient buildings, which have increased insulation but reduced air infiltration (Crump et al., 2009).

**Historic buildings**

Northern Ireland’s historic buildings are culturally important. However, as discussed above, due to construction methods, they are susceptible to damp and condensation. Historic buildings breathe, allowing moisture to pass through walls, doors and windows. Historic construction methods (heavy masonry/single glazing) can cause high relative humidity regularly promoting the formation of mould and damp. Modern housing improvements may exacerbate mould and damp in historic buildings. Modern moisture proof plaster or insulation traps moisture internally increasing the risk of damp and condensation (English Heritage, 2002).

Historic buildings commonly suffer damp problems arising from water ingress due to damaged gutters, downpipes, windows and roofing, causing decay within the traditional construction materials (Historic Scotland, 2007). An increase in extreme weather events may cause greater structural damage. Furthermore, milder winters may reduce

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\textsuperscript{106} An equivalent assessment of private homes and private rental accommodation is not available.
prolonged artificial warming of historic buildings (English Heritage, 2002) resulting in condensation and damp becoming more prevalent.

An increase in flood risk to historical and cultural buildings may have severe consequences, with not only the direct damage cause by flood waters and associated debris, but also an increase in dampness after the flood waters have subsided.

Conversely, the projected increase in summer and winter temperature may reduce the need for insulation within buildings and a reduction in average rainfall may prevent the application of waterproof renders and membranes allowing the historic buildings to function as intended. This could reduce damp and condensation problems within Northern Ireland's historic buildings.

This is a potential consequence of climate change that would benefit from further research.

4.5.2 Urban space

There are both opportunities and threats to urban space as a result of climate change. Increasing temperatures could lead to higher temperatures in cities caused by the 'Urban Heat Island' effect (see below). Increasing temperatures and reduced summer rainfall could also have impacts on urban green spaces and lead to changes in lifestyles with more outdoor living, for example more street cafes.

Green space

One of the main adverse consequences identified in the CCRA analysis is the effect of higher summer temperatures and reduced rainfall on urban green space, although this was not selected as a Tier 2 impact by Northern Ireland stakeholders. The capacity of green space to provide cooling benefits within urban environments may reduce, both as a result of temperature rise and a reduction in cooling from evapotranspiration of moisture. The landscape would also be affected as vegetation dries out.

The effect of climate change on the cooling benefit of urban green space was represented in the CCRA by a reduction in the effective area of green space, but it was only possible to undertake the analysis for England due to data availability. A reduction of about 15% by the 2050s rising to over 30% by the 2080s as projected for England (Medium emissions scenario p50). The analysis was based upon relative aridity scores. In Northern Ireland, relative aridity is projected to be between 2 and 5 (Low emissions p10 to high emissions p90 for the 2080s), which is not dissimilar to the figures projected for river basins in England. Therefore, a similar response may be expected for Northern Ireland.

Urban Heat Island (UHI)

The temperature at the centre of a large city can be several degrees higher than in the surrounding rural areas. Several factors contribute to the development of this urban microclimate. There is greater absorption and storage of short-wave solar radiation by the urban fabric during the day. This energy is then re-emitted at night as long-wave radiation. Surface water is typically drained away and is therefore not available for evaporative cooling. Anthropogenic heat emissions, such as exhaust air from air-conditioning systems, also act to increase the local air temperature. The magnitude of UHI effects is dependent upon the interplay of local conditions including land coverage, built form, wind regimes, cloud cover (see Section 2.4.5) and relative humidity (see Section 3.2.7)
In the case of London a UHI effect on night time temperatures of up to 9 °C has been recorded; in Manchester 5 – 10 °C and in Birmingham 5 °C. UKCP09 projections for the mean average summer night temperature would see an increase of the order of 2°C to 3 °C in 2050 (Medium emissions p50 scenario) across the UK; this would increase to 3 to 4 °C in the 2080 projections.

While a precise relationship between elevated night time temperatures during heatwave events and the magnitude of consequences for human health and comfort is unclear, these changes are likely to see present night time temperature thresholds for heatwave action exceeded more frequently by the 2050s.

Modelling of UHI effects across the UK is currently being undertaken by the Met Office Hadley Centre. This is still at an early stage, but early indications suggest that there may be a major effect in the Greater London and Greater Manchester areas by the 2050s. However, early indications suggest that there will not be a major effect in the Greater Belfast area (see the Built Environment Sector Report).

**Pests and waste disposal**

Pest infestations, particularly in urban areas, are another concern of Northern Ireland stakeholders. Little at present is know about how vulnerable urban spaces are to an increase in pest infestations as a result of milder, wetter winters. Insufficient data was available to undertake analysis as part of the CCRA.

The effect of climate change on waste disposal practices was also raised as an important issue by Northern Ireland stakeholders, with respect to:

- Leachate production, land degradation and composition;
- Flooding of site facilities;
- Vermin, odour, litter and dust;
- Pathogen activity;
- Subsidence and slope instability at landfills
- Types of flora and fauna covering or around facilities and choice of ecological communities used to restore landfill sites.

Climate change is set to have an impact on waste management within Northern Ireland. Northern Ireland’s ten landfill sites are likely to remain operational for 30-40 years and stay biologically active for a further 60-70 years, allowing projected climate changes to have a large impact on landfill waste (EA, undated).

With an increase in summer temperatures and a decrease in precipitation, it is likely that landfill sites will produce more dust and a greater odour. As many landfill sites are located in close proximity to housing, there could be an impact on the local community. Additionally, temperature projections indicate a more favourable climate for vermin (EA, Undated).

The effects of temperature on landfill are complex, but changes in gas production and settlement may occur. Landfill bacteria are temperature dependant therefore a large temperature rise (P90, 2080 scenario) may act to increase the volume of landfill gas produced significantly.

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Projected increases in winter rainfall and heavy rainfall days may have an impact through soaking and dispersing waste awaiting collection, changes in leachate production and concentration and altering the rate of decomposition, affecting the lifetime of the site.

Additionally, increased flooding through rainfall events can disrupt the infrastructure causing delays in waste collection and dispersing pollutants. Capping layers and bunds may be eroded and slope stability may be affected, increasing the chance of materials and pollutants being washed off site.\(^\text{109}\)

### 4.5.3 Built heritage

The built heritage\(^\text{110}\) of Northern Ireland is an important feature of the Province’s culture and landscape. Northern Ireland has:

- More than 1,800 scheduled historic monuments (including castles and abbeys)\(^\text{111}\);
- Over 16,000 archaeological sites; and
- More than 8,000 listed buildings.

Since 2003, there has been a modest increase in the number of listed buildings, with a total of 8,424 buildings recorded in 2009/10. In 2009/10, there were 445 listed buildings and structures classified as being at risk (DOENI, 2011). As well as the buildings themselves, the settings of many of these sites are also of significant cultural importance (see Figure 15).

All of the consequences of climate change described above are at least as important if not more so for Northern Ireland’s built heritage. In addition, coastal erosion, although not considered a significant issue for Northern Ireland as a whole, and, therefore, not assessed in detail, is a particular concern for a number of built heritage sites and their surrounding landscape (whether natural or designed). Examples include:

- Dunluce Castle in County Antrim - The castle was abandoned in the 17\(^{\text{th}}\) century when the kitchens fell into the sea. The cliffs are still being eroded.

- Mussenden Temple at Downhill Castle near Castlerock – Since it was built over 200 years ago, the erosion of the cliff face has brought the building ever closer to the edge of the 40m cliff. In 1997 the National Trust carried out cliff stabilisation work to prevent the loss of the building.

\(^{109}\) [http://www.energysavingtrust.org.uk/nottingham/Nottingham-Declaration/Local-Services/Waste-and-Recycling/Disposal/(tab)/1]

\(^{110}\) This is buildings and structures that are considered architecturally, historically (including archeologically) or culturally important.

\(^{111}\) A total of 1,853 scheduled monuments based on 2009/10 figures (DOENI 2011).
Sand dune retreat caused by coastal erosion would also put at risk some of the most archaeologically rich dune systems in Northern Ireland: Grangemore, Portstewart, Portrush, White Park Bay and Dundrum. All of these sites have important Neolithic, Bronze Age and later archaeological deposits (CMA, 2011).

Built heritage and archaeological features can also be found within and adjacent to rivers, loughs, canals, bogs and marshland. Based on current climate projections, these sites would also experience wetter winters, drier summers and increased risk of flooding, including damaging flash flooding.
Figure 15  Built Heritage in Northern Ireland

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4.5.4 Summary of results for buildings, urban space and built heritage

Many of the potential risks for buildings, urban space and built heritage in Northern Ireland cannot be assessed at present, because the data is not available or the risks are intrinsically too uncertain.

However, based on future projections for rainfall and sea level rise and evidence available for other parts of the UK, flooding may become the greatest single climate change concern for buildings, urban space and built heritage in Northern Ireland. The PFRA should help to estimate future flood risks for Northern Ireland (see Appendix D).

The results of the analysis are summarised in Table 4.13.

The potential threat identified with the highest consequences by the 2080s is effectiveness of green space for cooling (BE5). However, we only have low confidence in these projections for Northern Ireland as these are based on analysis undertaken for England.

Overheating of buildings (BE3) and condensation, damp, mould, algal/fungal growth in buildings (NEW) are only projected to have a medium negative consequence by the 2080s. These have only been given a low confidence due to the limited evidence available for Northern Ireland on which they are based.

Both subsidence (BE5) and rainwater penetration (NEW) are projected to have low negative consequences. Projections for subsidence have a low confidence as this has been simply based on the limited extent of clay soils in Northern Ireland. Projections for rainwater penetration also have a low confidence, as these are based on results for Scotland.

Projections for the Urban Heat Island effect are not provided as this is too uncertain to determine except on a site by site basis. However, this is not anticipated to be a significant problem for Northern Ireland.

Several potential threats related to flooding could not be assessed due to lack of data. However, DARD Rivers Agency has recently completed the preliminary flood risk assessment for Northern Ireland, which included an assessment of the extent of potential flood risk for commercial and residential properties. Publication of maps showing areas that have the most significant flood risk is scheduled by December 2011. Further information is provided in Appendix D.

The remaining potential threats were also not assessed due to lack of data.
### Table 4.13 Climate change consequences for buildings, urban space and built heritage

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<td>Overheating of buildings</td>
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<td>BE1</td>
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<td>Flood damage to cultural heritage</td>
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<td>Flood risk for Scheduled Ancient Monument sites</td>
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*Coverage of analysis  **Method of analysis*

NI Analysis undertaken for Northern Ireland only   IJ Informed judgement
UK Analysis undertaken for the UK                 Q Quantitative
4.5.5 Transport

Road network

Northern Ireland is highly dependent on its road network (25,000 km in total). Due to the dispersed nature of the population, there is about 2.5 times the kilometres of road per capita compared to the average for the UK. The majority of these roads are rural. Unclassified roads account for 60% of all roads, compared to 0.5% are motorways (Arkell et al., 2007). All freight in Northern Ireland is moved by road transport.

Flooding and coastal erosion

Flooding is anticipated to be the most significant impact on the road network. The consequences of a severely disrupted road network due to flooding were demonstrated in the 2009 floods in Fermanagh, where businesses and communities within and beyond the flood extent were affected (see section 5.2.3).

There are very few primary routes along the coastline in Northern Ireland. Therefore, sea level rise should not result in significant transport disruption across the Northern Ireland road network, but it may result in increased frequency of localised flooding. For example, areas around Strangford Lough and the Outer Ards peninsula already have roads that become impassable or dangerous following high tides, strong winds and heavy rain.

Increased intensity of rainfall events in the future may lead to excess surface water and localised flooding, which could have an impact on road safety.

Figure 16 Regional Strategic Transport Network
Source: DRD (2005)\textsuperscript{112}

\textsuperscript{112} Regional Strategic Transport Network Transport Plan
The consequences of coastal erosion on the transport network were not considered as a priority impact. However, there are notable scenic coastal routes, such as the Antrim Coast Road, which could be affected (see Box 10).

DARD, Rivers Agency has recently completed the preliminary flood risk assessment for Northern Ireland which included an assessment of the extent of potential flood risks to the transportation network, taking into account climate change. This has included the gathering and sharing of flood risk information with the NI Transportation Authorities and other stakeholders. Further information is provided in Appendix D.

Bridge scour

Bridge scour is often associated with flooding and is, therefore, an area of concern. Scour is the term used to describe the movement of riverbed sediment as a response to the shear forces associated with flowing water in the presence of a hydraulic structure, such as a bridge.\textsuperscript{113} Bridges built with footings in rivers and estuaries are at risk of scour occurring around these foundations. If the development of scour at these foundations becomes significant, then the stability of the foundations may be threatened and there is associated danger of structural damage or failure. In the last 10 years there have been at least 7 road or rail bridge failures in the UK and one fatality. Older bridges (especially pre 20\textsuperscript{th} century) tend to be more vulnerable to scour; major modern bridges are rarely vulnerable due to advances in structural design and understanding of scour.

The CCRA analysis looked at scour under conditions of changed flood risk (see Transport Sector Report). The rate of increase in scour would be dependent on local conditions, namely the construction of the bridge, the hydrodynamics of the flowing water and characteristics of the river bed. Gravel beds present a greater risk than sand beds. Table 4.14 shows the projected increase in scour for piers and abutments in both sand and gravel beds. A 10\% increase in peak flow may be exceeded by the 2020s, based on current climate change projections. A 30\% increase in peak flow may be reached by the 2080s (see Section 3.2.10).

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<tr>
<td>20</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>30</td>
<td>9</td>
<td>5</td>
</tr>
</tbody>
</table>

For an armoured bed, the increase in scour can be dramatic once the armour layer is eroded. However, the effects of bed armouring are still an uncertain science. Therefore, these projections should only be considered as indicative. Despite this, it was possible for the CCRA analysis to conclude that, based on currently projected climate change, some bridges that are currently classed as being adequately protected from scour would be moved into the scour critical category. However, at present there is insufficient data available to estimate the number of bridges that may be affected in this way.

It should be noted that bridge failure due to flooding may not necessarily be scour related. Structural failure can also be caused by the bridge being hit by floating debris such as vehicles; the washout of masonry and fill material due to poor maintenance; or through a combination of these.

\textsuperscript{113} Where sediment is moved irrespective of a man-made structure this is usually termed erosion.
Slope stability and subsidence

Slope stability is also a particular area of concern. Landslips and associated ground instability are common features around the edge of the basalt plateau in Counties Antrim and Londonderry (ed. Creighton, 2006). The Antrim Coast Road suffers from numerous road closures due to the rock faces, slopes and sea-defences suffering from erosion and landslips (see Box 10).

The incidence of landslips is anticipated to increase with increased winter rainfall, but based on the central estimate (p50) for the Medium emissions scenario the likelihood of such an increase is relatively low for Northern Ireland. The length of road at risk is projected to remain at current levels (125km per year) until the 2080s. It would only be under the conditions of the High emissions scenario (p50 and p90 projections) or the upper estimate (p90) Medium emissions scenario that the length of road at risk would increase significantly to approximately 250km per year. However, these estimates are based on the detrimental effect of increased rainfall on slope stability alone and should only be considered as indicative. Land management practices can also have a significant effect on slope stability in many locations.

Subsidence has not been considered as a significant issue by the CCRA. It is generally managed effectively as part of existing road maintenance programmes. Therefore, subsidence or low level ground movement is not quantified or reported separately from general road condition. Hence, data is not readily available to undertake analysis.

Higher temperatures

Thermal loading may have an impact on the life of the bituminous surfacing of roads and result in increased maintenance costs. The overall costs likely to be incurred as a result of thermal loading on roads is estimated to be relatively modest for Northern Ireland, when compared with the costs associated with flooding for example. However, this is based on seasonal average temperatures. A better estimate might be derived by considering extreme temperatures. Also, the analysis undertaken by the CCRA did not cover the associated disruption to transport arising from road damage and repairs.

Warmer winters on the whole would benefit road users, as disruption and delay caused by snow and ice would probably reduce. However, there would remain issues associated with repeated freezing and thawing of the road surface, which would have implications for maintenance.

Comfort of travellers and transport staff due to high temperatures is also expected to be affected. A consequence of this could be additional fuel usage needed to provide air conditioning in cars. However, analysis indicates that this is likely to pose a very low risk in Northern Ireland.

Future road usage

Road usage may change in the future for a number of reasons that may or may not be related to climate change. For example, it may increase due to economic growth or a growth in domestic tourism and outdoor activities; it may decrease due to fuel prices. To date, road usage in Northern Ireland has increased mostly as the result of increases in personal wealth. Car ownership increased by 53% between 1992 and 2004 and vehicle use (specifically cars, taxis and vans) nearly doubled between 1993 and 2003. Car ownership in Northern Ireland has now reached levels similar to the rest of the UK (DRDNI 2010).
Box 10: Landslips along the Antrim coast

The Antrim coast is currently at risk from coastal erosion and flooding, landslips and associated ground instability. Increases in sea level and heavy rainfall events may further exacerbate these problems.

The A2 coastal route runs from Derry to Newry. Owing to its length and the fact that it follows the coast, the A2 passes many of Northern Ireland’s most popular tourist attractions, including Carrickfergus Castle, the Old Bushmills Distillery, Dunluce Castle and the Giant’s Causeway, as well as the stunning scenery of the Mourne Mountains and the Glens of Antrim. The Antrim Coast Road is regarded as one of the most scenic drives in Northern Ireland. The A2 also passes through Larne, which is one of the busiest ferry ports in the UK.114

Landslips and associated ground instability are common features around the edge of the basalt plateau in Counties Antrim and Londonderry, where they contribute significantly to the character of the landscape (Creighton 2006). These fall into the following categories: rotational landslips; mudflows and debris flows; and rock falls.

Mudflows and debris flows are a significant hazard along parts of the Antrim Coast Road. These flows have periodically blocked the road at Minnis North south of Glenarm and are commonly triggered by ground saturation following periods of heavy rainfall. (Creighton 2006)

Rock falls are also an ever present hazard along many parts of the County Antrim coast, especially where the road and rail routes run along the narrow strip of land between the shore and the edge of the basalt plateau. Rock falls have been a regular occurrence on the Antrim Coast Road where steep and overhanging basalt faces require ongoing management.

Along the north coast, the Belfast to Londonderry rail track, which runs on a narrow coastal strip between Castlerock and Downhill Strand, has been particularly vulnerable to rock falls. On Tuesday 4 June 2002 a rock fall derailed a passenger train at Downhill. All three coaches were derailed, but only eight people (out of a total of 22 passengers and 2 crew members), including the driver, were admitted to hospital for treatment. The train struck a large boulder that had fallen from the nearby cliff face onto the track. The train was travelling at 60mph. At the site of the accident, the rail line runs on an embankment beside Downhill beach. The A2 Coast Road runs parallel to it on the landward side and was also closed due to the rock fall. Beside and above the road, the cliff face is between 40-50 metres high.115

These coastal routes are also at risk from coastal erosion and sea level rise. Sea defences have been washed away along this coastline fairly recently, for example along the A2 at Ballygalley.

Should climate change result in an increased frequency of events like this or increase the number of locations where this might occur, this would have consequences for all of the communities located along this route. Any management of this risk needs to be sensitive to the geological, biodiversity and cultural implications of any actions, as well as enabling businesses and communities to continue to prosper.

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114 Alternative routes are available for Larne. The A2 is not the primary route.
115 http://www.niassembly.gov.uk/record/reports/020610.htm#2
Rail network

There are only approximately 360 km of track in Northern Ireland. The rail network mainly serves the eastern half of the Province, providing commuter rail services for Greater Belfast, the North West and the cross-border link with Dublin.

Flooding

Flooding is anticipated to increase damage and disruption to the rail network in the future. Projections of the extent of the rail network in the UK at risk from flooding in the future have not been determined as part of the CCRA. There are only two stretches of railway line along the coast in Northern Ireland: the Belfast to Larne line along Larne Lough and the Belfast to Derry line between Coleraine and Derry. Sections of both lines fall within the 0.5% probability (1 in 200 year return period) tidal flood extent under present day conditions, although some of the line to Derry is behind flood defences. The inland railway lines often follow river valleys and where this is the case they are often within the present day 1% probability fluvial flood extent. The consequences of coastal erosion on the transport network were not considered a priority impact by stakeholders.

Rail buckling may increase in the future with higher summer temperatures. Analysis undertaken for Great Britain indicates that the future costs associated with rails buckling could be substantial with the annual mean number of rail buckles increasing from 50 (based on 1995 to 2009 figures) to 185 by the 2080s. However, this would probably be classed as a low to medium risk compared to other risks for the transport network. Data was not available to undertake a similar analysis for Northern Ireland.

Slope stability will also be an issue for the rail network (see Box 10). However, analysis of this has been limited to the road network (see Road Network above).

Bridge scour will also be an issue for the rail network (see Road Network above).

Ports

It is important that Northern Ireland protects the supply routes for its imports and exports, especially via its port operations. The recent integration of Northern Ireland into the logistics chains of the major UK supermarkets has only increased the dependency on sea freight.

There are 5 commercial ports in Northern Ireland. Four of these are public trust ports (Belfast, Derry, Warrenpoint and Coleraine) and collectively handle 84% of seaborne trade (95% of Northern Ireland’s external trade). The remainder is handled by the privately owned port of Larne. Approximately 27 million tonnes of cargo, 2.1 million domestic sea passengers and 36 cruise ships passed through these ports in 2009. In addition, there are 3 main fishing ports at Portavogie, Ardglass and Kilkeel (Gibson 2011).

To date very little work has been carried out to assess the impacts of climate change on ports and shipping. However, a scoping report on behalf of Associated British Ports (ABPmer 2007) identified a number of potential consequences for ports resulting from marine climate change. The main issues highlighted related to the following:

- Delays, closures of ports and prevention of port activities arising from flooding and severe weather;
- Damage to infrastructure and cargo from flooding and severe weather; and

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116 Based on the Medium emissions scenario.
- Changes to sedimentation and tidal patterns leading to increases in the costs of maintaining navigation channels.

Feedback received from the ports industry as part of the CCRA analysis indicated that climate change risks are not considered to be substantial in the near to medium term. Ports can tolerate some degree of flooding. Therefore, sea level rise is not a major concern. In addition to this, neither wind nor storminess is projected to increase (see Section 2.4.6) although there is a high degree of uncertainty regarding this. Therefore, projections for port operational downtime have not been determined as part of the CCRA.

A number of studies have attempted to assess the potential impact of future climate change on the operation of roll-on-roll-off ferries throughout Europe, including an assessment of the sensitivity of ferry services to the Western Isles of Scotland to changes in wave climate (Woolf et al., 2004; Weisse et al., 2009), but these do not go as far as providing projections of future disruption. Further information regarding Scotland can be found in the Marine & Fisheries Sector Report and in the Scotland Report.

There are also gaps in understanding regarding:

a. The potential scale of the knock-on effects of port disruption (even if this is considered as having a low likelihood); and

b. The indirect consequences for ports as commercial businesses in a future economy affected by climate change. This includes the international dimension regarding climate change impacts on transportation hubs in other parts of the world and subsequent trading routes, in particular sea freight. This could offer up opportunities as well as threaten business in Great Britain and Northern Ireland. However, understanding of the extent of this is very limited (Foresight, 2011).

### 4.5.6 Water

Northern Ireland depends very heavily on surface water. Lough Neagh, for example, provides 50% of the raw water for Northern Ireland. In total, 95% of Northern Ireland’s water supply comes from reservoirs, loughs or rivers. The remaining 5% comes from boreholes.117

**Box 11: Northern Ireland Water Assets**

<p>| | |</p>
<table>
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<th></th>
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</thead>
<tbody>
<tr>
<td><strong>40</strong></td>
<td>impounding reservoirs</td>
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<tr>
<td><strong>44</strong></td>
<td>major water treatment works (65 in total)</td>
</tr>
<tr>
<td><strong>1,124</strong></td>
<td>wastewater treatment works</td>
</tr>
<tr>
<td><strong>287</strong></td>
<td>water pumping stations</td>
</tr>
<tr>
<td><strong>1,194</strong></td>
<td>wastewater pumping stations</td>
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<td><strong>26,500</strong></td>
<td>kilometres of water mains</td>
</tr>
<tr>
<td><strong>14,500</strong></td>
<td>kilometres of sewers</td>
</tr>
</tbody>
</table>

Potential climate change impacts for the water sector include:

- Availability of water
- Water abstractions
- Energy supply
- Flooding of water infrastructure
- Impounded water bodies
- Water quality

These are discussed below. There remain a number of other potential consequences for the water industry, including wastewater treatment processes, which have not been discussed here as they were not selected for the Tier 2 list of impacts for either the UK or Northern Ireland. Further details of other consequences can be found in the Water Sector Report.

**Availability of water**

The most significant issue for the water industry in the future will be the availability of water. Water availability in the summer is projected to reduce as a result of rising temperatures and reduced precipitation. Whilst little change is projected in overall annual precipitation, in combination with projected increases in temperature and demand, this would mean than the overall availability of water would reduce.

Estimates of changes in water availability based on Deployable Output, supply demand deficits and population affected by shortage of supply are shown for each river basin area in the figures below. Although two of the river basin areas are trans-boundary areas with the Republic of Ireland, the following projections relate to the areas that fall within Northern Ireland only.

Deployable outputs are projected to reduce by 104Ml/day by the 2050s from the present day baseline of 758Ml/day. Reservoir yields were identified as a specific aspect of deployable outputs that was important for Northern Ireland. However, separate analysis has not been carried out for this. The projected deployable outputs for the three river basin areas in Northern Ireland are presented in Figure 17. These are based on baseline figures provided by NI Water in its Water Resource Management Plan (draft 2010).

At present there is a water supply surplus in Northern Ireland of approximately 51 Ml/d. Figure 18 shows the projected water supply surplus or deficit. These projections are based on the assumption that there is no sharing between river basin areas. Based on the Medium emissions scenario, by the 2050s the North Western Ireland basin would have a slight deficit of 4 Ml/d, the Neagh Bann basin would have a surplus of 15 Ml/d and the North Eastern Ireland basin would have a deficit of 19 Ml/d. By the 2080s, each of the three river basin areas would have a water supply deficit, with a combined deficit of 59 Ml/d based upon the medium emissions scenario p50 projection.

The projections in Figure 19 show that about 1.49 million people in the three river basins (84% of current population) could potentially be living in areas affected by water shortages by the 2050s, although the uncertainty associated with these estimates is
large. If the projected increase in population\textsuperscript{121} is factored in, then about 2.1 million people would be living in areas affected by water shortages by the 2050s.

\textsuperscript{121}Principal population.
There is likely to be an increasing risk of drought in future warmer drier summers. Whilst measures will be taken in the future to adapt to changing water availability, drought is considered to be a major potential future risk. This is supported by the aridity projections (see Section 3.2.3).

The overall impact on water supplies will be strongly affected by adaptation measures (for example, increased water storage) and changes in regulation and water use.

By 2050 household demand for water is projected to increase by around 4% for the Medium emissions scenario p50. This increases further by the 2080s to 5%.

**Water abstraction for industrial use**

The amount of water that can be abstracted for public water supply, agriculture and industry is sensitive to the annual water balance and subject to changing licence conditions. Data was not available for Northern Ireland, but based on data for England and Wales, water abstraction may become unsustainable in a large proportion of UK rivers, due to low summer flows (Water Sector Report). A shift in seasonal and/or total availability of water resources, as a result of climate change, has the potential to have significant impacts on industry in the UK.

Industrial abstraction should be viewed in the context of other abstraction sectors, as changes in water resource availability will have an effect on the way in which all abstraction is regulated. The responses and adaptive approaches of other sectors, (especially that of public water supply, as the dominant sector), will determine the extent of any effect on industrial abstraction. Industrial demand is a relatively small proportion of overall water demand in Northern Ireland. Therefore, it is more likely that adaptive measures or regulation will have a greater impact on water supplies for industry. A particular concern is the need for increased cooling requirements for industrial machinery. Not only would this require greater water abstraction, but waste water could cause additional environmental impacts on biodiversity (see section 4.2.2).
There are also concerns regarding the disposal of solid and liquid wastes due to lower river flows.

See Section 4.3.1 for information regarding increasing water demands from agriculture.

**Energy supply for the water industry**

Northern Ireland Water is the largest electricity consumer in Northern Ireland and is dependent on an uninterrupted supply, as it only has the capacity to continue operations for six hours using emergency generators. Therefore, any disruption or failure of the energy supply in Northern Ireland has severe consequences for water supply. Also any increase in demand from the water sector would have consequences for the energy sector.

**Flooding of water infrastructure**

An increase in flooding in the future would also lead to an increase in risk of damage to water supply infrastructure. This in turn would affect water supplies and potentially lead to failures of supplies, as occurred in England during the 2007 floods. This has not been quantified in the CCRA analysis owing to a lack of suitable data. The PFRA, however, goes some way to address this (see Appendix D).

**Impounded water bodies**

It has been estimated that there are 156 impounded water bodies in Northern Ireland with a capacity greater than 10,000 m³. Approximately 65 of these are in private ownership. Northern Ireland currently does not have legislation for the management of reservoir safety, which means that detailed structural assessments are not available or readily derivable. Without these, it is not possible to accurately determine significant flood risk from reservoirs.

DARD, Rivers Agency has produced inundation maps that estimate the potential impact of reservoir failure. From these we have identified Reservoir Risk Areas. It was estimated that in excess of 66,000 people are located in areas that could potentially
flood from a reservoir failure. DARD, Rivers Agency is currently taking forward Northern Ireland legislation for the management of reservoir safety.

The preliminary flood risk assessment for Northern Ireland has included an assessment of the extent of potential flood risks from impounded water bodies, taking into account climate change. This has included the gathering and sharing of flood risk information with NI Water and other stakeholders. Further information on the PFRA is provided in Appendix D.

**Water quality**

The potential consequences for the water industry of a deterioration in raw water quality are also important, including increased costs associated with water treatment. Raw water quality is discussed in detail in Section 4.2.2, but the knock-on effects for the water industry have not been assessed as part of this first CCRA.

### 4.5.7 Energy supply

Potential climate change impacts for the energy sector include:

- Disruption caused by increased flooding
- Effects of heat on the transmission and distribution network
- Costs and disruption from international suppliers
- Water availability for power generation
- Changes in demand, particularly for heating and cooling

These could have indirect consequences for those suffering from fuel poverty, should energy prices increase as a result (see Section 4.6.9).

Other climate change consequences for the energy sector, such as heat related damage or disruption, power station cooling and turbine efficiency, were not considered high priority for Northern Ireland and, therefore, are not discussed here. However, more information is available in the Energy Sector Report.

It should also be noted that the CCRA analysis did not look at climate change impacts on primary energy sources (oil, gas, coal, nuclear, etc.) The focus of the analysis was on generation/production, transmission and distribution and supply/demand. The impacts of climate change on renewable sites were only included in the analysis for flooding (hence only for England and Wales). Other impacts on renewables were not considered high enough priority to be included on either the UK or Northern Ireland Tier 2 lists.

Figure 20 shows the energy infrastructure for Northern Ireland. Northern Ireland has three major electricity generating stations: Ballylumford and Coolkerragh, which are gas fired, and Kilroot, which is coal and oil fired. Currently, approximately 6% of power generation in Northern Ireland is from renewable sources (nearly all of this is wind generated)\(^ {122} \) and the target is for this to increase to 40% by 2020, coupled with an overall energy consumption reduction of 1% per annum.

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Flooding

All of the main electricity generating stations are located on the coast. According to the Strategic Flood Map\textsuperscript{124} only one of these (Coolkeeragh) is in the floodplain. However, the vulnerability of all 18 electricity substations to flooding is currently unknown.
Transmission and distribution

Northern Ireland has an aging transmission infrastructure, especially in the west and north, with a predominance of overhead transmission. Elements of the transmission and distribution network are over 30 years old. These are less likely to be affected by flooding, but increases in temperature could affect the efficiency of electrical transmission and distribution systems resulting in the de-rating of equipment and reduction in capacity. This in turn would mean that it would be more costly for the supplier to deliver the same amount of energy to customers and these costs would at least in part be passed on to the customers. Network capacity losses due to de-rating of overhead power lines are projected to be between 1% and 5% by the 2080s for the transmission network and between 1% and 19% by the 2080s for the distribution network, across the UK. Regional projections, however, suggest that relatively small percentage change would occur in Northern Ireland (Energy Sector Report).

Box 12: Electricity supply in Northern Ireland

The electricity supply industry in Northern Ireland was privatised in 1993 with one company responsible for procurement, transmission, distribution and supply. Most of Northern Ireland’s electricity is provided by two private companies (namely Coolkeeragh ESB and AES) who own three power stations in total.

There are also interconnectors with Scotland (500 MW capacity) and the Republic of Ireland (600 MW). The link between the Northern Ireland grid and that of the Republic of Ireland was re-established in 1996. In 2007 the two grids were fully integrated and a joint body (Single Electricity Market Operator) was set up to oversee the new market. Northern Ireland’s grid was also linked with Scotland in 2001 (DECC 2010).

The All-Island Project125 aims to create a single market for electricity and natural gas on the island of Ireland. The Single Electricity Market126 is the first part of this process.

Reliance on international fossil fuels

Currently Northern Ireland’s main power stations are reliant on imported fossil fuels. The future viability of this supply may be affected by future global and local impacts of climate change and this represents an area where further research is required.

Northern Ireland is at ‘the end of the pipeline’ in Europe for natural gas, and would be affected by disruption of the gas supply from countries such as Russia. This is compounded by the lack of gas storage available in Northern Ireland. The international energy market is changing as reserves (such as those in the North Sea) are being depleted and greater reliance is being put onto a smaller number of large reserves. This is resulting in longer supply chains and the longer the supply chain, the greater the vulnerability of that supply chain to disruption and associated cost implications (either derived from increased operational costs or market forces). Examples of disruption caused by climate change include the thawing of permafrost impacting on trans-Russian and trans-Alaskan pipelines. In the future, this may affect the prices and security of UK energy and fuel imports (Foresight, 2011).

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125 http://www.allislandproject.org/
126 This consists of a gross mandatory pool market, into which all electricity generated or imported onto the island of Ireland must be sold, and from which all wholesale electricity for consumption on or export from the island of Ireland must be purchased.
Box 13: Natural gas in Northern Ireland

The first natural gas pipeline for Northern Ireland was completed in 1996, from Portpatrick in Scotland. Initially this was to supply Ballylumford power station, which was converted from oil. A second gas-fired power station was built at Coolkeeragh in 2005. In 2007, the South-North gas pipeline was completed to allow gas to be imported from the Republic of Ireland. In 2009, 76% of all gas supplies in Northern Ireland were for generating electricity. The onshore line is still being extended to serve wider industrial, commercial and domestic markets (DECC 2010).

Water for cooling

Water is required for cooling of power stations. If temperatures rise, the amount of water required for power station cooling would change as the water becomes warmer. More water would be needed to achieve the same amount of cooling. If water quantities were not increased, there would be a reduction in generation capacity. As all of Northern Ireland’s power stations are on the coast, this would mean that there would be an increase in demand for water from the sea or estuaries, rather than inland sources. Therefore, the consequences of this will be limited to within energy sector and not affect the water sector.

Demand

If temperatures rise, the demand for energy to provide cooling (for air conditioning of homes, offices, factories, ICT, etc.) may increase, although this is unlikely to be significant for Northern Ireland based on projections for cooling degree days (see Section 3.2.2). Actual future cooling demand is also likely to be highly dependent on a number of other factors, including the extent of future uptake of cooling systems and changes in building design (although the scale of this is limited by the turnover in building stock). In turn, these factors will be influenced by the measures taken to achieve a low carbon future and economic growth.

Currently the total demand for electricity is much higher in the winter than the summer due to heating and lighting requirements. Projections of future demand for electricity in Northern Ireland were not determined due to lack of data. Analysis for Great Britain indicated that winter demand would continue to be higher than summer demand and this is also likely to be the case for Northern Ireland. Based on projections for heating degree days, however, a significant reduction in total energy demand for heating is anticipated for Northern Ireland by the end of this century (see Section 3.2.2). The implications of this on fuel poverty in Northern Ireland are discussed in Section 4.6.9.

Some of the projections related to energy supply are uncertain because of the current transition to a low carbon economy, both in terms of generation and demand. Northern Ireland has a particularly large potential for onshore and offshore wind energy generation. A large shift in types and locations of power generation and, hence, transmission grid, may alter the scale and source of climate change impacts for the energy sector.

4.5.8 ICT

According to a recent study (Horrocks et al., 2010) the UK is heavily reliant on the effective functioning of the Information and Communication Technologies (ICT) and there remains substantial scope of growth in this dependency. The report concluded that the majority of devices (computers, mobile phones, etc.) typically used in the UK already have operating tolerances that will accommodate the projected temperature
changes, provided they are installed and maintained appropriately. It is the enabling infrastructure (both below and above ground) that is vulnerable to the weather conditions surrounding it, which can have consequences for service provision. ICT infrastructure is already vulnerable to extreme weather damage or disruption and increasing temperatures (particularly heatwaves) and more frequent flooding are the main areas of concern for the future.

ICT (both the devices and infrastructure) is also dependent on energy supplies and any disruption of this sort would have direct consequences for ICT systems. In addition, energy demands for ICT would increase with increased air temperatures, for example, cooling requirements of data centres. The siting of data centres may become increasingly dependent on access to cool air for free air cooling systems (Horrocks et al., 2010). This may present opportunities for the cooler regions of the UK, such as Northern Ireland.

The ICT industry is of the general view that the broader ICT infrastructure is relatively resilient to disruption because the communications grid is much more distributed (than, for instance the energy grid) as a variety of technologies are being used. Very few impacts would be expected to affect the entire national ICT network. The majority of impacts would cause disruption at the level of individual organisations or local geographical areas. Some of the more remote parts of Northern Ireland may be particularly vulnerable, where the network is limited.

It is estimated that about 80% of businesses are ‘heavily dependent’ on ICT, and therefore any disruption would have immediate effects. It has not been possible to provide an estimate of the number of days that might be lost due to disruption to ICT owing to a lack of suitable data. However, the risk of major ICT disruption due to climate change is considered to be relatively low for large businesses, as they are often based in large urban centres and have flexibility in managing their ICT systems. Smaller companies (including SMEs) and remote workers, on the other hand, are much more vulnerable to ICT disruption and the knock-on effects are greater. This is because they are often dependent on a single link which, if it fails, causes a complete loss of service. Further discussion of SMEs is provided in Section 4.4.3.

An increased dependence on ICT services during extreme events, such as people either choosing or forced to work at home (as experienced during the winters of 2009 to 2011), would also add to the difficulties for the industry in providing a high quality, uninterrupted and reliable service. For example, the limited mobile network coverage in Fermanagh was identified as a problem during the flooding in 2009.

The important role that ICT will play in enabling the UK to move towards a low carbon economy, such as ‘smart-meters’ and operation of remote renewable energy generation sites, will also add to our dependency on these services.

### 4.5.9 Summary of results for infrastructure

There is potentially a significant opportunity for Northern Ireland related to reduced energy demand for heating, although this may be offset slightly by a projected increased demand for cooling.

As well as demand for cooling, the most significant threats that have been identified by this assessment relate to water availability for public water supply and performance of sewerage (indicated by an increase in combined sewer overflow spill frequency).
However, many of the potential risks for infrastructure in Northern Ireland cannot be assessed at present, because the data is not available or the risks are intrinsically too uncertain.

Based on future projections for rainfall and sea level rise and evidence available for other parts of the UK, flooding may become a significant climate change threat for infrastructure in Northern Ireland. The PFRA should help to estimate future flood risks for Northern Ireland (see Appendix D).

The results of the analysis are summarised in Table 4.15.

Compared to other themes, a relatively large proportion of projections for infrastructure have been given a medium confidence, as the assessment has been based on reasonably robust evidence.

The potential opportunity of reduced energy demand for heating (BE9) has only been given low confidence because projections are based on analysis for Great Britain.

The potential threats that have only a low confidence are:

- Combined sewer overflow spill frequency (WA10), due to the simplistic analysis approach adopted.
- Potential disruption to shipping due to rough seas (MA7), as these is high uncertainty whether seas will get rougher in the future.
- Water abstraction for energy generation (EN4), as this is based on UK analysis and there is limited confidence that this is applicable to Northern Ireland.
- Household water demand (WA4) is based on analysis for England and Wales, which may be inaccurate for Northern Ireland as the provision of domestic water is managed and charged differently in Northern Ireland.

Loss of productivity due to ICT disruption is too uncertain to provide projections, as discussed in Section 4.5.8.

The remaining potential threats have not been assessed due to lack of suitable data for analysis.
Table 4.15 Climate change consequences for infrastructure

<table>
<thead>
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<th>Threats</th>
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<tr>
<td>Energy demand for cooling</td>
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<td></td>
<td></td>
<td>NI</td>
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<tr>
<td>Population affected by water supply-demand pressures</td>
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<td></td>
<td></td>
<td>NI</td>
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<td>Reduction in water available for public supply</td>
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<td></td>
<td>NI</td>
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<tr>
<td>Population affected by water supply-demand pressures</td>
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<td>NI</td>
<td>U</td>
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<tr>
<td>Energy transmission efficiency capacity losses due to heat - over ground</td>
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<td>NI</td>
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<td>Algal growth in raw water supply sources</td>
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<td>Change in reservoir yields for public water supply</td>
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<td>Key workers unable to get to work due to extreme events</td>
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**Coverage of analysis**

- **NI**: Analysis undertaken for Northern Ireland only
- **UK**: Analysis undertaken for the UK

**Method of analysis**

- **IJC**: Informed judgement
- **Q**: Quantitative
4.6 Health and wellbeing

Northern Ireland has a population of about 1.8 million people. This is projected to rise to about 2.044 million by the 2080s (range 1.143 to 3.107 million). Climate change may affect Northern Ireland’s population in the home, the workplace and at the community level.

The impacts of climate change on human health in Northern Ireland may include:

- Higher temperatures, causing both benefits (warmer temperatures in winter) and adverse impacts (higher temperatures in summer);
- Increase flooding from sea level rise, higher winter precipitation and more intense summer storms;
- Changes in both air and water pollution.

The emergency services are also likely to be particularly affected by climate change, as they are required to respond to emergencies including floods and fires, both of which are projected to increase.

Human health effects of climate change are likely to have the greatest impact on vulnerable people, particularly those in poor socio-economic conditions (see section 1.6.5). The health effects of climate change on vulnerable people are likely to be disproportionately severe because of their limited ability to cope. A study across eleven European countries showed that high excess mortality among the elderly population of lower socio-economic status (as measured by education and housing tenure) constitutes an important health problem for Europe (Huisman et al., 2005).

The effects of weather and climate on human health have been widely researched and are relatively tangible. Because of this, the CCRA analysis has focused on health related impacts, which is reflected in the following sections.

Wellbeing is a much broader concept and more difficult to measure. It can relate to (NEF, 2011):

- External conditions, including economic conditions that affect income and material wealth, the places that people live and work and access to green space and the natural environment.
- Personal resources, including people’s physical and mental health, resilience or ability to recover from extreme events, knowledge and personal outlook.
- Functioning and satisfaction of needs, including awareness and ability to plan for and respond to risks, staying safe and secure and being part of the local community.

Some of the conditions that affect these aspects of wellbeing have been covered by the previous themes in this report. In summary, future wellbeing is most likely to be influenced by the following projected changes in climate: warmer summers (both positively and negatively), warmer winters (positively), increased flooding and other extreme events (negatively). Methods for measuring wellbeing directly are still in their infancy, so it is not yet possible to link climate change directly to these measures. A number of issues linked to wellbeing were identified by Northern Ireland stakeholders, namely:

- The effects of flooding on communities;
Population migration; and

Fuel poverty.

The contrasting effects of flooding on communities in Belfast and Fermanagh are discussed in Section 5. The remaining two issues are discussed in this section.

4.6.1 Flooding

If flooding increases in the future, there would be a potential increase in deaths\(^{127}\), injuries\(^{128}\) and mental health effects\(^{129}\). As well as flood inundation, there is an additional risk associated with coastal waves striking people during storms, which are projected to increase as a direct result of increased sea levels.

Generally, vulnerability is greater amongst the elderly as noted for the 1953 flood by Baxter (2005). However, there is a suggestion that the elderly also have more of an inbuilt resilience as a result of past experiences, Tunstall et al. (2006).

Due to the small number of flood related deaths in the UK, it is difficult to estimate current risk of flood related deaths and, hence, estimates of the change in risk as a result of a changing climate. This is particularly the case on the coast, where there have been no known deaths due to coastal flooding in the UK since 1953. This also applies to flood related injuries, which are assumed to correlate with flood related deaths. The small numbers of deaths due to coastal wave action are very specific to the location and the conditions on the day, as well as the behaviour of the people involved.

No regional estimates of potential deaths, injuries or mental health affects were produced for the CCRA. However, the annual number of flood related deaths and injuries are small and unlikely to exceed around 1-2 and 20-30 respectively for Northern Ireland by the 2080s based on the high emissions scenario. However, this estimate is based solely on the population of Northern Ireland compared to the UK as a whole.

For the UK as a whole, the number of additional people per year who suffer a mental health effect due to flooding was estimated to increase to between 4,000 and 7,000 by the 2050s and 5,000 to 8,000 by the 2080s based on present day demographics. Currently in the UK, around 3,500 to 4,500 people a year suffer a mental health effect due to flooding.

Stress can be associated with, for example, the loss of personal possessions, length of time people spend out of their homes while repairs take place and problems with insurance provision for properties at risk from flooding and the knock-on effects for mortgages (see Section 4.4.5 and the Belfast case study in section 5.2.1).

4.6.2 Increased temperatures

If summer temperatures increase in the future as projected, this may have a consequent effect on the number of additional premature deaths and additional hospital

\(^{127}\) A flood death is defined as any death that can be considered to have taken place as a result of a flood, whether as a direct or indirect result (see for example Health Protection Agency (2010). This would include for example the case of a farmer who in May 2009 committed suicide, as a result of several incidents, but for which the underlying cause could be considered to be the continual flooding of his rare breed’s farm. [http://www.getsurrey.co.uk/news/s/2073454_distraught_farmer_had_threatened_suicide_inquest](http://www.getsurrey.co.uk/news/s/2073454_distraught_farmer_had_threatened_suicide_inquest).

\(^{128}\) For the CCRA, a flood related injury was defined as an injury sustained during a flood event that required medical attention as a result of a hospital admission.

\(^{129}\) A mental health effect due to flooding has been defined in the CCRA as a person who goes from a 12 item Global Health Questionnaire (GHQ-12) score of below 4 to 4 or above as a result of a flood event.
admissions as a result of heat related illnesses (cardio-vascular and respiratory diseases). These numbers tend to increase above a set temperature threshold.

If winters become milder in the future as projected, the number of premature deaths avoided may increase and the number of additional cold related hospital admissions may reduce. Again, these numbers tend to increase when the temperature drops below a set threshold. However, in winter there are increased numbers of cases of infectious diseases such as influenza and pneumonia, which means that deaths and hospital admissions are more difficult to attribute to cold weather alone.

The thresholds for summer and winter vary for each region of the UK, and a level of natural adaptation means that the thresholds are generally lower for colder regions and higher for hotter regions.

Based on current population figures for Northern Ireland, the numbers of additional premature deaths due to higher summer temperatures were projected to be approximately 30 by the 2050s and 60 by the 2080s. Based on future (principal) population projections, these figures increase to approximately 40 and 70 respectively. In 2009 there were 14,000 deaths in Northern Ireland (8.1 deaths per 1,000 population), with the median age of death being 71.6 for men and 78.2 for women. Therefore, these projected increases in deaths are very small.

Based on current population figures for Northern Ireland, the numbers of premature deaths avoided due to milder winters were projected to be approximately between 160 and 240 by the 2050s and between 240 and 360 by the 2080s. Based on future (principal) population projections, these figures increase to approximately 190-280 and 270-410 respectively.

Box 14: Vulnerability and deprivation

Middelkoop et al. (2001) found that mortality risk generally increased with an increase in the deprivation score of a residential area, based on data for the under 65s in The Hague. The key diseases contributing to the differences between the high and low deprivation quartiles were ischaemic heart disease and other diseases of the circulatory system. These diseases increase sensitivity to heat, which suggests that sensitivity to heat may be partly conditioned by the degree of deprivation.

Research by the Joseph Rowntree Foundation identified a number of deprived groups that are also vulnerable to heat stress (Benzie et al., 2011). For example:

- Low income jobs are more likely to involve outside labour or long hours spent in confined spaces such as driving cabins (TUC, 2009), which increases exposure to heat;
- Low income groups may be more likely to suffer from poor health in general, which could increase sensitivity to heat;
- Low income householders are also more likely to live in social housing and have lowered capacity to adapt their homes, either for tenure or affordability reasons, which reduces their capacity to adapt to high temperatures.

Evidence presented in the CCRA analysis (see the Health Sector Report) indicated that heat and cold related hospital admissions were of the order of 100 times greater than the number of deaths, with the effects being particularly felt by the elderly, very young and sick (Vassallo et al. 1995). These numbers are more significant than the

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130 Medium emissions scenario, p50.
132 Medium emissions scenario, p50.
133 This is the number of separate patient admissions.
numbers of deaths when compared with figures for hospital admissions in 2008/09 of around half a million inpatient and day case admissions to hospital, 1.5 million outpatient attendances and 750,000 emergency attendances at Accident & Emergency Departments.\textsuperscript{134} However, the evidence was not considered robust enough to generate projections as part of the CCRA analysis.

### 4.6.3 Sunlight/UV exposure

If exposure to UV radiation increased as projected, levels of skin cancers and cataracts would be expected to increase, as well as other less common detrimental health effects including sunburn, photodermatoses, photoaggravation of inflammatory skin disorders and immunosuppressive effects on the skin. Health benefits of UV exposure include the synthesis of vitamin D, and, although UV exposure may exacerbate inflammatory skin conditions, it also has some therapeutic effects.

The amount of UV radiation that reaches the surface of the earth is dependent on a number of factors, the main one of which is the amount absorbed by the stratospheric ozone layer. However changes in cloud cover in the future, as well as social behaviour and changes to UVB radiation flux\textsuperscript{135} would also affect exposure at ground level.

However, the main effects on health are anticipated to be related to social behaviour and demographics. These include:

- Skin cancers are more prevalent in the elderly. With the predicted age shift in populations, this may result in an increase in tumour incidents in the UK (Diffey \textit{et al.}, 2005).
- Cases of skin cancers have a positive correlation with affluence (Quinn \textit{et al.}, 2001).
- Incidence rates of skin cancers have a strong regional variation, typically above average in the south and below average in the north (Cancer Research, 2010).
- Fairer skinned individuals are more prone to skin cancers, (Cancer Research UK, 2010).
- Melanoma is rare in black people. Non-white ethnic groups are also anticipated to increase at greater rates than white ethnic groups, and are also considerably younger on average than the white population, Employers Organisation (2004).
- There is anticipated to be a future increase in population in the south relative to the north, which will vary for different age groups (Employers Organisation, 2004).
- Melanoma cases are likely to increase with increased foreign travel and increased use of sunbeds (Autier \textit{et al.}, 1994 and Cancer Research, 2010).
- Projected warmer summers may result in people generally spending more time outdoors, therefore exposing themselves to greater levels of UV radiation (Horton, 2004).

With the strong correlation between social behaviour and demographics outlined above as well as the strong correlation between levels of UVB and the stratospheric ozone

\textsuperscript{134} \url{http://www.nisra.gov.uk/publications/default.asp9.htm}

\textsuperscript{135} UVB, which has a wavelength of 280-315nm, is the most significant cause of melanoma and non melanoma skin cancers. This is considered the most important health effect linked to sunlight / UV radiation exposure.
Air quality has improved substantially in Northern Ireland in recent years. In particular, concentrations of sulphur dioxide, which is associated with coal and oil combustion, have declined significantly over the past two decades. There has also been a general reduction in urban background particle matter concentrations since 1990. By contrast, mean ozone concentrations do not appear to show any clear overall trend, although there are distinct year-to-year fluctuations, which is consistent with UK-wide observations. This metric is strongly dependent on summer temperatures and weather conditions. There is also no clear trend in nitrogen dioxide concentrations. (AEA, 2010)

Air quality in Belfast is generally considered to be of good quality, although in some areas certain pollutants remain a concern. Most air quality issues in Belfast relate to nitrogen dioxide and particulate matter pollution, which contribute to the formation of low level ozone. This is limited to areas bordering major arterial roads and principally attributed to vehicle exhausts (Belfast City Council, 2010).

Particulate matter
The health effects of particulate matter (PM) are more significant than those of other air pollutants. PM is made up of a complex mixture of solid and liquid particles, including carbon, complex organic chemicals, sulphate, nitrates, ammonium, sodium chloride, mineral dust, water and metals suspended in the air. They may be produced directly from a source such as an engine or formed from reactions between other pollutants in the air (e.g. NO₂, SO₂, NH₃). Chronic exposure to PM contributes to the risk of developing cardiovascular diseases and lung cancer. PM can have either a cooling or a warming effect on climate, depending on its properties and also has a key role in the ecosystem impacts of air pollution (Defra, 2010c).

Ground level ozone
This is formed when pollutants such as nitrogen oxides and volatile organic compounds react in the presence of sunlight. Ozone concentrations can be lower in towns than in rural areas downwind. These reactions may happen over several hours, so the highest ozone concentrations may occur a long distance downwind of the sources of the primary pollutants. It may also persist for several days. Therefore, ozone pollution can be a transboundary problem and difficult to control locally.

Ground level ozone is one of the main constituents of summer smog. High levels can cause breathing problems, reduce lung function and trigger asthma symptoms. Ground level ozone can also seriously damage crops and vegetation (Defra, 2010c). Future changes in climate will impact on air quality; increases in temperature may affect the formation of ozone, increasing the frequency and severity of summer smogs.

Air quality linked to climate change is projected to reduce in summer mainly as a result of increased ground-level ozone concentrations, leading to an associated increase in mortality and morbidity levels. In addition, higher temperatures may cause an earlier and possibly longer pollen season, and more days with higher pollen concentrations would result in more people with hay fever and pollen asthma, Sommer et al. (2009).
However, these effects will be offset in the winter by a likely decline in the frequency and intensity of winter air pollution episodes, resulting in a proportional decrease in associated mortality and morbidity.

Currently there is little evidence to quantify the climate effects on winter pollution and summer pollen; only the effects of ozone were quantified as part of the CCRA.

Current estimates indicate that there are approximately 230 deaths brought forward and 1,140 additional hospital admissions as a result of ozone in Northern Ireland. These are projected to increase by approximately 15-65 and 75-330 respectively by the 2080s.\textsuperscript{136} However, these estimates are based on a linear non-threshold relationship between ozone and the health outcomes, and therefore provide an upper limit on the effects of ozone. This is discussed more fully in the Health Sector Report.

\subsection*{4.6.5 Diseases}

Water, food and vector borne diseases were not assessed in detail as part of the CCRA. However, some additional analysis was attempted for Scotland for water-borne diseases (see Scotland Report).

Future climatic conditions are anticipated to become more favourable for the spread of certain water, food and vector-borne diseases. However, the environmental and public health infrastructure in the UK would probably prevent the indigenous spread of these diseases (Kuhn et al., 2003).

According to Medlock et al. (2005), the risk of new vector species being introduced to the UK is considered relatively low, although British citizens visiting vector-borne endemic countries overseas will be at higher risk. Ticks and Lyme disease may present local problems in the UK, due to changes in the ecosystem, but the increase in their overall impact is likely to be small and will mainly dependant on agricultural and wildlife management practices.

The accidental ingestion of contaminated surface waters during recreational activities has been a significant cause of water-borne disease in Northern Ireland (Moore et al., 2001). For instance, campylobacter spp. is a common cause of acute bacterial gastroenteritis and studies have found it present in a number of untreated surface waters including loughs and rivers in Northern Ireland (Moore et al., 2001). This includes Lough Neagh, where the levels of pathogenic bacteria in areas used for water sports are a concern (LNAC, 2002). The presence of such harmful bacteria in untreated surface water sources also presents a threat to domestic livestock and pets. Contamination of surface waters can come from a number of sources, including the discharge of sewage effluent, runoff from agricultural and urban land and floods. Outbreaks of drinking-water associated cryptosporidiosis caused by Cryptosporidium (a protozoan parasite) have also been an issue in Northern Ireland in the past (Glaberman et al., 2002). However, drinking water quality continues to improve and in 2009 there were no reports of cryptosporidiosis outbreaks associated with mains water supply in Northern Ireland (NIEA, 2010).

Changes in coastal water quality (which may occur as a result of increased point and diffuse pollution discharges, see Section 4.2.2) could lead to an increase in the incidence of human disease via bathing and also the consumption of seafood, particularly shellfish.

\textsuperscript{136} Ozone is only partially climate driven. Therefore, the standard CCRA emission scenarios are not applicable. See the Health Sector Report for more details regarding the scenarios applied.
4.6.6 Medicines

 Longer allergy seasons and increased severity of symptoms would lead to higher costs and demands on the NHS for diagnosis and treatment of more complex allergies.

 Mental health, psychological support and counselling services may experience a rise in demand after extreme weather events such as floods. Meeting these demands will require long-term planning and investment in the health sector.

 Exposure of medicines to high temperatures during storage and transit could reduce their efficacy (most licences specify storage below 25°C). In a hot British summer, medicines stored in homes, health centres, hospitals, etc. could be exposed to temperatures that might in theory reduce their efficacy (Crichton, 2004). This may compromise access to NHS services, as well as health care staff performance and patient recovery.

 These metrics were not assessed as part of the CCRA.

4.6.7 Emergency Response

 Emergency response includes preparing for emergencies, responding in an emergency, and recovery after the event. Those involved in emergency response extends beyond the Emergency Services (Police, Fire & Rescue, Health) to Local Authorities and the voluntary sector. The voluntary sector, in particular, may be vulnerable to increased demand for their services or be directly affected by extreme events, due to limited resources to adapt.

 The need for emergency response to extreme events will increase if projected increases in the magnitude and frequency of extreme events occurs. Extreme events of greatest concern include floods, fires, heatwaves and drought.

 Emergency medicine is also likely to have an increase in demand, with pre-hospital care and disaster response activities both being likely to increase.

 As part of the CCRA there has been a review of the potential consequences for the Emergency Services of future climate change. This review concluded the following:

 - **Flooding** - Based on projections for increased flooding, it is expected that there will be a similar increase in effort required by Emergency Services to deal with flooding incidents. Based on data available for England and Wales, this effort may increase by a factor of 2.5 by the 2080s, increasing costs to the Emergency Services by 210%. This may be an overestimation for Northern Ireland, as the overall level of flood risk is generally lower than for England and Wales, but it provides an upper estimate for the potential scale of the threat.

 - **Wildfires** - Based on projections for increased wildfires, the number of incidents attended by the Fire and Rescue Service may increase by up to 20% by the 2080s. However, these would be concentrated within the wildfire season, which may put significant pressure on this service during these months.

 - **Heatwaves** - These may become more frequent and last longer in the future, based on current climate change projections. This would increase the probability that during a heatwave there would be secondary events that require a response from the Emergency Services. There may be as much as a ten-fold increase in the frequency of such events by the 2080s.
There are also potential consequences for Emergency Services as a result of changing patterns in human behaviour. For example, increased numbers of tourists or a longer tourist season may result in more call outs for Rescue Services in upland areas and in freshwater and coastal waters.

### 4.6.8 Population migration

According to the Northern Ireland Statistics & Research Agency (2010), there is a downward trend in international migration to Northern Ireland and a consequent fall in net migration.

Between mid-2008 and mid-2009 there was a net inward migration of 2,100 people to Northern Ireland (net 1,500 international migrants and net 700 people from Great Britain moving to Northern Ireland). In combination with an excess of births over deaths, the Northern Ireland population increased from 1.775 million people in 2008 to 1.789 million people in 2009.

Between 2001 and 2004 the population of Northern Ireland grew by around 7,000 people or 0.4% each year. This increase was due to natural change (more births than deaths) with virtually no change in the size of the population due to migration. As a result of the European Union expansion in 2004 the annual migration to Northern Ireland increased, reaching a peak in 2007. Since 2007, the numbers of people migrating to Northern Ireland has been on a downward trend. In 2009 there were estimated to be 39,000 people of Central and Eastern European background living in Northern Ireland, which is equivalent to 2% of the population.

Information obtained through new health service registrations during 2009 indicated that 50% of migrants came to Northern Ireland for work related reasons, 27% came for family reasons, 12% for education and 10% of migrants gave another or no reason.

The immigrant population has the potential to be more vulnerable to climate change impacts due to issues such as language difficulties, awareness of who to contact in an emergency, lack of insurance, fewer links with the local neighbourhood, etc.

Numbers of environmental refugees/migrants in the future are unclear. For example, sea level rise is a particular concern, but the economically rational response in most developed areas of the world would be to provide flood defence or other forms of protection. The likely major sources of migrants are small island communities. The likely importance of the UK, and in particular Northern Ireland, as a destination for these people is unclear (Foresight 2011). However, migration/displacement could also be a consequence of disease, heatwaves, flooding and droughts. There is an ongoing Foresight project on Global Environmental Migration, which is looking at this in more detail.

### 4.6.9 Fuel poverty

Fuel poverty affects an estimated 44% of Northern Irish homes (2009 projected statistics). Tackling fuel poverty is fundamentally about the cost of domestic energy/fuel bills and the financial security of households. It is more usually associated with climate change mitigation measures, principally improving energy efficiency and reducing the

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138 This refers to the 8 countries that joined the European Union in May 2004: Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia.
140 Defined as households where 10% or more of income is spent on heating.
need for energy. However, climate change could alter the relative significance of different factors that cause fuel poverty. For example:

**Energy demand** - Patterns in energy demand might change with the projected increase in temperatures, such as decreased demand for heating in the winter, but an increased demand for cooling in the summer (although poorer people tend to have less access to air conditioning). Based simply on projections for heating degree days versus cooling degree days (see Section 3.2.2), for Northern Ireland it is reasonable to assume that the benefit of reduced winter heating costs will outweigh increased cooling costs in the summer.

**Energy costs** – Other factors, such as international markets and industry regulation, are likely to play a major role in setting future energy/fuel bills, but changes in climate may also affect energy costs in a number of ways, including (but not limited to):

- The capacity to generate electricity from renewable sources within the UK and the Republic of Ireland, which may increase or decrease depending on the source;
- The investment required to ensure a reliable power supply despite more frequent extreme events;
- Impacts elsewhere may significantly alter the global energy supply.

**Quality of housing stock** – Occupants of single storey and terraced housing are more likely to suffer fuel poverty, as are 63% of those living in pre-1919 buildings, in part due to poor heating efficiency. In turn, inadequate heating can then exacerbate condensation and damp problems, which may become more prevalent with climate change (see Section 4.5.1). Additionally, half of all isolated rural accommodation experience fuel poverty.

**Incomes** – Any consequences for the Northern Ireland economy resulting from climate change impacts could have knock-on effects for household incomes. 81% of those earning £14,999 pa or less and 57% of Housing Executive housing occupants experience fuel poverty (Frey et al., 2011). For those aged 75 or over, three-quarters of people reportedly suffer fuel poverty. Unsurprisingly the highest incidences of fuel poverty occurred in households of those unemployed or retired (both 65%) (Frey et al., 2011).

In summary, there are several climate change related factors that might influence the levels of fuel poverty in the future, but the relative scale of these is unclear, which means that it is not possible to indicate whether there is an overall positive or negative impact. In addition, other socio-economic factors may have a much greater effect on future fuel poverty. Therefore, at present it is not possible to determine whether the effect of climate change on fuel poverty is significant. The method for calculating fuel poverty may be reviewed in the future, allowing a more accurate analysis of those affected and to what extent. A new approach may also reduce the large swings in the number reported as being affected, caused by fluctuating fuel prices, allowing for a more targeted approach for policy makers (Hills, 2011).

As well as consideration of future levels of fuel poverty, the consequences of fuel poverty should also be taken into account and these may change in magnitude or character in the future due to climate change. For example, algal and fungal growth in buildings is expected to increase if winters become milder and wetter in the future. This would have consequences for those vulnerable to asthma and other respiratory diseases (see Section 4.6.10). People suffering from fuel poverty and, hence, not heating their homes adequately, would be at particular risk.
Box 16: Fuel Poverty in Northern Ireland

Fuel poverty is the inability to heat a home to an acceptable level for reasons of cost. It is a complex and multi-dimensional issue that can be caused by a number of factors, most notably the following:

- Low household income – the costs of heating a home form a greater proportion of total income for those on low incomes.
- Fuel costs – higher fuel prices reduce the affordability of fuel.
- Energy efficiency – the thermal quality of the home and the efficiency of the heating system determine the amount of energy required to adequately heat the home. Improvements in Northern Ireland building stock would reduce this factor.
- Under-occupation – this can be a particular problem for older occupants, especially those who live alone.

The average cost of household energy in Northern Ireland is higher than other parts of the UK. In 2006, the average annual fuel bill was equivalent to 4.9% of an average disposable income, compared to 3.0% for the UK as a whole, with 226,000 households being in fuel poverty.\(^{141}\) The 2006 figures showed that older person households and single person households had higher levels of fuel poverty, as both of these household types typically have lower incomes.

According to the Utility Regulator for Northern Ireland’s Social Action Plan consultation paper (2009), Northern Ireland has higher levels of fuel poverty than the rest of the UK for the following reasons:

- **Climate** – the Northern Ireland climate is typically colder than that of England and Wales, leading to a greater heating requirement.\(^{142}\)
- **Dispersed population** – a large proportion of the population in Northern Ireland live in rural areas outside the ‘heat islands’ that surround urban areas, which reduce individual heating requirements.
- **Higher gas costs** – being at the end of the transmission network means Northern Ireland pays the additional cost of transportation from Great Britain or Ireland. Furthermore, the gas industry is still in its infancy with comparably low penetration rates. Recovering the cost of developing the gas network from this smaller customer base means that average unit costs are higher compared to other parts of the UK.
- **Greater reliance on oil for home heating** – this is especially the case in rural areas and this leaves households vulnerable to oil price rises.
- **Lower incomes** – average household income is generally lower in Northern Ireland compared to the UK.

Fuel poverty can damage people’s quality of life and physical and mental health, which in turn can have wider cost implications for the community. Not only can a cold home result in illness, but, when decisions have to be made about how income is spent, this can also lead to poor diets and withdrawal from the community. It is broadly accepted that older people, people with disabilities or long-term illnesses and children are particularly vulnerable.

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\(^{141}\) These 2006 figures predate recent fuel price rises and the UK-wide economic recession. Therefore, it is likely that these figures would be higher now. The 2009 Northern Ireland House Condition Survey is yet to be released. See [http://www.nihe.gov.uk/index/sp_home/research-2/house_condition_survey.htm](http://www.nihe.gov.uk/index/sp_home/research-2/house_condition_survey.htm)

\(^{142}\) Northern Ireland is not as cold as many parts of Great Britain in winter, but it is also not as warm in the summer. It is also relatively damp.
4.6.10 Algal and fungal growth in buildings

There are approximately 182,000 people with asthma in Northern Ireland, with approximately 34 deaths per year. Correlating people with asthma against dwellings within Glasgow, Williamson et al., (1997) indicated a clear link between damp housing and asthma, and for the analysis carried out, it indicated that occupants were approximately 50-60% more likely to have physician diagnosed asthma if they lived in a property affected by damp or condensation (Wilkinson, 1999).

The impact of damp and mould on respiratory conditions is greater in children (Williamson et al., 1997, Evans et al., 2000) and recent surveys have shown that roughly 18% of poor children live in a damp home in Northern Ireland (Monteith and McLaughlin, 2004), resulting in a higher prevalence of respiratory conditions within children (Barnados, 2005; Olsen, 2001).

The relative significance for asthma sufferers of increased damp and mould due to climate change compared to increased temperatures (say) is unclear. The effect of temperature influences asthma more than any other climatic factor, with increased temperatures and heatwaves affecting those with respiratory conditions.

4.6.11 Summary of results for health and wellbeing

There is potentially an opportunity (or benefit) for Northern Ireland related to a decline in the number of premature deaths and hospital admissions due to milder winters. This projected decline in deaths is greater than the projected increase in premature deaths caused by high temperatures in summer.

The most significant threats relate to the projected increase in emergency response required to deal with wildfires and other climate events, such as flooding.

Based on future projections for rainfall and sea level rise and evidence available for other parts of the UK, flooding may become a significant climate change threat to people’s health and wellbeing. The PFRA should help to estimate future flood risks for Northern Ireland (see Appendix D).

The results of the analysis are summarised in Table 4.16.

All of the projections have been given low confidence, as the results are based on very limited data available for Northern Ireland.

Many of the potential risks for health and wellbeing in Northern Ireland cannot be assessed at present, because the data is not currently available or the risks are intrinsically too uncertain.

Where new threats (i.e. those that were not on the Tier 2 list for the UK analysis) have been identified, these have not been assessed for Northern Ireland due to time constraints.

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143 http://www.asthma.org.uk/northern_ireland/
144 http://www.bbc.co.uk/northernireland/mindyourself/top_fives/killers/bronchitis.shtml
145 http://www.asthmainformationguide.com/asthma-and-weather
146 http://www.epa.gov/climatechange/effects/health.html#direct
### Table 4.16  Climate change consequences for health and wellbeing

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE5</td>
<td>Decline in winter mortality due to higher temperatures</td>
<td>NI</td>
<td>NI</td>
</tr>
<tr>
<td>HE6</td>
<td>Decline in winter morbidity due to higher temperatures</td>
<td>NI</td>
<td>NI</td>
</tr>
<tr>
<td>NEW</td>
<td>Fuel poverty (people affected)</td>
<td>Too uncertain</td>
<td>Too uncertain</td>
</tr>
<tr>
<td>NEW</td>
<td>Winter air pollution</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>NEW</td>
<td>Cold weather working/travelling</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>Threats</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEW</td>
<td>Emergency response to grassland and forest fires</td>
<td>NI</td>
<td>NI</td>
</tr>
<tr>
<td>NEW</td>
<td>Emergency response to climate events (including flood)</td>
<td>NI</td>
<td>NI</td>
</tr>
<tr>
<td>NEW</td>
<td>Summer mortality due to higher temperatures</td>
<td>NI</td>
<td>NI</td>
</tr>
<tr>
<td>NEW</td>
<td>Summer morbidity due to higher temperatures</td>
<td>NI</td>
<td>NI</td>
</tr>
<tr>
<td>NEW</td>
<td>Extreme weather event (flooding and storms) mortality</td>
<td>NI</td>
<td>NI</td>
</tr>
<tr>
<td>NEW</td>
<td>Extreme weather event (flooding and storms) injuries</td>
<td>NI</td>
<td>NI</td>
</tr>
<tr>
<td>NEW</td>
<td>Increased algal or fungal/mould growth in buildings affecting respiratory conditions</td>
<td>NI</td>
<td>NI</td>
</tr>
<tr>
<td>HE4a</td>
<td>Mortality due to summer air pollution (ozone)</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>HE4b</td>
<td>Morbidity due to summer air pollution (ozone)</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>NEW</td>
<td>Sunlight/UV exposure</td>
<td>Too uncertain</td>
<td>Too uncertain</td>
</tr>
<tr>
<td>NEW</td>
<td>Vector-borne diseases</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>NEW</td>
<td>Food-borne diseases</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>FL1</td>
<td>Number of people at significant risk of flooding</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>FL2</td>
<td>Vulnerable people at significant risk of flooding</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>FL12ab</td>
<td>Hospitals and schools at significant risk of flooding</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>HE10</td>
<td>Effects of floods/storms on mental health</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>MA2b</td>
<td>Risks of human illness due to marine pathogens</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>NEW</td>
<td>Increased immigration</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>NEW</td>
<td>Transport and communications network failure</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>NEW</td>
<td>Pollen and allergens</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>NEW</td>
<td>Demand for emergency medical care</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>NEW</td>
<td>Medicine efficacy</td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
</tbody>
</table>

**Opportunities**
- **High consequences (positive)**
- **Medium consequences (positive)**
- **Low consequences (positive)**
- **Low consequences (negative)**
- **Medium consequences (negative)**
- **High consequences (negative)**

**Coverage of analysis**
- NI: Analysis undertaken for Northern Ireland only
- UK: Analysis undertaken for the UK

**Method of analysis**
- IJ: Informed judgement
- Q: Quantitative
5 Summary of consequences

5.1 Overview of potential consequences

The potential consequences of climate change are assessed by theme in Section 4, based on the Northern Ireland Tier 2 list of impacts. This section considers the main consequences that have the potential to affect different parts of Northern Ireland, based on the following geographical areas:

- Towns and cities
- Uplands
- Rural lowlands
- Freshwater loughs
- Coastal areas
- Coastal waters and marine environment

Some consequences are not directly related to geographical area and, therefore, are not reflected in this section. For example, climate change impacts on the financial sector would have consequences on investment and business in all parts of Northern Ireland.

5.2 Consequences for different parts of Northern Ireland

5.2.1 Towns and cities

Belfast is by far the largest city in Northern Ireland. The city itself has a population of approximately 268,000\textsuperscript{147}, while the greater Belfast urban area is home to approximately one third of the population of Northern Ireland, with heavy urbanisation and industrialisation along the Lagan Valley and both shores of Belfast Lough. There are four other urban conurbations with city status: Armagh (14,590), Derry (83,652), Lisburn (71,465) and Newry (27,430).\textsuperscript{148}

Potential climate change consequences for major towns and cities include the following:

- A reduction in water availability, which would affect all water users including homes, industry and businesses. In total up to 2.1 million people in Northern Ireland may be affected by water shortages by the 2050s (see Section 4.5.6).

- An increase in flooding from the sea, rivers, surface water and sewers or any combination of these, putting lives at risk, causing damage to properties and increasing the cost of insurance premiums (see Section 4.5.1).

\textsuperscript{147} Based on mid-year estimates for 2008
\textsuperscript{148} 2001 census figures
• An increase in disruption to infrastructure and services caused by flooding (see Section 4.5); and, in turn, an increase in disruption and costs for communities, the economy and employment (see Section 4.4), with the effects being more severe for vulnerable groups and small businesses (see Section 4.4.3).

• An increase in discharges into urban watercourses from combined sewer overflows by up to 10% by the 2080s, resulting in reduced water quality (see Section 3.2.10).

• An increase in disruption to and reduced reliability of ICT (see Section 4.5.8).

• An increase in demand for cooling for homes, offices, factories, schools, hospitals and other public buildings, due to overheating during the summer months (see Section 4.5.7). Loss of productivity for days exceeding 26°C may exceed 25% by the 2080s (see Section 4.5.1).

• An increased number of deaths brought forward due to hot weather, but this would be offset by a reduction in deaths due to cold weather. Over 400 deaths a year may be avoided due to milder winters compared to 100 deaths brought forward by high temperatures by the 2080s (see Section 4.6.2).

Historical Example: How flooding has affected the people of Belfast

| The consequences of flooding can far outreach the initial shock of being flooded. Social, physical and psychological consequences and financial hardship can continue for years after the event, as experienced by communities in Greater Belfast. |

The British Red Cross was commissioned by the Belfast Resilience Forum of Belfast City Council to undertake research into the impact of flooding on people living in identified flooding hot spots across Greater Belfast (British Red Cross 2010). This research found that the emotional and practical consequences can be devastating for people affected and that support needs can be immense.

The following are examples of the consequences faced by these communities as a result of the flooding:

Social and community consequences
• Lack of confidence in response agencies and confusion about who to contact;
• Older people were reluctant to leave their homes as they were anxious about not being able to return;
• Fears over security of homes from burglary and vandalism;
• Evidence of strong community resilience in some areas while others had poor community networks;
• Family separation, as fathers often remained at home for reasons of security, despite it being uninhabitable, and mothers and children would stay in temporary accommodation.

Physical and psychological consequences
• Heightened anxiety and fear of future events;
• Loss of weight, lack of appetite, disturbed sleep patterns, fatigue and depression;
• Increased dependence on GPs and need for medication; and
• Difficulties readjusting when returning to a home that looks and feels different.

Financial consequences
• £1000 hardship payments\textsuperscript{149} were insufficient to cover costs such as subsistence and travel costs while in temporary accommodation, redecoration, rewiring, structural repairs, refurbishment and laundry;
• Decreased market value of homes; and
• Problems getting home insurance in high-risk areas or significant increases in excess limits.

5.2.2 Uplands

There are three distinct upland areas in Northern Ireland that provide important biodiversity, landscape, public amenity and tourist areas: the Sperrin Mountains, the Mourne Mountains and the Antrim Plateau. All three areas are designated as AONBs. There are also smaller ranges in South Armagh and along the Fermanagh-Tyrone border. Although not uplands as such, there are also extensive areas of drumlins\textsuperscript{150} in counties Fermanagh, Armagh, Antrim and Down.

Potential climate change consequences for upland areas include the following:
• A reduction in soil moisture, resulting in the drying out of bogs, hollows and other habitats, leading to a loss of biodiversity and carbon storage. This would also affect the mountain landscape (see Section 4.2.1) and important irregular shaped inter-drumlin bogs which contain rare moss species and are surrounded by intensively managed land.
• An increase in occurrences of pests and invasive non-native species, resulting in potential loss of native species (see Section 4.2.1).
• A change in available climate space (both loss or gain), including migration of species to higher altitudes. This would affect both biodiversity, including the potential loss of species, and landscape (see Section 4.2.1).
• An increase in soil erosion (or damage, then subsequent erosion) in drier summers, potentially exacerbated by an increase in tourism. Consequences include damage to habitats and footpaths, and sedimentation in watercourses. The erosive potential of future rainfall may increase by over 50\% by the 2080s (see Section 3.2.5).
• An increased risk of wildfires, which may lead to significant loss of biodiversity. Some ecosystems, such as woodlands, semi-natural grasslands, heathlands and those on peat soils (e.g. blanket bog) are particularly sensitive to fire. The risk of wildfires may increase by 30\% by the 2080s (see Section 3.2.4).

\textsuperscript{149} These payments were from the DOENI via Belfast City Council’s Emergency Social Fund.
\textsuperscript{150} Low hills caused by glacial activity
Case Study: Mourne Mountains

The Mourne Mountains are a relatively unspoilt Area of Outstanding Natural Beauty, home to many rare and important species. Local land use is primarily agriculture and tourism. Land management in the Mourne Mountains will continue to play a significant role in shaping the natural environment. This needs to take into consideration both direct and indirect impacts of climate change.

The Mourne Mountains run throughout south-east Northern Ireland and comprise an area of steep rocky summits rising to 850m at Slieve Donard. The peaks are separated by loughs, rivers and small streams; the narrow plateaus also often contain areas of blanket bog. The landscape comprises rough grass and heather that is used primarily for sheep grazing with small areas of commercial forestry. Other than agriculture and forestry, tourism makes up the main human use of this landscape, with the Silent Valley and its reservoir being a very popular destination. The landscape is managed to ensure that development, tourism and grazing do not place unnecessary pressures on the fragile landscape (DOENI, 2006). The mountains are designated as an Area of Outstanding Natural Beauty (ANOB) and a Landscape Character Area (LCA) (DOENI, 2007). The Eastern Mournes are also designated as an Area of Special Scientific Interest (ASSI) as a result of their geological, physiographical and biological features (DOENI, 2006).

Rough upland grassland in the Mourne Mountains covers over 40% (DOENI, 2010a) of the land and is expanding at the expense of the heather heath. The heather heathland, dominated by common and bell heather, is one of the most extensive in Northern Ireland and is nationally important, although it is declining. The dominance of bell heather within the existing heathland makes the habitat rare in the UK. The grassland and heathland often form complex mosaics, indicating the degradation of the heathland habitat as a result of persistent sheep grazing. Wet-heaths, characterised by cross--

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151 Source: http://www.geograph.ie/photo/1138189 © Copyright Ross
leaved heath, deer sedge, purple moor grass, carnation sedge and bog mosses also provide suitable habitat for the rare northern Atlantic silky swan-necked moss (*Campylopus setifolius*), which is abundant in this community. This region is one of very few in Northern Ireland where montane communities exist and only a few small patches of blanket bog exist. The upland heath and blanket bog communities are important habitats for upland birds, including the rare ring ouzel and red grouse as well as a multitude of invertebrates. At Slieve Donard, predatory ground beetles *Notiophilus aesthuanus* and *Miscodera arctica* and the sawfly (*Pontania crassipes*) are found. This is the only place in the whole of Ireland to be known to have all three of these species.

Although the tree cover in this area is low, there is a long-established and possibly ancient oak woodland called Rostrevor Wood (an ASSI and National Nature Reserve) that is of national significance. This woodland includes rare plants such as wood fescue, toothwort and bird’s-nest orchid and rare species of lichen including *Melaspilea granitophia*. Small pockets of Upland calcareous grassland, rare in eastern Northern Ireland, include species such as wild thyme, and wet acid grasslands dominated by purple moor-grass, rushes and sedges provide additional habitat diversity.

Climate change has the potential to put further pressure on an already strained and sensitive landscape:

- **Waterlogging and windthrow** - The woodlands in the Mourne Mountains suffer loss of trees though felling and windthrow; certain areas are showing little regeneration without human intervention which is cause for concern. Any increase in windthrow due to waterlogging would increase this problem.

- **Grazing** – As grazing places significant pressure on upland grass and heathlands, monitoring and policy on grazing and burning controls are extremely important.

- **Wildfires** - Further stress from changing temperatures and rainfall with future climate change and consequences such as wildfire risk increasing could further damage the habitats and negatively impact tourism.

- **Tourism** - Use of the area by hill walkers also places stress on the environment, leading to soil erosion in particular (DOENI, 2010a); if this increases with improved weather in the future, then the risk of soil erosion could also increase, degrading habitats.

- **Climate space** - Stiff sedge (*Carex bigelowii*), which is an important UK species in acid grassland and montane habitats, has the potential to lose climate space with climate change. Similarly, cowberry (*Vaccinium vitis-idaea*) will potentially lose suitable climate space in Northern Ireland. Other species however may experience an increase in range if they are able to follow their projected increase in climate space, for example, western gorse (*Ulex gallii*), has the potential to gain climate space with climate change (see the Biodiversity and Ecosystem Services Sector Report).
5.2.3 **Rural lowlands**

The Lower and Upper River Bann, River Foyle and River Blackwater form extensive fertile lowlands.

Potential climate change consequences for rural lowlands include the following:

- A reduction in water availability, particularly in the summer, which would affect all water users including homes, agriculture and businesses (see Section 4.5.6)

- A deterioration in water quality of rivers and streams resulting from pollution discharges from point and diffuse sources (see Section 4.2.2) and increased sediment loading with increased soil erosion.

- Low flows may become lower in rivers and streams during the summer, which would limit abstraction, contribute to the deterioration in water quality and impact on recreation. Q95 flows\(^{152}\) may drop by 30% by the 2080s (see Section 3.2.9).

- An increase in flooding from rivers, surface water and sewers or any combination of these, causing damage to properties (including built heritage) and putting people and livestock at risk. Peak river flows may rise by 27% by the 2080s (see Section 3.2.10).

- An increase in disruption to infrastructure and services caused by flooding (see Section 4.5) and extreme events (snow, storms, and drought) (see Section 4.5.5). In turn, an increase in disruption and costs for communities, the economy and employment, with the effects being more severe for vulnerable groups and small businesses (including farmers) and the loss of service connections and disruption to the transport network.

- An increase in disruption to and reduced reliability of ICT affecting urban hubs (see Section 4.5.8). Has the ability to impact across all sectors simultaneously and impact independent of geographical differences.

- A reduction in soil moisture with consequences for the landscape, biodiversity and cultural heritage. Relative aridity may increase by 2.8 by the 2080s (see Section 3.2.3).

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\(^{152}\) The flow exceeded for 95% of the time.
- An increased risk of wildfires, which could encroach upon communities (see Section 3.2.4).
- An increase in occurrences of pests and diseases in crops, trees and livestock (see Section 4.3).
- An increase in grass yields may allow grazing seasons for livestock to be extended (see Section 4.3.1).
- An increase in wheat yields (see Section 4.3.1).

**Historical Example: How flooding affected the county of Fermanagh**

Despite a relatively high level of preparedness, Fermanagh can still experience extensive flooding. This was demonstrated by the floods of Autumn 2009, which led to significant financial and social hardship. The long-term sustainability of local businesses and communities may become a concern, if floods similar to Autumn 2009 became more frequent.

During late October and November 2009, County Fermanagh experienced very heavy and persistent rainfall, which exceeded the drainage capacities of the Erne System. In total, 336.8mm of rainfall fell between 17 October and 27 November 2009. In November alone there was 280mm compared to the long-term average for the month of 103mm. The previous record for rainfall in the county during November was 191mm, which occurred in 1939. This level of rainfall was well in excess of a 1 in 100 year event.

The bulk of the flooding occurred after 19 November 2009, owing to rising water levels in the Loughs and the system’s inability to convey the flows. However, there was also flooding in the Boho area from 4 November 2009, which was the result of inundation of the floodplain of the Sillees River.

**The county of Fermanagh**

Fermanagh covers an area of 187,582 hectares, with a population of 57,600. The county town of Enniskillen has a population of 13,600, but many of the residents live in rural and often remote locations. The population density of the county is only 31 persons/km², compared to a density of 119 persons/km² for Northern Ireland as a whole. Agriculture is a key sector within the county and businesses in general have been bolstered recently by an influx of trade from across the border. Loughs and waterways make up approximately 30% of the total area. The Erne system with its associated loughs and channels are very important in terms of the drainage of the county, as well as for tourism.

**The Erne system**

The River Erne rises from Lough Gowna in County Cavan, but then flows through County Fermanagh to the sea at Ballyshannon in County Donegal. The river is approximately 100km long and drains an area of around 4,350km².

There are many loughs in the catchment upstream of Enniskillen, the largest being Upper Lough Erne, which has a surface area of about 38km². Water from the Upper Lough flows through the inter lough channel to Lower Lough Erne, which is the larger of the two loughs with an area of about 111km². Sluice gates in the inter lough channel ensure that water levels do not fall too low in the Upper Lough. Flow from the Lower Lough passes through Belleck Channel to the hydro-electric power station at Cliff. The dam at Cliff controls the water level in the Lower Lough. There is a second hydro-electric power station 5km further downstream at Cathaleen’s Falls (Ballyshannon).
Each October, in preparation for the higher levels of rainfall during the autumn and winter periods, the water levels are drawn down in both loughs in order to maximise storage capacity within the system.

According to the Flooding Taskforce\(^{153}\), The Erne System complies with recognised drainage standards and it would not be economically or environmentally feasible to increase the capacity of the system to a level where flooding from extreme events, such as the November 2009 flooding, could be prevented. Neither would it be feasible to significantly reduce existing water levels, given the detrimental impact this would have on the natural environment and on water based tourism. (OFMDFM 2010) However, recommendations were made regarding:

- Reviewing the Erne System Operating Regime, including looking at the feasibility of bringing forward the winter drawdown of Lough levels to maximise storage;
- Investment in flood mitigation works;
- Enhancement of existing emergency plans;
- Protecting the delivery of essential services to local people during times of flood;
- Educating and improving the preparedness of the public.

The consequences
The widespread flooding in November 2009 led to significant disruption for individuals and communities. The flooding affected most of the population of the county in some form or another. The main consequence of the November flooding was the inundation of key roads which, given the topography of the area, had a disproportionate effect on the community.

The challenges faced by the local population in the immediate aftermath included:

- Difficulties in accessing homes, shops, schools/nurseries, farmland and businesses;
- Problems in caring for the vulnerable;
- Public health concerns; and
- Animal welfare issues.

Then in the longer term:

- Wider economic impacts for local businesses arising from increased operating costs and lost trade;
- Damage to the area’s reputation as a tourist destination, a good place to do business and even as a good place to live.

The flooding brought to the fore a strong sense of community spirit, with the local population displaying resilience and a readiness to help themselves and their neighbours to cope with the worst effects of the floods, assisted by the responding agencies. However, the prolonged duration of these impacts put an additional strain on those affected. Many of those who gave evidence to the Taskforce mentioned the

\(^{153}\) In December 2009, the Northern Ireland Executive decided that a Flooding Taskforce should be established to investigate the causes of the flooding, identify lessons learned and consider measures required to mitigate the impact of any future flooding. The content of this case study is based mainly on the Taskforce’s report.
stress suffered and the hardship both in economic and social terms that had been caused.

**Homes** – A number of homes, mostly around the shores of Upper Lough Erne, were entirely cut off by flood water. Access was only possible by tractor or boat. Some entire families had to leave their homes, while others were separated with some family members remaining at the home. Some individuals with care responsibilities for elderly relatives were unable to make necessary journeys due to the waters being too deep.

**Schools** – Children were subjected to long detours to get to schools and nurseries. In one case, a temporary school was established in a church hall to enable children to attend lessons, as the long detour was considered too arduous for some of the younger children.

**Care of the vulnerable** – Care workers had difficulties accessing the homes of vulnerable and elderly residents, who relied on their assistance on a daily basis. Sometimes patients had to be moved to alternative locations away from their familiar surroundings. Residents in rural locations also grew increasingly concerned about the ability of the emergency services to access their homes had an emergency arisen.

**Animal welfare** – The farming community experienced prolonged difficulties providing feed to animals and dealing with any sick animals in areas cut off by the water.

**Natural environment** – Flooding may facilitate the spread of invasive species, from affected to currently unaffected areas.

**Public health** – Some locations received no refuse collections during the flooding. Farmers were concerned about delays in the collection of dead stock as the lorries could not gain access to farms. In the urban areas, there was concern about the contamination of flood water with sewage, especially as people had to wade through it on a regular basis. In rural areas, some slurry tanks were flooded, resulting in slurry mixing with the flood water. The Killyhevlin Water Treatment Works was almost overwhelmed; had this occurred much of Enniskillen would have been without drinking water.

**Rural communities** – Concerns were also raised about the reputation of rural schools and even a community centre as being able to provide reliable services for the public. For example, parents might be tempted to look elsewhere for school placements. If this happened, this would have damaging and lasting impacts on the local community. Poor mobile phone coverage in rural areas was also a cause for concern.

**Farming sector** – Animals that would normally have been grazing outside during November had to be housed early, depleting winter feed stocks that had to be replaced at an extra cost. Milk tankers were not able to make collections from dairy farms, and consequently the milk and income was lost.

**Commercial sector** – There was a significant loss of trade due to fewer people coming into Enniskillen and surrounding towns. The reduction in shoppers was attributed to loss of key transport routes, associated traffic congestion, and the assumption that shops would not be open.

**Tourism sector** – The local tourism industry is worth about £33million per year (2008). Facilities suffered considerably in terms of access and damage to property. Although the flooding did not take place during the main tourist seasons, cancelled bookings and loss of facilities were expected to impact on business viability in the longer term.

**Businesses in general** – Increased travel to work time for staff and inward and outward deliveries, not only caused disruption but also resulted in increased fuel costs. On occasions, deliveries had to be aborted.
Emergency services – The NI Fire and Rescue Service (NIFRS) was actively involved during the flooding. Members of the Specialist Rescue Team were also deployed to Fermanagh and carried out a number of reconnaissance and high-risk search operations. All fire stations in Fermanagh were called out to assist with public safety, pumping out of flooded properties and generally providing a reassuring presence in the areas worst affected. The NI Ambulance Service deployed 4x4 vehicles to ensure that response times were met.

5.2.4 Freshwater loughs

Northern Ireland is particularly rich in freshwater and wetland habitats, with the largest lake in the British Isles (Lough Neagh); other very large lakes such as Lower Lough Erne and Lough Melvin; and a myriad of other smaller loughs, fens and raised bogs.

Potential climate change consequences for freshwater loughs include the following:

- An increase in risks from pests, diseases and invasive non-native species that, for example, could result in a decline of native freshwater fish species (see Section 4.2.2) and thus tourism.
- Changes in species migration patterns, which may impact on biodiversity and recreation/tourist activities (see Section 4.2.2).
- An increase in water temperatures and stratification of water bodies, leading to deterioration in water quality and increased algal growth (see Section 4.2.2).
Case Study: Lough Neagh

Lough Neagh is extremely important for biodiversity and freshwater supply. Land management in the area has already had a significant impact on the lough. As the lough is shallow, it is sensitive to pollution and vulnerable to eutrophication and climate change may exacerbate these problems, which would have consequences for the local ecology.

Lough Neagh is the largest freshwater lake in the UK covering an area of approximately 383 km² in the centre of Northern Ireland. It is shallow for its size with an average depth of 8.9 metres and this factor in combination with prevailing winds from the south-west mean that the lough is almost always well-mixed (NIEA, 2008). Five of the six counties in Northern Ireland have shores on the Lough.

Lough Neagh is rich in biodiversity, supporting and allowing a number of different rare or local species to flourish. Lough Neagh was designated as a Ramsar site in 1976, along with a smaller lough on site, Lough Beg. It has also been designated an Area of Special Scientific Interest (1992), and a Special Protection Area (from 1993). There are eight nature reserves. Plant species include marsh pea and eight-stamened waterwort, while invertebrates include rare beetles such as *Stenus palposus* and *Dyschirus obscurus*. The lough also supports a great number of breeding birds and it is considered the most important non-estuarine site for wintering wildfowl in the UK (Allen and Mellon, 2006). Lough Neagh is important to wildfowl for a number of reasons; it has plenty of food in the form of Chironomid larvae; ample shelter; a well positioned location, as well as being a good depth for diving ducks (Enlander, 2006).

Lough Neagh also supplies around 50% of NI Water’s available treated water supplies. NI Water are authorised to abstract up to a total of 392 Ml/d from Lough Neagh under the existing abstraction licence, with a negligible impact on water levels (NIW, 2010). Lough Neagh also supports a number of recreational activities including fishing and water sports.

Both Lough Neagh and Lough Neagh Peripherals have been assessed with high confidence as having Bad Ecological Potential (BEP). Indeed, Lough Neagh together with its catchments has been identified as a Sensitive Area because it is highly eutrophic (hyper-trophic) due to nutrients coming from both agricultural and urban sources. Efforts have been made to reduce the levels of nutrients in the lough, including the introduction of phosphate stripping at waste-water treatment works (WwTWs) in the 1980s, originally thought to be the cause of eutrophic conditions in the lough (LNAC, 2002). However, the improvements to water quality have since been negated by the presence of agricultural runoff, and phosphorus concentrations have risen steadily since 1987. Additional water quality concerns in the Lough include large quantities of litter, floating animal carcases as well as levels of pathogenic bacteria in areas used for water sports (LNAC, 2002).

Over the last 150 years, the flora of the Lough has changed dramatically due to eutrophication. Algae growth has increased, leading to a reduction in light penetration to the depths of the lough which has contributed to a decline in once-abundant macrophytes (Allen and Mellon, 2005). Activities such as the introduction of a series of drainage schemes have also influenced the Lough’s ecosystem by drawing down water levels (LNAC, 2002).

Lough Neagh is the most important site for diving ducks in the UK; however there has been a severe decline in numbers of certain internationally important species (Pochard, Tufted Duck and Goldeneye) since winter 2001 – 02 (Enlander, 2006). A study commissioned in 2006 by the Environment and Heritage Service in Northern Ireland (EHS) looked at the possible reasons for this and it was found that chemical changes in the lough, particularly oxygen depletion, could possibly adversely affect some species.
of invertebrate in the loughbed fauna affecting food supply for the diving ducks (Allen and Mellon, 2006). This decline could however also be attributed to redistribution and further research is recommended in order to come to firmer conclusions.

Another species that has seen a decline in numbers is the pollan. Lough Neagh is one of four loughs in Ireland to contain the only European populations of pollan, making it one of the most important species in Ireland. The All-Ireland Species Action Plan mentions that eutrophication acts against pollan in a number of ways including favouring the dominance of the introduced roach over pollan (EHS and NPWS, 2005). However, due to the presence of higher numbers of pollan in Lough Neagh than in the other loughs that have a lower trophic status, the exact extent of the influence of eutrophication is unknown.

Being shallow, Lough Neagh may be particularly vulnerable to any changes in water levels and temperature that might occur due to climate change, exacerbating existing water quality issues such as eutrophication and affecting local ecology. For example, there is a danger that kills of Mysis relicta may occur, should temperature and pH continue to increase (Griffiths 2007). M. relicta populations decrease significantly as water temperature increases above 16° C, with recent temperature trends mirroring reduced densities. This may then have wider implications for the local ecology including rare pollan stocks, of which M. relicta is an important winter food source (Harrod, 2008). An increase in winter rainfall and the frequency of intense rainfall events may lead to an increase in nitrogen being leached from the surrounding agricultural land as well as discharges of effluent from point sources. This would be likely to further contribute to eutrophication in the lough, with potential implications for recreation and water supply including a possible requirement for more intense treatment processes.

The Department of Agriculture and Rural Development is the statutory drainage and flood protection authority for Northern Ireland, and the Rivers Agency undertakes the associated duties and responsibilities on its behalf. Rivers Agency, through its Hydrometric Section, manages and operates the Northern Ireland surface water hydrometric network. The network monitors water levels on rivers, loughs and sea at approximately 130 locations.

DARD, Rivers Agency aims to ensure that levels in Lough Neagh are maintained within specific ranges, other than during periods when climatic conditions make this impossible, and so far as reasonably practicable, in the general interest of stakeholders. Water levels are monitored on a daily basis and the control of water levels entails liaising with organisations representing commercial, recreational and environmental interests.

The Agency is required to regulate and control water levels in Lough Neagh within a specified range, that is 12.45 m to 12.6 m Ordnance Datum, as defined in the Lough Neagh Levels Scheme (1955) (as amended). Water levels in the lough are controlled by means of 3 sets of flood gates situated on the Lower Bann River. These are located at Toome, Portna (near Kilrea), and The Cutts at Coleraine. Incremental adjustment of floodgates is practiced, whenever possible, in order to minimise impact on the range of environmental and other interests associated with the lough.

The channel in the Lower Bann River, downstream of Lough Neagh, tends to impede the rate of outflow from the lough during periods of heavy rainfall. At such times the floodgates at Toome are fully opened, where possible, in advance of an anticipated rise in water level.
Lough Erne is a protected conservation site and important for tourism and recreational activities. It is also a source of freshwater supply for Northern Ireland. Pollution already negatively impacts on the lough and zebra mussels are common. Climate change may exacerbate pollution problems and give zebra mussels an advantage over native species.

Lough Erne is in two parts: Lower Lough Erne and Upper Lough Erne, which are located mainly within County Fermanagh. The River Erne flows through both Loughs before reaching Donegal Bay. The landscape around the two large loughs is very distinctive, featuring a number of islands and inlets.

Lough Erne provides around 4% of Northern Ireland’s water supply. It also supports a number of tourist and recreational activities including water sports such as waterskiing and sailing. Moreover, Upper Lough Erne has been designated as both a Special Area of Conservation under the Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora, 1992) with one of the strongest populations of otters in the UK and a Special Protection Area under the Birds Directive (Directive 2009/147/EC), supporting large numbers of wintering whooper swans (Cygnus cygnus) as well as other species including the great crested grebe (Podiceps cristatus).

Lough Erne is eutrophic and has been identified as an EC Urban Waste Water Treatment (UWWT) Directive (91/271/EEC) Sensitive Area. It is affected by both diffuse and point source pollution. Due to the impact on invertebrate communities, 73% of the surface water bodies in Lower Lough Erne Local Management Area (LMA) have been classified as less than good (NIEA, 2009a). In Upper Lough Erne LMA, 76% of surface water bodies have been classified as less than good due to inadequate levels of dissolved oxygen (NIEA, 2009b). Invertebrate communities were also found to be affected. Lower Lough Erne and Upper Lough Erne, both classified as heavily modified water bodies, have been assessed as having Moderate Ecological Potential (MEP).

Lough Erne is also affected by the zebra mussel (Box 5), perhaps one of the most well known invasive non-native species in Northern Ireland. It has been found to be present throughout both Upper and Lower Lough Erne. The zebra mussel affects water quality by filtering as much as one litre of water a day through its gills when it feeds, clarifying the water and leading to increased macrophyte growth (EHS, 2000b). Lough Erne can be entirely filtered by the zebra mussel population every 2 weeks and there has been a significant increase in water clarity as a result, with phytoplankton abundance decreasing to 10% of peak summer maximum. Lower Lough Erne favoured roach before zebra mussels were introduced. Now with the increase in water clarity and reduction in abundance of phytoplankton, it appears to favour perch. As a result there has been a decline in roach recruitment (Maguire and Sykes, 2004).

Climate change could put the zebra mussel at an advantage over other species in the lough due to its tolerance to a wide range of temperatures and low levels of dissolved oxygen, while an increase in winter rainfall could also benefit the zebra mussel particularly in shallow areas of the loughs (Maguire and Sykes, 2004).

Existing water quality issues in the lough could be exacerbated through a decrease in summer rainfall, an increase in temperature or a combination of both, with implications for the treatment of water for supply, as well as local ecology and recreational activities. An increase in winter rainfall and the frequency of intense rainfall events and the higher resulting runoff would also have the potential to influence water quality by leading to an increase in nitrogen being leached from the surrounding agricultural land.

DARD, Rivers Agency aims to ensure that levels in Lough Erne are maintained within specific ranges, other than during periods when climatic conditions make this
impossible, and so far as reasonably practicable, in the general interest of stakeholders. Water levels are monitored on a daily basis and the control of water levels entails liaising with organisations representing commercial, recreational and environmental interests.

Water level control in Lough Erne is undertaken in conjunction with the Electricity Supply Board in the Republic of Ireland under the terms of an agreement made in 1950 when the River Erne was harnessed for hydroelectric power generation. The agreement requires that levels are maintained in the Upper Lough between 150 ft. and 154 ft. (April to September) / 155 ft. (October to March), and in the Lower Lough between 147 ft. and 152 ft.

Water levels in Upper and Lower Lough Erne are managed by control structures located at Portora (Enniskillen), Cliff (near Belleek) and Ballyshannon in the Republic of Ireland. The Agency is responsible for the control structure at Portora only. During the summer period the Electricity Supply Board aims to maintain the water level at Portora, at or above, 150 ft. to avoid the need for these gates (locks) to be closed. This is to prevent undesirable restriction to boat traffic using the navigation facilities at this peak tourist period.

Rapid draw down of water levels in the Upper Lough is prevented by the restricted capacity of the inter-lough channel section. Allowance for this has to be made, as best as possible, in level control management procedures.

5.2.5 Coastal areas

In Northern Ireland no-one lives more than 35 miles from the coast. Northern Ireland has 650 km of coastline between the tidal River Foyle in the north-west to Newry in the south-east. There are three broad types of landscape along the coastline:

- The north and northeast coastline is a combination of rocky headlands and cliffs interspersed with beaches of boulders, gravel and sand. The north coast is particularly exposed to the Atlantic Ocean. There are three AONBs: the Antrim Coast and Glens; the Causeway Coast (including the World Heritage Site of the Giant’s Causeway); and Binevenagh.

- The coast of County Down is gentler and lower lying. The shore is predominantly sand or gravel beaches or rocks. Any cliffs are made of soft material easily eroded by the sea.

- The remainder of the coastline is mostly made up of sea loughs (see Section 5.2.6).

Almost three quarters of the coastline is covered by some form of environmental designation, ranging from local and national to European and World status (including the Giant’s Causeway Coast).

Potential climate change consequences for the coast include the following:

- Loss of existing beaches, foreshores, salt marshes and sand dunes, due to more frequent flooding of the existing floodplain; higher extreme flood levels and potentially greater erosion. This would affect biodiversity, archaeology, tourism and the coastal landscape. Up to 100 hectares of beach may be lost by the 2080s (see Section 4.4.4).

- An increase in cliff instability and weakening of existing sea defences, due to coastal erosion. This may put buildings (including built heritage),
infrastructure (such as roads, railway lines, power stations, etc.) and the coastal landscape at increased risk (see Section 4.5.5).

- Changes in species migration patterns, which may impact on biodiversity and tourist activities (see Section 4.2.1).

- A longer tourist season with more visitors and increased tourism revenues, but also putting more pressure on limited natural assets and infrastructure (see Section 4.4.4).

**Case Study: The Giant's Causeway and Causeway Coast**

The Giant's Causeway and Causeway Coast World Heritage Site is a spectacular area of global earth science interest straddling the north coast of Northern Ireland. Celebrated in the arts and in science, it has been a visitor attraction for at least 300 years and has come to be regarded as a symbol of Northern Ireland. The complex geology of this coastline creates a multitude of micro-habitats and the area is important for seabirds. Climate change may increase erosion rates and the frequency of landslips along this coastline, altering the range and types of habitat as well as reducing public access periodically (Orford et al., 2007). Should climate change also lead to increased tourism and changes in land management, this would put additional pressure on the natural environment.

The Giant's Causeway and Causeway Coast World Heritage Site is located in County Antrim on the northeast coast of Northern Ireland. It was declared a World Heritage Site (WHS) by UNESCO in 1986 as an important cultural (due to the wreck of the Girona) as well as natural site. Since 1987 it has been a National Nature Reserve and also forms part of the Giant's Causeway and Dunseverick Area of Special Scientific Interest (ASSI). Most of the terrestrial area of the WHS falls within the North Antrim Coast Special Area of Conservation (SAC) designated under the Habitats Directive (Natura 2000).

The Giant's Causeway lies at the foot of basalt cliffs along the sea coast on the edge of the Antrim plateau. It is made up of some 40,000 interlocking basalt columns, the result of an ancient volcanic eruption estimated to have taken place between 50-60 million years ago. The tops of the columns form stepping stones that lead from the cliff foot and disappear under the sea. Most of the columns are hexagonal, although there are also some with four, five, seven and eight sides. The tallest are about 12 metres high, and the solidified lava in the cliffs is 28 metres thick in places. Geological studies of these formations over the last 300 years have contributed greatly to the development of the earth sciences.

The Giant's Causeway is considered as being one of the greatest natural wonders in the UK. It is owned and managed by the National Trust and the Visitor Centre remained the single most visited attraction (excluding country/forest parks and gardens) in Northern Ireland in 2009, with 714,612 visitors. Only Crawfordsburn Country Park had more visitors with 950,000 in 2009. (Northern Ireland Tourist Board 2010)

The area is a haven for sea birds such as fulmar (*Fulmarus glacialis*), petrel (*Hydrobates pelagicus*), cormorant (*Phalacrocorax carbo*), shag (*Phalacrocorax aristotelis*), redshank (*Tringa totanus*), guillemot (*Uria aalge*) and razorbill (*Alca torda*). Rock pipits (*Anthus petrosus*) and wagtails (*Motacillidae spp.*) explore the shoreline and eider duck (*Somateria mollissima*) are found in sheltered water. The National Trust has also made an inventory of rare and interesting plants which include sea

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155 For this designation the key feature is the vegetated sea cliffs.
spleenwort (*Asplenium spp.*), hare's foot trefoil (*Trifolium arvense*), vernal squill (*Scilla verna*), sea fescue (*Festuca spp.*) and frog orchid (*Coeloglossum viride*).

The coastal environment of the WHS is a combination of steep slopes, fractured rocks, high rainfall and active marine erosion. Therefore, the region is characterised by a wide range of landslides. These pose a risk to visitors, but are an essential component of the site. The complex and constantly changing landscape provides a range of microenvironments that support a diverse flora and fauna.

Slope failures range from shallow, translational flows to large scale rotational landslides and block falls (size ranges from individual boulders to hundreds of tonnes). There are two broad slope classes – those found on headlands (where there are vertical or near-vertical cliffs) and those found in the bays (where there are extensive scree slopes).

Specific areas of the WHS have been categorised as moderate or high hazard areas, but it is not possible to predict where individual falls, slides or flows will occur. Final trigger for these failures is often a period of prolonged and/or intense rainfall, but underlying factors include the undermining of cliffs by coastal erosion, human excavations and gradual weathering and weakening of the geology (Queen's University Belfast, n.d.).

As current projections suggest that there will be wetter winters and more intense rainfall events in the future, it is possible that there could be an increase in landslides along this coastline.

The natural erosion is already gradually altering the cliff exposures. This could be accelerated with climate change and path routes (and perhaps even site boundaries) may need to be changed to accommodate the effects of this process. The rising sea level may also, in the future, affect the degree to which the causeway is accessible or visible. Both of these processes are being monitored at the site.

Increased erosion would also impact on the habitats on the site, such as coastal saltmarsh and coastal vegetated shingle. According to the National Trust, particular plants at risk would include oysterplant (*Mertensia maritima*) and Scot's Lovage (*Ligusticum scoticum*) and the most notable invertebrate likely to be affected would be...
the tiny narrow mouthed whorl snail (*Vertigo angustior*), which is only found in Northern Ireland at this site (Orford et al., 2007).

Other factors that have the potential to impact on the site include: damage to the natural features caused by human activities (managed/controlled by the National Trust) and damage to the landscape caused by human activities (managed/controlled by legal and spatial planning control measures). Tourism and land use are both likely to be affected by a changing climate in Northern Ireland; without careful management and control, these impacts could have consequences for this coastline.

### 5.2.6 Coastal waters and marine environment

The seas around Northern Ireland are home to a wide variety of marine life, maritime heritage and, in the future, could be an important source of minerals and renewable energy. They also support local fishing communities and are popular for tourism/leisure activities (particularly the sea loughs).

Northern Ireland’s sea loughs have a total area of 522 km² and drain 40% of the land area of Northern Ireland. The sheltered shores within the loughs are usually composed of fine sand or muddy sediments.

- Lough Foyle is Northern Ireland’s largest estuary and forms the north-west border with the Republic of Ireland. The large volume of freshwater draining into the lough means that it only has about two thirds of the salinity of the open sea.
- Strangford Lough is the second largest lough and the deepest.
- Belfast Lough is the third largest and the most heavily industrialised. It is semi-enclosed with 96% of its area sub-tidal.
- Carlingford Lough forms part of the southern border with the Republic of Ireland. Apart from a narrow channel along its centre, it is a relatively shallow lough.
- Larne Lough is the smallest sea lough and has the port of Larne at its seaward end.

Shipping also plays a vital role in Northern Ireland with the largest towns in the Province being associated with ports.

Potential climate change consequences for coastal waters and the marine environment include the following:

- An increase in harmful algal and jellyfish blooms, affecting both people and wildlife (see Section 4.2.3).
- Damage to aquaculture and sea fisheries (including shellfish) due to sea level rise, a deterioration in water quality and ocean acidification (see Section 4.2.3).
- A shift in marine species, resulting in changes to biodiversity that may include a reduction in commonly fished species and the introduction of new species. This would result in both threats and opportunities for the fishing industry and the wider environment (see Section 4.2.3).
- An increase in non-native species, which could have significant economic and environmental consequences where they occupy the same niche as native or commercial species if they become invasive (see Section 4.2.3).
The opening of the North East and North West Arctic passages, providing new opportunities for shipping routes (see Section 3.3.4).

**Case Study: Strangford Lough**

Strangford Lough has high biodiversity value, not least because of the presence of rare horse mussel reefs, and it also has considerable economic importance for the local community. Climate change may lead to increased problems from pollution and changes in the composition of species, including the localised extinction of horse mussel and disruption of the reefs they form.

**Landscape**

Strangford Lough is a shallow sea lough located on the east coast of Northern Ireland. It covers an area of roughly 150 km² and is approximately 30 km in length. The northern part of the Lough is very different from the southern part. It is much shallower and calm and around 50km² of sand and mudflats are exposed on northern shores at low tide. Towards the south of the lough, the waters are turbulent and fast-flowing due to the advance and retreat of tidal waters through a deep and constricted channel known as the Narrows (Strangford Lough Information Network, 2010). The lough is saline, except at the mouths of the Quoile and Comber rivers, which provide the main freshwater input.

**Value**

**Biodiversity** - Extensive areas of mudflats, sandflats and saltmarshes are contained within the indented shoreline of the lough, and over 2000 marine species have been recorded (Strangford Lough Information Network 2010). As a result the Lough is designated as a Marine Nature Reserve, the only one in Northern Ireland; it is also a Marine Protected Area under the OSPAR convention. Strangford Lough is also designated as a Special Area of Conservation (SAC) under the Habitats Directive (92/43/EEC) as well as a Special Protection Area (SPA) under the Birds Directive (2009/147/EC) as it supports internationally and nationally important numbers of species, in particular, the sublittoral *Modiolus modiolus* biogenic reefs (reefs formed by
horse mussels, a “keystone” species because of the physical structure they form). *M. modiolus* beds are relatively rare and due to their threatened status are highlighted under the OSPAR convention for conservation focus. The area of Strangford Lough and Lecale have also been designated an Area of Outstanding Natural Beauty.

Severe declines in *M. modiolus* reefs have already occurred. Changes in community structure have also been observed including: increases in seagrass (*Zostera* spp.), ascidians (sea squirts) and oysters (*Ostrea* spp.); decreases in *Ascophyllum* spp. (common brown alga); declines in fisheries landings of some species and the collapse in the queen scallop fishery; and distributional changes in sea snails, such as *Gibbula umbilicalis* (Flat or Purple topshell) and *Ostlinus lineatus* (Thick Topshell).

**Economy** - The lough is of considerable economic importance too, sustaining a number of different recreational activities including diving, sailing and walking. The tourism industry is a key factor in the management of the protected areas. The high amenity value of the area and conservation designations draws in tourists and provides an attractive and popular venue for informal recreation by locals (dog walking, etc.) (Environment and Heritage Service, 2001b). There are over 40 boat tour operators and the local fishing industry is small but important to the local community and environmental protection of the area (catching 54 tonnes of fish, to a value of £156,000 in 2007). The lough also supports tidal power generation (see Section 4.2.3) and is noted for having a very large proportion of artists and craft people (Strangford Lough Management Advisory Committee, 2010).

**Climate change impacts**

**Water temperature** - Being a shallow lough, it is expected that water temperature would rise with higher air temperatures (Roberts *et al.* 2004). This could cause a shift in the balance of communities through encouraging certain species to thrive while others decline. The increase in sea snails such as *Gibbula umbilicalis* (Flat or Purple topshell) could be due to increases in water temperature as they are particularly tolerant of this type of change (FSC 2008). In terms of the *M. modiolus* beds, habitat disturbance by mobile fishing gear for example, which may also incidentally allow increased predation, is identified as the most likely cause of the initial damage to *M. modiolus* beds in Strangford Lough. However, other factors, such as water temperature increases may be preventing recovery, which could lead to significant changes in the ecosystem as *M. modiolus* are keystone species. In the longer term climate change may reduce *M. modiolus* beds in the south of their range (in UK waters) and increase it to the north (further into the arctic). Owing to the long life-span of these molluscs and the apparent persistence of established beds there would be a considerable time-lag between climate shift and observable habitat changes. At present it is not possible to discriminate climate change declines confidently against a background of fishing impacts. However, having shown an ability to colonise artificial habitats offshore, it is likely that where suitable habitat exists, the species will be able to spread further in the Arctic (Rees 2009).

**Water quality** - The main concerns for Strangford Lough are levels of Dissolved Inorganic Nitrogen (DIN) and impacts on phytoplankton and macroalgae communities (NIEA 2009c). As a result, the current overall ecological status of Strangford Lough is ‘Moderate’; however a number of rivers that feed into the lough are currently classified as ‘Poor’ (including Blackwater, Balree and Enler) and even ‘Bad’ (Blackstaff) (NIEA 2009c). Direct runoff from land contributes a major source of nitrogen to Strangford Lough, with agriculture (specifically improved grassland and arable) being the predominant land use in Strangford Local Management Area (LMA). Nitrogen has been shown to influence primary productivity level of plant life in the lough (Service *et al.* 1996). An increase in winter rainfall and the frequency of intense rainfall events and
the higher resulting runoff may lead to an increase in nitrogen being leached from the surrounding agricultural land as well as discharges of effluent from point sources.

Invasive non-native species can also influence water quality in Strangford Lough. The alga *Sargassum muticum*, for example, has been found to influence water temperature in Strangford Lough by causing strong temperature stratification (Strong *et al.* 2006).

In addition, there is increasing urbanisation at the north end of the lough, and potential sewage discharges from these areas could also influence water quality in the lough.

**Sea-level rise** - Sea-level rise could also have a dramatic impact on Strangford Lough. For example, a rise in sea-level of 0.2m would result in the low tide line moving between 20m and 30m inland; a rise of 1m would result in the low tide line moving between 400m and 500m inland. The latter would cause a significant proportion of existing mudflats to be permanently underwater (National Trust 2007).

Further habitats such as saltmarsh could also be eroded or lost, unable to migrate due to the presence of sea defences (coastal squeeze). A great number of species could be affected by such changes including winter birds and Common and Grey seals, as well as summer breeding seabirds due to the loss of nest sites.

Strangford Lough has been exploited for fish, shellfish and seaweeds for centuries with fisheries declining in recent years. This has contributed to the disturbance of the lough bed in places, releasing sediment into the water column, causing local ecological disruption and affecting water clarity (Roberts *et al.* 2004).

**Salinity** - Decreases in summer rainfall could affect salinity mainly in the northern part of the Lough by influencing the amount of freshwater flowing into it; however the exact effects of this on the conservation features of the lough are unknown (EHS 2001b).

**Case Study: Rathlin Island**

| The waters around Rathlin Island are a biodiversity hotspot, particularly for marine invertebrates such as sponges and other groups of habitat forming species such as maerl. Increasing sea temperatures may result in a shift in climate space, with maerl beds moving northwards away from their current range. This would have knock-on effects for other species that depend upon them and may severely disrupt the marine habitats around Rathlin Island. |

**Value**

The waters around Rathlin Island are designated as a marine Special Area of Conservation (SAC). A survey by the Environment and Heritage Service and Ulster Museum in Belfast in 2007 found 134 species of sponges alone, 29 of which were new to science. This makes Rathlin one of the most important sites for sponges in the world. Sponges are very important ecologically as they form the structural basis of the habitat; they are low down in the food chain i.e. lots of species rely on them as a food source; they also recycle nutrients, consume bacteria and improve water quality. Including the sponges, the survey team found two-thirds of all Northern Ireland’s marine invertebrate species at Rathlin Island (Goodwin and Picton 2008), including a previously unknown maerl bed\(^{156}\) and a live fan mussel, *Atrina fragilis*, the UK’s largest and rarest bivalve mollusc.

\(^{156}\) A calcareous reef-forming algae that supports many other species such as juvenile Atlantic cod.
Human impacts

Benthic species tend to be particularly sensitive to substrata loss, smothering, any increase in suspended sediment, abrasion and physical disturbance. In addition, groups of species such as sponges can be greatly affected by pollution, as they filter the water to obtain food (OSPAR Commission 2008). Bottom trawling and dredging is a risk to some habitats around Rathlin. However, pollution is currently not a significant problem (EHS 2001c).

Climate change impacts

Climatic change impacts, principally caused by increasing water temperatures, will vary depending on the species in question. These may include:

- Species currently at the southern limit of their range may contract, moving northwards, as higher temperatures make reproduction and survival difficult.
- Species currently at the northern limits of their range may expand, moving northwards, as the higher temperatures make reproduction easier and larval survival increases.
- Some species may decline or increase in abundance, because their grazers or predators increase or decline in abundance.
- Changes will be most apparent first in mobile species such as fish. Amongst benthic species, the response will be greatest in those with a planktonic (i.e. free in the water column) stage in their life cycle.
- Increased storminess may shift communities, particularly intertidal communities, to those characteristic of more wave exposed conditions (Hiscock et al. 2001).
- Elevated sea temperatures may lead to outbreaks in bacterial infection of benthic species (Bally and Garrabou 2007).

The different response of different species would lead to changes in the community composition of marine habitats. In the case of sponges and maerl, that perform important roles in the structure of the habitats, any changes that were experienced by these groups would have knock-on effects for the species that rely on them. Maerl beds are projected\textsuperscript{\ref{footnote:maerl-movement}} to move northwards with increasing temperatures, moving them away from their current range surrounding Northern Ireland, Scotland and parts of northern England, to covering only the northern most tip of Scotland and the islands (Hiscock et al., 2001).

\begin{footnotesize}
\begin{enumerate}
  \item \textsuperscript{\ref{footnote:maerl-movement}} Assuming a 2 degree rise based on a bioclimatic model (Hiscock et al. 2001).
\end{enumerate}
\end{footnotesize}
6 Gaps in evidence

6.1 Summary

Gaps in evidence come in a number of forms, including:

- UK-wide gaps identified as part of the CCRA analysis for the UK;
- Northern Ireland specific gaps identified as part of the CCRA analysis for the UK; and
- Northern Ireland specific gaps identified as part of this assessment for Northern Ireland.

This section summarises all of the above from the perspective of what is believed to be important to Northern Ireland. Gaps in evidence relating to each of the five themes are discussed in the sections below. Appendix E provides a list of all risks for Northern Ireland that are indicated as not assessed in this report and the reasons why.

A separate report is being produced as part of the CCRA that provides recommendations for the next CCRA, which will cover the whole of the UK including Northern Ireland (CCRA, 2012b).

The most significant gaps in evidence for Northern Ireland relate to future flood risk, which may have significant consequences for the coastal environments, agriculture, residential and non-residential properties, infrastructure (including transport, energy, water and ICT) and the health and wellbeing of people affected.

As part of the Preliminary Flood Risk Assessment (PFRA) for Northern Ireland, which takes account of flooding from all sources, a broad range of flood risk indicators have been generated to measure the adverse impacts of potential future floods on groups of receptors and these quantitative indicators will be available when the PFRA is published in December 2011. However, due to the inherent uncertainties in the flood modelling techniques and data used to produce this national snapshot of Northern Ireland’s flood prone areas, the Strategic Flood Map (SFM) is not sufficiently accurate to determine the flood risk to individual properties or specific point locations. The second generation flood hazard and risk maps that will be produced for the Areas of Potential Significant Flood Risk shall be much improved with less uncertainty, as these will be derived from predictive models, developed in accordance with best practice.

The Climate Change Flood Map, produced by the PFRA, only provides the estimated flood plains relevant to the year 2030. To help increase our understanding of the consequences of climate change, remove uncertainties regarding their scale and nature and aid climate change adaption, further research is needed to enable a more detailed analysis of future flood risk for Northern Ireland, similar to that carried out for England and Wales as part of the CCRA. This would require the use of the range of climate scenarios (based on the projections presented in UKCP09 for the 2020s, 2050s and the 2080s) and associated socio-economic scenarios selected for the CCRA analysis. Further information on the PFRA can be found in Appendix D.

Another key area of further research required for the UK as a whole, rather than uniquely for Northern Ireland, is the inclusion of the interactions between impacts and consequences within a climate change risk assessment. As part of the CCRA a systematic mapping exercise was undertaken that produced a network with around 2400 consequences. This is described more fully in the CCR Evidence Report (CCRA,
However, further research is required to be able to use such mapping as part of a detailed assessment exercise.

6.2 Natural environment

Much of the climate change research conducted to date has, of necessity, been focused either upon individual species or on specific locations or habitat types. Development of systems-based approaches that can improve understanding of the multitude of interactions within the natural environment, and their links to the human environment, remain in the early stages.

The basic knowledge gap is our understanding of change and ecosystem dynamics, including the interaction of people within ecosystems (and the role that biodiversity plays in driving functions and underpinning ecosystem services). This is essentially due to the complexity of responses and feedbacks involved, but also because this has often been a neglected topic in research. As a consequence, key functions and services provided by ecosystems have fundamental uncertainty in terms of how they will respond to change. A coherent baseline is required on the current state of ecosystems, the impacts that can be expected and how they relate to both the rest of the UK and to the Republic of Ireland.

Continuous data records that are comparable across years or standardized across the UK are also limited, although some very good examples do exist. In Northern Ireland specifically, data and research issues often centre on whether data exist, their accessibility and their comparability and compatibility (NEA, 2011).

The following have been identified as knowledge gaps relevant for Northern Ireland, using this and the UK level CCRA assessment. It should be noted that many of these gaps are applicable to the rest of the UK too which reflects the number of gaps in our knowledge of the natural environment. It should also be noted that Northern Ireland is in the unique position of bordering another country and cross-border knowledge may be required for some of these gaps:

Cross-cutting

- Integrated modelling of species distributions and interactions, habitat shifts and landscape structure based upon models that combine biological, ecological and climate factors. This would provide a more robust evidence base than the current reliance on bioclimate envelope models to project future changes in range shifts.

- Better understanding of the implications to ecosystem function and services from climate change. For example, what will be the net effect of phenological mismatches (mismatches or asynchrony in the timing of species life-cycle events); what will be the costs to humans?

- Detailed epidemiological knowledge of different pests and diseases (and their vectors) and their relationship with climate and climate change.

- Detailed knowledge of different non-native species with the potential to become invasive; their associated economic costs and their relationship with climate and climate change.
Terrestrial

- Exploration of the role of biodiversity in ecosystem function and services. Of particular to Northern Ireland is the role of soil biodiversity in the production and maintenance of soil organic matter, nutrient and water cycling and carbon sequestration (NEA, 2011).

- Climate change mitigation:
  - Opportunities for the natural environment. For example, how efforts to increase carbon storage in soils may benefit soil biodiversity and flora.
  - Threats for the natural environment: For example, exploration of where future wind farms will be located and the impact that will have on bird and bat strikes.

- Improving the effectiveness of the protected area network. Evaluation of current protected areas, how they might change (e.g. change in species use due to changes to migration paths) and how they might be strengthened and better integrated into the wider landscape.

- Develop a baseline understanding of the incidence and consequences of wildfire currently.

Freshwater

- Improved understanding of the combined impact of climate change and pollution on ecosystems.

- Water quality and provision:
  - Exploration of the role that the environment plays, in addition to climate, in determining raw water quality; how these things may change under future climate and environmental conditions and how water quality changes may be monitored is required. The associated consequences for water provision and on priority habitats and species need to be better understood.
  - Exploration into the combined effects of climate change and the point or diffuse sources of pollutants that may lead to eutrophication and unwanted algal growth.
  - Exploration into the relationship between current abstraction rates and implications for biodiversity under drought conditions and future climate change.

- Exploration into the national-level impacts (not just local studies) of increasing water temperatures on biodiversity and the regulation of water quality for the natural environment and human use.

- An understanding of the impact of climate mitigation measures on biodiversity is required. The information needed to improve this understanding is:
  - The spatial strategy for future renewable energy expansion
  - Distribution of important habitats and species in the future.
Coastal and marine environments

- Coastal flooding and coastal erosion:
  - Baseline maps of habitats are required. Coupled with quality and biodiversity assessments and investigation of the impacts on ecosystem services.
  - Maps of past erosion, current state and future erosion conditions are required.
  - Need an understanding of what and where cultural heritage is at risk.

- Water Quality
  - More complete monitoring of potential bathing waters
  - Exploration of the potential for Harmful Algal Blooms, specific to the seas around Northern Ireland. Consideration of stratification as well as average temperature increases is important.

- Exploration into the drivers of eutrophication of sea loughs to ascertain the level of impact climate change may have.

- Fish and shellfish stocks. Understanding the future implications of climate change for fishing fleets, fishermen, economies and society with regard to changes in fish ranges, recruitment and the impacts of ocean acidification on shellfish stocks.

- The impacts of climate change on plankton blooms, and the interaction any changes may have on marine life, carbon and nutrient cycling and invasive species should be further investigated. There is an associated risk to the shell-fish industry which may require further exploration.

- The impact of climate mitigation measures. This has been analysed in the Biodiversity and Ecosystem Sector report regarding terrestrial bird strikes, but it does not include sea birds. An improved understanding the impacts of marine renewable energy sites, including wave power and wind turbines, is needed to fully understand the risks to biodiversity and the marine environment. With Northern Ireland expected to increase the number of offshore wind farms, and potentially also use wave and tidal generation (such as SeaGen), there is a requirement for further research into how these may affect the marine and coastal environments.

6.3 Agriculture and forestry

A number of key areas relevant to Northern Ireland have been identified, where further work would increase understanding of the consequences of climate change on agriculture and forestry, help remove uncertainties regarding their scale and nature, and aid climate change adaptation. These are the following:

Agriculture

Future projections of river and tidal flood risk to arable, horticultural and grassland are not provided for Northern Ireland due to a lack of suitable data at the time of the assessment. Additionally, data was unavailable to analyse the risk of saline intrusion on agricultural land despite this being highlighted as a potential problem by stakeholders. Whilst it is now possible to have a strategic overview of future risk using
the Strategic Flood Map (SFM) and output from the recent preliminary flood risk assessment. However due to the inherent uncertainties in the flood modelling techniques and data used to produce this national snapshot of flood prone areas, the SFM is not sufficiently accurate to determine the flood risk to individual properties or specific point locations. The second generation flood hazard and risk maps that will be produced for the Areas of Potential Significant Flood Risk shall be much improved with less uncertainty as these will be derived from predictive models, developed in accordance with best practice.

- UK wide assessments indicate that greater evidence is needed on specific social vulnerability issues for the climate change risks analysed, as these currently focus on agricultural and forestry production rather than the broader issue of the rural economy. The vulnerabilities of rural communities to cope and the impact on their lives and livelihoods could be explored further. The overall impacts on farming systems need a greater insight into how Northern Ireland’s farmers adapt to climate change.

- To fully quantify climate change risks, further investigation into the impact of extreme events on livestock welfare and production is needed for Northern Ireland. An assessment of heatwaves and drought impacts on livestock is also required.

- Additionally, an assessment of livestock water use could be undertaken to include the impacts of climate change, and the effect on local hydrology.

- Analysis of the impacts of climate change on potato yield currently excludes the effects of CO₂. The adaption of this model to include CO₂, or the development of a similar model to also include Northern Ireland, would help quantify the risk for Northern Irish potato farming for future climate change.

- Currently climate change evidence impacts on crop pests and disease is qualitative and provides a weak assessment of the risks. A quantitative assessment of crops, pests and pathogens and their relationship to climate change would increase the risk analysis.

- Further analysis into grassland productivity and the influence of CO₂ fertilisation is needed for Northern Ireland. There is an indication that the increases projected as part of the CCRA may be too high, but there is a lack of robust research to confirm this.

- GHG emission may increase with a change in land use, brought about by climate change and agricultural development. Little data is available on the potential carbon release as a result of the drying-out of wetlands.

- A more detailed study into the impacts of waterlogging would enable a more regionally representative assessment of the future risk. This would allow for adaptation measures to be suggested for Northern Ireland’s important agricultural sector.

**Forestry**

- The impact on frost and snow damage would benefit from further evidence and analysis.

- Further developments in the modelling of storms would allow more confident projections regarding windthrow and storm damage.

- Tree productivity, biodiversity and tree suitability modelling excludes Northern Ireland. Impacts on forest biodiversity and ecosystem services
could be better understood with the aid of national datasets and an understanding of rising temperature on vegetation growth and reproduction. The development of a tool similar to the Ecological Site Classification System, used for the rest of the UK, for Northern Ireland would help analysis of tree productivity metrics.

- Further research into the link between tree pests and diseases and their interaction with climate drivers would aid forestry planning and development. Greater insight to pest and disease physiology would help understand their spread and response and allow for a more robust assessment of future risks. Additionally, the development of tree productivity modelling to include the effects of pests and diseases would aid future projections.

6.4 Business and services

The potentially most significant gaps in knowledge regarding the consequences for businesses and services in Northern Ireland relate to flooding (see Section 6.1).

In addition to these, a number of key areas where further work would increase understanding of the consequences of climate change on business, help remove uncertainties regarding their scale and nature, and aid climate change adaptation were identified as part of the UK-wide assessment. Those relevant to Northern Ireland include the following:

- At the moment, there is limited substantive evidence of the consequences of changes in climate on UK financial institutions, including the impact on investment funds. The confidential nature of the underlying data and the fact that there are many other socio-economic drivers operating, mean that disentangling the impacts of climate change is challenging.

- The complexity of supply chains is similarly, difficult to analyse because it involves the interaction of a number of networks that are themselves complex. Nonetheless, there may be scope to develop a better understanding of network interactions as modelling improves.

- The information on the disruption caused to business by extreme events, such as floods and heatwaves is limited and largely reliant on insurance industry reporting. More systematic data collection would enable a more complete assessment to be developed.

- Two risks were highlighted as potentially becoming increasingly important towards the middle of the century, namely water abstraction for industry and a loss of productivity due to over-heating. Both of these assessments have been made with very limited information on the likely response and the potential of adaptation measures to reduce the extent of the impact. More detailed assessments would be helpful better to understand the likely significance of these impacts, although over-heating may be less of an issue for Northern Ireland than for other parts of the UK.

- Creation of data regarding water abstraction for energy supply. The development of the Abstraction and Impound Regulation licences provide an opportunity monitor the volume of abstraction.

Additional consequences identified as important for Northern Ireland that have not been assessed as part of this first CCRA are:
• Changes in UK trading patterns
• Underestimation of decommissioning liabilities and end of life costs
• Seasonal interruptions to construction activities
• Further assessment of the risk posed by key workers being unable to get to work due to severe weather. Research into this risk would allow for management and action plans to be implemented for future extreme events.

6.5 Buildings and infrastructure

6.5.1 Gaps specific to Northern Ireland

The potentially most significant gaps in knowledge regarding the consequences for buildings and infrastructure in Northern Ireland relate to flooding (see Section 6.1).

Other issues that are considered important specifically for Northern Ireland (and were not part of the UK-wide analysis) that would benefit from additional analysis include:

• Reliance on imported fossil fuels
• Energy demand by water suppliers
• Failure of water impoundment structures
• Algal growth in raw water supply sources
• Changes in reservoir yields for public water supply
• The disaggregation of projected supply-demand deficits for the river basins shared with the Republic of Ireland
• Pest infestations
• Waste management
• Rainwater penetration and damage to buildings
• Condensation, damp, mould, algal/fungal growth in buildings

6.5.2 UK-wide gaps

In addition to these the following gaps in knowledge were identified as part of the UK-wide assessment:

Buildings and the urban environment

Areas where further work could underpin more robust projections and adaptation strategies for the built environment sector include:

• Development of a better understanding of the complex cause-and-effect interactions of climate change impacts.

158 These were included in, but not looked at separately from, deployable outputs as part of this assessment.
• Development of a clearer understanding of technical solutions, their costs and their financial viability.
• Development of an improved appreciation of the economic impacts of climate change.
• Development of low-carbon solutions that are also robust to the effects of climate change.
• Research into potential impacts (e.g. increased pest infestations) on historic buildings and the heritage sector in general.
• The effects of an Urban Heat Island, with greater consideration to impacts on human health.

Energy
Key areas where more clarity is needed about the effects of climate change on the energy sector include:

• Site-specific flood risks to individual locations where energy infrastructure is located.
• Relating CDD to energy demand taking into consideration non-climate factors (such as building stock and uptake of air-conditioning).
• Positive and negative impacts of warmer temperatures on electricity demand and supply and the interdependence between these impacts.
• Climate projections for other parts of the world relevant to the UK energy sector (e.g. the Middle East).
• The particular vulnerability of cities to climate change.
• The impact of climate change on the UK’s wind energy resource.
• Timescales within which different adaptation approaches need to be implemented in order to be successful.

More broadly, future climate change risk assessments should aim to look more closely at alternative future pathways for delivering a low carbon economy (in particular regarding the future energy mix) and how these may be affected by climate change.

Transport
The underlying issue for this sector is a lack of coherent data across the UK, resulting in a predominantly qualitative assessment with a significant amount of uncertainty in the outcomes.

The transport sector is integral to the smooth running of society and the economy and further work is required to help meet the challenge of establishing reliable and relevant climate change impact projections and adaptation strategies. Technological innovation should be considered alongside other socio-economic factors.

Ongoing research, such as the TRACCA project (Tomorrow’s Railways and Climate Change Adaptation), will be a first step to providing more knowledge in some areas.
Water

Despite the extensive work already undertaken in this sector, there are a number of areas where additional research would either strengthen the evidence base on which climate change impact projections can be made, or inform decision-making on potential adaptation measures. They include:

- The potential impact of climate change on water quality and the knock-on effects to the public water supply.
- The environmental impacts of drought (and climate modelling of droughts lasting more than one season).
- The impacts of changes in water demand on river flows.
- Techniques enabling early detection/attribution of manmade climate-related impacts on the water sector.
- Development of tools and techniques for scaling up local case studies to UK level.

Telecommunications

There is a limited evidence base regarding climate change impacts for the telecommunications sector. This makes forward planning difficult and is compounded by the short-term business models applied by industry.

Telecommunications within the context of our future climate are important due to the interdependencies described in earlier sections of this chapter. Further research and awareness-raising is needed regarding the resilience of ICT systems. It is particularly important that the role of ICT systems in potential cascade failures is understood more fully, especially in light of the growing usage of ICT systems and the sharing of ICT infrastructure within the UK and abroad.

6.6 Health and wellbeing

Although a significant amount of research has been carried out into the Health effects of climate change for the UK, much of this work has been carried out for England and Wales only, and as such in certain areas there are specific gaps in knowledge pertinent to Northern Ireland.

The CCRA analysis focused on England and Wales as the data was in the public domain and the relationships had already been established. For Northern Ireland (and Scotland), the data is not yet in the public domain and would require an ethical clearance order to release it, which can take a long time. If this data were obtained, it would be possible to carry out similar analysis for Northern Ireland, but the project timescale prevented this.

Some future health impacts are very uncertain, as they are an accumulation of several climate variables, and/or mainly driven by human behaviour or actions rather than climate.

Key areas of research where further work could increase understanding of the impacts of climate change, help remove uncertainties regarding their scale and nature, and aid climate change adaptation in relation to Health and Wellbeing for Northern Ireland include:

- Temperature mortality (heat and cold)
There are no known published temperature-mortality relationships for Northern Ireland. As a result, the results presented are likely to be overestimated for heat (although not significant), yet under-estimated for cold related mortality. Although these relationships would be relatively easy to establish, the data sets required for the analysis cannot be released without ethical clearance, which typically takes six months. In addition, many winter deaths are as a result of infectious diseases such as influenza and pneumonia which means that it is difficult to attribute individual deaths to a cold related disease. Based on current published evidence, this means that any estimate of cold related deaths would be unreliable, although still significant.

- **Temperature morbidity (heat and cold)**

  Although there is certain evidence that very high and very cold temperatures have an impact on a range of morbidity outcomes, with an increase in patient-days per year due to heat and cold related illnesses, the rate of change is highly uncertain. In addition, as for cold mortality noted above, winter hospitalisations are clouded by infectious diseases more common in the winter which means that it is difficult to attribute individual hospitalisations to a cold related disease. Similar to above, this impact is likely to provide a significant opportunity for Northern Ireland due to cold, yet a relatively small impact compared to the rest of the UK due to heat.

- **Extreme weather event (flooding and storms) mortality and morbidity – analysis**

  Very little research has been carried out into the relationship between extreme weather events and their impacts, and the consequent increased deaths and injuries as a result of these events. This is particularly the case for countries such as the UK that are not exposed to weather events such as hurricanes, and/or the large scale deep flood events experienced in recent decades in places such as the USA, India and Bangladesh. Northern Ireland is also not exposed to the levels of wave activity from the Atlantic Ocean and North Sea experienced on many parts of the British mainland, and the risk due to coastal activity would therefore be expected to be less significant here than for the rest of the UK.

- **Extreme weather event (flooding and storms) mortality and morbidity – data sets**

  Baseline data sets are poor, with no central record of deaths or injuries related to individual floods or storms kept in Northern Ireland. There is also no clear accepted definition of what is a flood or storm related injury. With relatively few deaths and injuries due to extreme weather event flooding and storms, as well as the highly clustered nature of these events, it is currently difficult to establish baseline estimates for Northern Ireland. Current and future flood risk is also unknown, although ongoing research due to deliver later this year should address this issue. However, the lack of long-term reliable tidal data sets particularly along the fast moving waters of the North Channel means that estimates due to coastal flood events would currently remain unreliable.

- **Summer air pollution (ozone)**

  Little research has been done on future ground-level ozone concentrations and how climate may affect them, and research that has been carried out has only considered plausible climates in the 2070s and 2080s, and no research specific to Northern Ireland. More research is required for time periods specific to Northern Ireland in both rural and urban environments and different thresholds below which ozone concentrations do not cause harm to human health.
- **Sunlight/UV exposure – skin cancer**
  The future change in the numbers of skin cancers per year is related to the change in risk of skin cancer due to the change in the mean annual flux. However, this variance is linked to a number of factors, including the main variable time spent outdoors, as well as a number of socio-economic factors including the future age structure of the population and the changing ethnic mix. Although current projections indicate little change to UVB radiation for Northern Ireland, future research is required into how the various socio-economic factors may change skin cancer risk, and whether this may change the current rate for Northern Ireland, which currently shows little variation from the UK average.

- **Sunlight/UV exposure – health benefits**
  UV exposure can have a number of health benefits, including the synthesis of vitamin D as well as some therapeutic effects. There is also some evidence for vitamin D protecting against some cancers, although evidence is currently weak. More research is therefore required into the health benefits of increased UV exposure and how these may weigh against the negative effects of increased cases of skin cancers.

- **Sunlight/UV exposure – registration of non melanoma skin cancers**
  Registration of non melanoma skin cancer cases is currently incomplete across the whole of the UK, particularly in relation to basal cell carcinomas. This needs to be corrected to enable a more robust analysis of this metric to be made.

- **Effects of floods/storms on mental health**
  Although significant progress has been made in recent years researching the mental health effects due to extreme weather events, little is known about the effects long term. The methodology commonly used in Northern Ireland flood studies uses the GHQ-12 to assess mental health effects. Although this methodology indicates that a mental health effect has occurred, it is unspecified and gives no indication of the nature or severity of the effect.

- **Hospitals at risk from flooding**
  There is a risk that hospitals in Northern Ireland may not be resilient to flooding, particularly during extreme events. It is not currently known how many hospitals are at flood risk in Northern Ireland, or how this is likely to change in the future. A strategic overview of the flood risk to hospitals and medical centres can now be undertaken using the Strategic Flood Map (SFM) and output from the recent PFRA (see Appendix D). However, due to the inherent uncertainties in the flood modelling techniques and data used to produce this national snapshot of flood prone areas, the SFM is not sufficiently accurate to determine the flood risk to individual properties or specific point locations. The second generation flood hazard and risk maps that will be produced for the Areas of Potential Significant Flood Risk shall be much improved with less uncertainty as these will be derived from predictive models, developed in accordance with best practice.

- **Insurance and mortgage availability**
  The more vulnerable members of society are more likely to live in flood risk areas, and are at significantly greater risk due to likely levels of increased flood levels and occurrence under a changing climate. With the potential reduced availability and increased cost of insurance, this could have not only consequential economic costs, but also mental health effects as more people
do not have the financial resources to cope. More research is required in this area, however, this could only be considered after the future flood risks for Northern Ireland are better understood (see comments under extreme weather event flooding/storms above).

- **Fuel poverty**
  Projected increases in mean temperatures are likely to be an opportunity for Northern Ireland, with lower heating requirements in the winter and reduced probability of people unable to heat their homes adequately. This would have consequential reduced levels of morbidity and mortality. There is little research that has been carried out in this area.

- **Winter air pollution**
  Although winter air pollution episodes are likely to decline in frequency and intensity mainly as a result of warmer temperatures, more research is required into how these are likely to change, and the consequent changes in levels of mortality and morbidity. This would include the effects of the changes in wind speeds projected for Northern Ireland.

- **Increased immigration**
  Although future outbreaks of certain vector borne diseases such as malaria are expected to be rare and limited in number in Northern Ireland, there will be a currently unknown increased risk of new diseases as a result of immigration, as well as international travel. How this risk may change therefore needs to be investigated, including the robustness of local populations.

- **Transport and communications network failure**
  There is little known research into the human health effects due to changes in levels and durations of transport and communications network failure.

- **Pollen and allergens**
  There is currently insufficient quantitative evidence for establishing the impact of climate change on aeroallergens including pollen and the associated risks for public health.

- **Emergency medicine**
  Emergency medicine will very likely experience a significant change in demand for its services over and above current annual levels as a result of climate change. This is likely to result in an increase in levels and variety of demand during extreme weather events, such as floods and heatwaves, as well as the prevalence and severity of allergic and respiratory illness through increases in the frequency, spatial distribution and concentrations of airborne allergens. These effects will show noticeable variations across the UK, which will need to be investigated for Northern Ireland, and will disproportionally affect certain population groups. There is a significant amount of research therefore required to better understand these impacts and how they are likely to change under the climate projected for Northern Ireland with the consequential impacts on emergency medicine.

- **Medicine efficacy**
  Manufactured drugs are in general licensed for storage at temperatures up to 25°C, and these medicines can be exposed to temperatures greater than this either on the premises, or in bags during home visits. However, as temperatures projected for Northern Ireland are typically lower than the rest of
the UK, this is not anticipated to be a significant impact, although additional research would still be required to investigate the efficacy of different medicines both on site and during home visits during future heatwaves.

- Cold weather working/travelling

  This would be seen as an opportunity for Northern Ireland, with increased winter temperatures and consequential reduced levels of cold weather working and travelling. However, there is currently little known research in this area and how it would impact on working conditions and general morbidity levels.

- Algal/fungal growth in buildings and respiratory diseases

  A lack of research undertaken since the mid 1990s has limited evidence and data available to analyse the impact of improved housing standards on damp and mould occurrences, and thus the impact on respiratory conditions. There seems to be limited data on the link between damp homes and respiratory conditions in Northern Ireland.
References

**CCRA Sector Reports**


**Other CCRA Reports**


CCRA (2012b) CCRA2 Recommendations (To be published in 2012)

CCRA (2012c) A climate change risk assessment for Scotland.


Other References


AEA (2010) *Air Pollution in Northern Ireland 2009*. Department of the Environment Northern Ireland


British Red Cross (2010) Living in fear of the rain: The impact of recent flooding in Greater Belfast. The British Red Cross Society


CMA (2011) The impacts of climate change on the built heritage of Northern Ireland, Centre for Maritime Archaeology at the University of Ulster at Coleraine with further contributions from Williams B. (NIEA:HMU) and Deery M. (NIEA:HBU). Online: http://www.doeni.gov.uk/niea/impacts_climate_change_on_built_heritage.pdf [Accessed: 21/04/2011]


Crump D, Dengel A and Swainson M (2009), Indoor air quality in highly energy efficient homes – a review, NHBC Foundation report NF18, IHS BRE Press.


Department of Culture Arts and Leisure (2010) Salmon and Inland Fisheries Annual Report 2008. TSO.


Environment and Heritage Service (2001a) *An Assessment of Estuarine and Coastal Water Quality Around Northern Ireland*


Engineering the Future. (2011) *Infrastructure, Engineering and Climate Change Adaptation – ensuring services in an uncertain future.* Online: 


Miloudi, S. (2008) *French cattle brought to Wales have bluetongue*. WesternMail. Wales


Northern Ireland Executive (2009) *Average earnings in Northern Ireland increased faster than in the rest of UK*. Online: http://www.northernireland.gov.uk/index/media-


Northern Ireland Fire & Rescue Service (NIFRS) (2010) Annual Report and Accounts, for the year ended 31st March 2010,


Queen's University Belfast (no date) Slope instability at the Giant's Causeway and Causeway Coast World Heritage Site. Online: http://www.qub.ac.uk/geomaterials/weathering/causeway/index.php [Accessed: 21/04/2011]


TEEB (2010) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

Climate Change Risk Assessment for Northern Ireland


UK NEA (2011) UK National Ecosystem Assessment: Synthesis of the Key Findings. UNEP-WCMC, Cambridge


Appendices
Appendix A  Northern Ireland Tier 2 list of climate change impacts

A.1  Tier 2 list by Sector

This version of the Northern Ireland Tier 2 list shows the impacts/consequences by sector. The relevant risk metric numbers (e.g. BU1) are also listed where these exist. Risk metric numbers in brackets represent the numbers used in previous releases of this report, where these have subsequently changed.

The impacts/consequences have been colour coded as follows:

- Pink impacts/consequences have been analysed for Northern Ireland as part of the UK CCRA
- Orange impacts/consequences indicate where an attempt has been made to look at the impact/consequence in more detail as part of the Northern Ireland assessment
- Blue impacts/consequences were added to the Tier 2 list by Northern Ireland stakeholders, but have not been looked at in detail
- White impacts/consequences have not been analysed for Northern Ireland as part of the UK CCRA, nor looked at in more detail as part of the Northern Ireland assessment. This has generally been due to relevant data not being available for Northern Ireland. A lack of data should not be considered to mean that the impact is less important. Its existence on this Tier 2 list for Northern Ireland means that the impact was highlighted as being important by Northern Ireland stakeholders.

It should be noted that this list has been updated/modified since Release 3 of the Northern Ireland Tier 2 list issued in January 2011. This is in order to (a) reflect additional analysis work or changes to the analysis work undertaken for the UK CCRA; and (b) to reflect the outcome of additional assessment work undertaken specifically for Northern Ireland.
### Agriculture

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in crop yield (wheat and rain-fed potatoes)</td>
<td>AG1a/c</td>
</tr>
<tr>
<td>Flooding of agricultural land</td>
<td>AG2</td>
</tr>
<tr>
<td>Risk of crop pests and diseases</td>
<td>AG3</td>
</tr>
<tr>
<td>Water demand for livestock</td>
<td>AG6</td>
</tr>
<tr>
<td>Changes in grassland productivity (additional metric analysed Feb 2011)</td>
<td>AG10</td>
</tr>
<tr>
<td>Livestock pests and diseases</td>
<td></td>
</tr>
<tr>
<td>Increase in GHG emissions</td>
<td></td>
</tr>
<tr>
<td>Saltwater intrusion</td>
<td></td>
</tr>
<tr>
<td>Waterlogging</td>
<td></td>
</tr>
</tbody>
</table>

### Biodiversity & Ecosystem Services

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk to species and habitat due to drier soils</td>
<td>BD1</td>
</tr>
<tr>
<td>Risks to species and habitats due to coastal evolution</td>
<td>BD2</td>
</tr>
<tr>
<td>Risk of pests (inc. invasive non-native species) to biodiversity</td>
<td>BD3</td>
</tr>
<tr>
<td>Risks of disease to biodiversity</td>
<td>BD4</td>
</tr>
<tr>
<td>Species unable to track changing climate space</td>
<td>BD5</td>
</tr>
<tr>
<td>Environmental effects of climate mitigation measures (positive/negative)</td>
<td>BD6</td>
</tr>
<tr>
<td>Risk of coastal habitats due to flooding</td>
<td>BD7</td>
</tr>
<tr>
<td>Changes in soil organic carbon</td>
<td>BD8</td>
</tr>
<tr>
<td>Changes in species migration patterns</td>
<td>BD9</td>
</tr>
<tr>
<td>Biodiversity risk due to warmer rivers and lakes</td>
<td>BD10</td>
</tr>
<tr>
<td>Generalists species more able to adapt that specialist</td>
<td>BD11</td>
</tr>
<tr>
<td>Wildfires due to warmer and drier conditions</td>
<td>BD12</td>
</tr>
<tr>
<td>Asynchrony between a species breeding cycle &amp; its food supply</td>
<td></td>
</tr>
<tr>
<td>Decline of native freshwater fish species</td>
<td></td>
</tr>
</tbody>
</table>

### Built Environment

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Heat Island effect</td>
<td>BE1</td>
</tr>
<tr>
<td>Increased subsidence risk due to rainfall changes</td>
<td>BE2</td>
</tr>
<tr>
<td>Overheating of buildings</td>
<td>BE3</td>
</tr>
<tr>
<td>Flood damage to cultural heritage</td>
<td>BE4/FL15</td>
</tr>
<tr>
<td>Non-residential properties at significant risk of flooding</td>
<td>FL6a</td>
</tr>
<tr>
<td>Coastal erosion to cultural heritage</td>
<td></td>
</tr>
<tr>
<td>Seasonal interruptions to construction activities (winter)</td>
<td></td>
</tr>
<tr>
<td>Pest Infestations</td>
<td></td>
</tr>
</tbody>
</table>
### Waste management
- Rainwater Penetration
- Condensation, damp, mould, algal/fungal growth in buildings

### Business, Industry and Services

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate risks to investment funds</td>
<td>BU1</td>
</tr>
<tr>
<td>Monetary losses due to tourist assets at risk from flooding</td>
<td>BU2 (BU3)</td>
</tr>
<tr>
<td>Risk of restrictions in water abstraction for industry</td>
<td>BU3 (BU4)</td>
</tr>
<tr>
<td>Risks of business disruption due to flooding</td>
<td>BU4 (BU5)</td>
</tr>
<tr>
<td>Loss of productivity due to ICT disruption</td>
<td>BU5 (BU6)</td>
</tr>
<tr>
<td>Mortgage provision threatened due to increased flood risk</td>
<td>BU6 (BU7)</td>
</tr>
<tr>
<td>Insurance industry exposure to UK flood risks</td>
<td>BU7 (BU8)</td>
</tr>
<tr>
<td>An expansion of tourist destinations in the UK*</td>
<td>BU8 (BU10)</td>
</tr>
<tr>
<td>A decrease in output for businesses due to supply chain disruption*</td>
<td>BU9 (BU11)</td>
</tr>
<tr>
<td>Loss of staff hours due to high internal building temperatures *</td>
<td>BU10 (BU12)</td>
</tr>
</tbody>
</table>

*New risk metrics for UK CCRA considered important for NI by CCRA team*

### Energy

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy infrastructure at significant risk of flooding</td>
<td>EN1</td>
</tr>
<tr>
<td>Demand for cooling</td>
<td>EN2</td>
</tr>
<tr>
<td>Risk of restrictions in water abstraction for energy generation</td>
<td>EN4</td>
</tr>
<tr>
<td>Energy transmission efficiency capacity losses due to heat - over ground</td>
<td>EN10</td>
</tr>
<tr>
<td>Substations at significant risk of flooding</td>
<td>FL11b</td>
</tr>
<tr>
<td>Reliance on imported fossil fuels</td>
<td></td>
</tr>
<tr>
<td>Fuel poverty</td>
<td></td>
</tr>
<tr>
<td>Energy demand by water suppliers</td>
<td></td>
</tr>
</tbody>
</table>

### Flooding & Coastal Erosion

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal and coastal flooding</td>
<td>FL1, FL2, FL4, FL6, FL7, FL8</td>
</tr>
</tbody>
</table>

Climate Change Risk Assessment for Northern Ireland
<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>River flooding</td>
<td>FL1, FL2, FL4, FL6, FL7, FL8</td>
</tr>
<tr>
<td>Pluvial and sewer flooding</td>
<td>FL1, FL6</td>
</tr>
<tr>
<td>Damage to critical infrastructure (energy generation and distribution)</td>
<td>FL11a/b,</td>
</tr>
<tr>
<td>Hospital and schools at significant risk of flooding</td>
<td>FL12a/b</td>
</tr>
<tr>
<td>Ability to obtain flood insurance for residential properties</td>
<td>FL13</td>
</tr>
<tr>
<td>Failure of water impoundment structures</td>
<td></td>
</tr>
</tbody>
</table>

### Forestry

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pests and diseases</td>
<td>FO1</td>
</tr>
<tr>
<td>Loss of forest productivity due to drought</td>
<td>FO2</td>
</tr>
<tr>
<td>Increase of potential yield of Sitka spruce</td>
<td>FO4b</td>
</tr>
<tr>
<td>Biodiversity loss</td>
<td>FO5&lt;sup&gt;159&lt;/sup&gt;</td>
</tr>
<tr>
<td>Windthrow and storm damage</td>
<td></td>
</tr>
<tr>
<td>Snow and frost damage</td>
<td></td>
</tr>
</tbody>
</table>

### Health

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer mortality due to higher temperatures</td>
<td>HE1</td>
</tr>
<tr>
<td>Summer morbidity due to higher temperatures</td>
<td>HE2</td>
</tr>
<tr>
<td>Extreme weather event (flooding and storms) mortality</td>
<td>HE3</td>
</tr>
<tr>
<td>Morbidity/mortality due to summer Air Pollution (ozone)</td>
<td>HE4a/b</td>
</tr>
<tr>
<td>Decline in winter mortality due to higher temperatures</td>
<td>HE5</td>
</tr>
<tr>
<td>Decline in winter morbidity due to higher temperatures</td>
<td>HE6</td>
</tr>
<tr>
<td>Extreme weather event (flooding and storms) injuries</td>
<td>HE7</td>
</tr>
<tr>
<td>Sunlight / UV Exposure</td>
<td>HE9</td>
</tr>
<tr>
<td>Effects of floods/storms on mental health</td>
<td>HE10</td>
</tr>
<tr>
<td>Vector-borne diseases</td>
<td></td>
</tr>
<tr>
<td>Winter air pollution</td>
<td></td>
</tr>
<tr>
<td>Transport and Communications Network Failure</td>
<td></td>
</tr>
<tr>
<td>Pollen and allergens</td>
<td></td>
</tr>
<tr>
<td>NHS Property Damage</td>
<td></td>
</tr>
<tr>
<td>Demand for Emergency Medicine</td>
<td></td>
</tr>
<tr>
<td>Food-borne diseases</td>
<td></td>
</tr>
<tr>
<td>Medicine efficacy</td>
<td></td>
</tr>
<tr>
<td>Algal/Fungal Growth in Buildings</td>
<td></td>
</tr>
</tbody>
</table>

<sup>159</sup> Forest biodiversity was not subsequently included in the analysis at UK or DA scale due to a lack of robust correlations with climate drivers.
<table>
<thead>
<tr>
<th>Marine &amp; fisheries</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Impact/consequence</strong></td>
<td></td>
</tr>
<tr>
<td>Risk of Harmful Algal Blooms due to changes in ocean stratification</td>
<td>MA1</td>
</tr>
<tr>
<td>Decline in marine water quality due to sewer overflows</td>
<td>MA2a</td>
</tr>
<tr>
<td>Risks of human illness due to marine pathogens</td>
<td>MA2b</td>
</tr>
<tr>
<td>Increased ocean Acidification</td>
<td>MA3</td>
</tr>
<tr>
<td>Changes in fish catch latitude/centre of gravity</td>
<td>MA4a/b</td>
</tr>
<tr>
<td>Opening of Arctic shipping routes due to ice melt *</td>
<td>MA5b</td>
</tr>
<tr>
<td>Distribution of marine alien/invasive species</td>
<td>MA6</td>
</tr>
<tr>
<td>Potential disruption to shipping due to rough seas</td>
<td>MA7 (MA8)</td>
</tr>
<tr>
<td>Eutrophication of sea loughs</td>
<td></td>
</tr>
<tr>
<td>Plankton Blooms</td>
<td></td>
</tr>
</tbody>
</table>

*considered an important opportunity for shipping by CCRA team (although also a threat to the marine environment)

<table>
<thead>
<tr>
<th>Transport</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Impact/consequence</strong></td>
<td></td>
</tr>
<tr>
<td>Disruption to road and rail due to flooding</td>
<td>TR1/FL8</td>
</tr>
<tr>
<td>Landslide risks on the road network</td>
<td>TR2</td>
</tr>
<tr>
<td>Energy demands</td>
<td>TR3</td>
</tr>
<tr>
<td>Cost of carriageway repairs due to high summer temperatures</td>
<td>TR4</td>
</tr>
<tr>
<td>Rail buckling risk</td>
<td>TR5</td>
</tr>
<tr>
<td>Scouring of road and rail bridges</td>
<td>TR6</td>
</tr>
<tr>
<td>Cold weather working/travelling</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Impact/consequence</strong></td>
<td></td>
</tr>
<tr>
<td>Lower summer river flows (Q95)</td>
<td>WA2</td>
</tr>
<tr>
<td>Reduction in water available for public supply</td>
<td>WA3</td>
</tr>
<tr>
<td>Change in household water demand</td>
<td>WA4</td>
</tr>
<tr>
<td>Public water supply-demand deficits</td>
<td>WA5</td>
</tr>
<tr>
<td>Population affected by water supply-demand pressures *</td>
<td>WA6</td>
</tr>
<tr>
<td>Raw water quality</td>
<td>WA9</td>
</tr>
<tr>
<td>Combined Sewer Overflow spill frequency</td>
<td>WA10</td>
</tr>
<tr>
<td>Substations at significant risk of flooding</td>
<td>FL11b</td>
</tr>
<tr>
<td>Hospitals and schools at significant risk of flooding</td>
<td>FL12a/b</td>
</tr>
<tr>
<td>Algal growth in raw water supply sources</td>
<td></td>
</tr>
<tr>
<td>Change in reservoir yields for public water supply</td>
<td></td>
</tr>
</tbody>
</table>

*considered an important opportunity by CCRA team
<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer demands for retail, manufacturing and engineering provide opportunities in a changing climate</td>
<td></td>
</tr>
<tr>
<td>Emergency response to climate events (including flood)</td>
<td>Additional</td>
</tr>
<tr>
<td>Emergency response to grassland and forest fires</td>
<td>Additional</td>
</tr>
<tr>
<td>Increased immigration</td>
<td></td>
</tr>
<tr>
<td>Changes in UK trading patterns with oversees suppliers</td>
<td></td>
</tr>
<tr>
<td>Key workers unable to get to work due to extreme events or infrastructure failure</td>
<td></td>
</tr>
<tr>
<td>Need for international emergency aid</td>
<td></td>
</tr>
<tr>
<td>More frequent air pollution episodes over the UK</td>
<td></td>
</tr>
</tbody>
</table>
### A.2 Tier 2 list by Theme

This version of the Tier 2 list shows the impacts/consequences by theme.

The sector impacts/consequences have been allocated to one or more themes. For example, there is no specific theme for ‘water’, but elements of the water sector appear in all of the themes.

#### Natural Environment - Terrestrial

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk to species and habitat due to drier soils</td>
<td>BD1</td>
</tr>
<tr>
<td>Risk of pests to biodiversity</td>
<td>BD3</td>
</tr>
<tr>
<td>Risks of disease to biodiversity</td>
<td>BD4</td>
</tr>
<tr>
<td>Species unable to track changing climate space</td>
<td>BD5</td>
</tr>
<tr>
<td>Environmental effects of climate mitigation measures</td>
<td>BD6</td>
</tr>
<tr>
<td>Changes in soil organic carbon</td>
<td>BD8</td>
</tr>
<tr>
<td>Changes in species migration patterns</td>
<td>BD9</td>
</tr>
<tr>
<td>Generalists species more able to adapt that specialist</td>
<td>BD11</td>
</tr>
<tr>
<td>Wildfires due to warmer and drier conditions</td>
<td>BD12</td>
</tr>
<tr>
<td>Asynchrony between species breeding cycle &amp; food supply</td>
<td></td>
</tr>
</tbody>
</table>

#### Natural Environment – Aquatic (freshwater)

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of pests to biodiversity</td>
<td>BD3</td>
</tr>
<tr>
<td>Changes in species migration patterns</td>
<td>BD9</td>
</tr>
<tr>
<td>Environmental effects of climate mitigation measures</td>
<td>BD6</td>
</tr>
<tr>
<td>Biodiversity risk to warmer rivers and lakes</td>
<td>BD10</td>
</tr>
<tr>
<td>Lower summer flows (Q95)</td>
<td>WA2</td>
</tr>
<tr>
<td>Potential decline in summer water quality (point source pollution)</td>
<td>WA9a</td>
</tr>
<tr>
<td>Potential decline in water quality due to diffuse pollution</td>
<td>WA9b</td>
</tr>
<tr>
<td>Decline of native freshwater fish species</td>
<td></td>
</tr>
<tr>
<td>Algal growth</td>
<td></td>
</tr>
</tbody>
</table>

#### Natural Environment – Coastal and marine

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risks to species and habitats due to coastal evolution</td>
<td>BD2</td>
</tr>
<tr>
<td>Environmental effects of climate mitigation measures</td>
<td>BD6</td>
</tr>
<tr>
<td>Risks to coastal habitats due to flooding</td>
<td>BD7</td>
</tr>
<tr>
<td>Changes in species migration patterns</td>
<td>BD9</td>
</tr>
<tr>
<td>Risk of Harmful Algal Blooms due to changes in ocean stratification</td>
<td>MA1</td>
</tr>
<tr>
<td>Decline in marine water quality due to sewer overflows</td>
<td>MA2a</td>
</tr>
<tr>
<td>Risks of human illness due to marine pathogens</td>
<td>MA2b</td>
</tr>
</tbody>
</table>
### Agriculture

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in wheat yield (due to warmer conditions)</td>
<td>AG1a</td>
</tr>
<tr>
<td>Change in potato yield (due to combined climate effects and CO₂)</td>
<td>AG1c</td>
</tr>
<tr>
<td>Flooding of agricultural land</td>
<td>AG2a/FL4b</td>
</tr>
<tr>
<td>Risk of crop pests and diseases</td>
<td>AG3</td>
</tr>
<tr>
<td>Water demand for livestock</td>
<td>AG6</td>
</tr>
<tr>
<td>Changes in grassland productivity (additional metric analysed Feb 2011)</td>
<td>AG10</td>
</tr>
<tr>
<td>Livestock pests and diseases</td>
<td></td>
</tr>
<tr>
<td>Increase in GHG emissions</td>
<td></td>
</tr>
<tr>
<td>Saltwater intrusion</td>
<td></td>
</tr>
<tr>
<td>Waterlogging</td>
<td></td>
</tr>
</tbody>
</table>

### Forestry

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest extend affected by red-band needle blight and green spruce aphid</td>
<td>FO1a/b</td>
</tr>
<tr>
<td>Loss of forest productivity due to drought</td>
<td>FO2</td>
</tr>
<tr>
<td>Increase in potential yield of Sitka spruce</td>
<td>FO4</td>
</tr>
<tr>
<td>Biodiversity loss</td>
<td>FO5¹⁶⁰ (-)</td>
</tr>
<tr>
<td>Wildfires risk due to warmer and drier conditions</td>
<td>BD12</td>
</tr>
<tr>
<td>Windthrow and storm damage</td>
<td></td>
</tr>
<tr>
<td>Snow and frost damage</td>
<td></td>
</tr>
</tbody>
</table>

### Business and Services

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate risks to investment funds</td>
<td>BU1</td>
</tr>
<tr>
<td>Monetary losses due to tourist assets at risk from flooding</td>
<td>BU2 (BU3)</td>
</tr>
<tr>
<td>Risk of restrictions in water abstraction for industry</td>
<td>BU3 (BU4)</td>
</tr>
<tr>
<td>Risks of business disruption due to flooding</td>
<td>BU4 (BU5)</td>
</tr>
<tr>
<td>Loss of productivity due to ICT disruption</td>
<td>BU5 (BU6)</td>
</tr>
<tr>
<td>Mortgage provision threatened due to increased flood risk</td>
<td>BU6 (BU7)</td>
</tr>
<tr>
<td>An expansion tourist destinations in the UK</td>
<td>BU8</td>
</tr>
</tbody>
</table>

¹⁶⁰ This metric was not robust enough for further analysis to take place.
A decrease in output for businesses due to supply chain disruption (BU10)
Loss of staff hours due to high internal building temperatures* (BU10 (BU11))
Opening of Arctic shipping routes due to ice melt * (MA5b)
Small and medium enterprises (SMEs) and micro-SMEs
Changes in UK trading patterns
Underestimation of decommissioning liabilities and end of life costs
Seasonal interruptions to construction activities (Winter)
Key workers unable to get to work due to extreme events or infrastructure failure

*considered an important opportunity for shipping by CCRA team (although also a threat to the marine environment)

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in energy demand for heating</td>
<td>BE9</td>
<td></td>
</tr>
<tr>
<td>Loss of productivity due to ICT disruption</td>
<td>BU5 (BU6)</td>
<td></td>
</tr>
<tr>
<td>Energy infrastructure at significant risk of flooding</td>
<td>EN1</td>
<td></td>
</tr>
<tr>
<td>Energy demand for cooling</td>
<td>EN2</td>
<td></td>
</tr>
<tr>
<td>Water abstraction for energy generation</td>
<td>EN4</td>
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<td>Energy transmission efficiency capacity losses due to heat - over ground</td>
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</tr>
<tr>
<td>Substations at significant risk of flooding</td>
<td>FL11b</td>
<td></td>
</tr>
<tr>
<td>Hospitals and schools at significant risk of flooding</td>
<td>FL12a/b</td>
<td></td>
</tr>
<tr>
<td>Potential disruption to shipping due to rough seas</td>
<td>MA7 (MA8)</td>
<td></td>
</tr>
<tr>
<td>Disruption to road and rail due to flooding</td>
<td>TR1/FL8</td>
<td></td>
</tr>
<tr>
<td>Landslide risks on the road network</td>
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<td>Cost of carriageway repairs due to high summer temperatures</td>
<td>TR4</td>
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</tr>
<tr>
<td>Rail buckling risk</td>
<td>TR5</td>
<td></td>
</tr>
<tr>
<td>Scouring of road and rail bridges</td>
<td>TR6</td>
<td></td>
</tr>
<tr>
<td>Reduction in water available for public supply</td>
<td>WA3</td>
<td></td>
</tr>
<tr>
<td>Change in household water demand</td>
<td>WA4</td>
<td></td>
</tr>
<tr>
<td>Public water supply-demand deficits</td>
<td>WA5</td>
<td></td>
</tr>
<tr>
<td>Population affected by water supply-demand pressures *</td>
<td>WA6</td>
<td></td>
</tr>
<tr>
<td>Combined Sewer Overflow spill frequency</td>
<td>WA10</td>
<td></td>
</tr>
<tr>
<td>Reliance on imported fossil fuels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flooding of critical water infrastructure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure of water impoundment structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Algal growth in raw water supply sources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in reservoir yields for public water supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key workers unable to get to work due to extreme events</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Buildings

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Heat Island effect</td>
<td>BE1</td>
</tr>
<tr>
<td>Increased subsidence risk due to rainfall changes</td>
<td>BE2</td>
</tr>
<tr>
<td>Overheating of buildings</td>
<td>BE3</td>
</tr>
<tr>
<td>Flood damage to cultural heritage</td>
<td>BE4/FL15</td>
</tr>
<tr>
<td>Effectiveness of green space for cooling</td>
<td>BE5</td>
</tr>
<tr>
<td>Loss of staff hours due to high internal building temperatures</td>
<td>BU10 (BU12)</td>
</tr>
<tr>
<td>Residential properties at significant risk of flooding</td>
<td>FL6a</td>
</tr>
<tr>
<td>Non-residential properties at significant risk of flooding</td>
<td>FL7a</td>
</tr>
<tr>
<td>Hospitals and schools at significant risk of flooding</td>
<td>FL12a/b</td>
</tr>
<tr>
<td>Ability to obtain flood insurance for residential properties</td>
<td>FL13</td>
</tr>
<tr>
<td>Flood risk for Scheduled Ancient Monument sites</td>
<td>FL15</td>
</tr>
<tr>
<td>Coastal erosion to cultural heritage</td>
<td></td>
</tr>
<tr>
<td>Pest Infestations</td>
<td></td>
</tr>
<tr>
<td>Waste management</td>
<td></td>
</tr>
<tr>
<td>Rainwater Penetration</td>
<td></td>
</tr>
<tr>
<td>Condensation, damp, mould, algal/fungal growth in buildings</td>
<td></td>
</tr>
</tbody>
</table>

### Health and Wellbeing

<table>
<thead>
<tr>
<th>Impact/consequence</th>
<th>Metric No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of people at significant risk of flooding</td>
<td>FL1</td>
</tr>
<tr>
<td>Vulnerable people at significant risk of flooding</td>
<td>FL2</td>
</tr>
<tr>
<td>Hospitals and schools at significant risk of flooding</td>
<td>FL12a/b</td>
</tr>
<tr>
<td>Summer mortality due to higher temperatures</td>
<td>HE1</td>
</tr>
<tr>
<td>Summer morbidity due to higher temperatures</td>
<td>HE2</td>
</tr>
<tr>
<td>Extreme weather event (flooding and storms) mortality</td>
<td>HE3</td>
</tr>
<tr>
<td>Morbidity/mortality due to summer Air Pollution (ozone)</td>
<td>HE4a/b</td>
</tr>
<tr>
<td>Decline in winter mortality due to higher temperatures</td>
<td>HE5</td>
</tr>
<tr>
<td>Decline in winter morbidity due to higher temperatures</td>
<td>HE6</td>
</tr>
<tr>
<td>Extreme weather event (flooding and storms) injuries</td>
<td>HE7</td>
</tr>
<tr>
<td>Sunlight / UV Exposure</td>
<td>HE9</td>
</tr>
<tr>
<td>Effects of floods/storms on mental health</td>
<td>HE10</td>
</tr>
<tr>
<td>Fuel poverty (people affected)</td>
<td></td>
</tr>
<tr>
<td>Winter air pollution</td>
<td></td>
</tr>
<tr>
<td>Increased immigration</td>
<td></td>
</tr>
<tr>
<td>Vector-borne diseases</td>
<td></td>
</tr>
<tr>
<td>Food-borne diseases</td>
<td></td>
</tr>
<tr>
<td>Issue</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>---</td>
</tr>
<tr>
<td>Transport and communications network failure</td>
<td></td>
</tr>
<tr>
<td>Pollen and allergens</td>
<td></td>
</tr>
<tr>
<td>Demand for Emergency Medicine</td>
<td></td>
</tr>
<tr>
<td>Medicine efficacy</td>
<td></td>
</tr>
<tr>
<td>Cold weather working/travelling</td>
<td></td>
</tr>
<tr>
<td>Emergency response to climate events (including flood)</td>
<td></td>
</tr>
<tr>
<td>Emergency response to grassland and forest fires</td>
<td></td>
</tr>
<tr>
<td>Increased algal or fungal/mould growth in building affecting respiratory conditions</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B  Human welfare value

A monetisation exercise has been carried out as part of the CCRA to provide an indicative cost per year of economic, environmental and social consequences that have an effect on human welfare.

B.1  Introduction
Climate change adaptation decisions that are designed to reduce climate change risks inevitably involve making trade-offs concerning the use of scarce economic resources. To the extent that economic efficiency is an important criterion in informing such decision-making, it is useful to express climate change risks in monetary terms, so that they can be:

- Assessed and compared directly (using £ as a common metric) and
- Compared against the costs of reducing such risks by adaptation.

For the CCRA, a monetisation exercise has been undertaken to allow an initial comparison of the relative significance of different risks within and between sectors. Since money is a metric with which people are familiar, it may also serve as an effective way of communicating the possible extent of climate change risks in Northern Ireland and help raise awareness.

It is important to note, however, that this exercise focuses on the effect on overall human welfare for Northern Ireland (described in more detail in the section below). The intrinsic value of elements of the natural environment is not captured, nor is the variation in social vulnerability within Northern Ireland considered. Therefore, the indicative ‘value rankings’ determined by this exercise do not always represent all factors that make a particular risk significant. In other words, the value rankings provided here should be considered as partial representations of the overall significance of these metrics, and additional non-quantified dimensions of these consequences need to be considered. These other dimensions are discussed and taken into consideration in the overall categorisation of risks provided in the main body of this report.

B.2  Method
Where possible, an attempt has been made to express the magnitude of individual risks (as described in this report) in monetary terms (cost per year). The aim is to express the risk in terms of its effects on human welfare, as measured by the preferences of individuals in the affected population. The total value to society of any risk is taken to be the sum of the values of the different individuals affected. This distinguishes this system of values from one based on ‘expert’ preferences, or on the preferences of political leaders.

Individual preferences are expressed in two, theoretically equivalent, ways. These are:

- The minimum payment an individual is willing to accept (WTA) for bearing the risk or
- The maximum amount an individual is willing to pay (WTP) to avoid the risk.

However, due to the availability of data, it has sometimes been necessary to use alternative approaches (e.g. repair or adaptation costs) to provide indicative estimates.

A variety of methods have been used to determine these costs. In broad terms, these methods can be categorised according to whether they are based on:
Informed judgement has been used where there is no quantitative evidence and was based on extrapolation and/or interpretation of existing data.

In general terms, these three categories of method have differing degrees of uncertainty attached to them, with market prices being the most certain and informed judgement being the least certain. It is important to stress that the confidence and uncertainty of risks differs. Therefore, care must be taken in directly comparing the results. A further caveat is that whilst an attempt has been made to use the best monetary valuation data available, the matching-up of physical and monetary data is to be understood as an approximation only.

In general, the approach adopted for Northern Ireland is consistent with that taken in the UK level sector reports and a detailed description of the data considered in the valuation of each risk is provided in these reports. Details of the monetary valuation approach applied to the CCRA as a whole can be found in the CCRA Method Report (Defra, 2010b).

However, in cases where a specific valuation approach was adopted for Northern Ireland, a description of the chosen method is outlined in the sections below. In each case, a justification is given for the approach taken.

Valuations have generally been scaled from the UK analysis to the Northern Ireland context, but account is also taken of differences between the situation in Northern Ireland and the UK as a whole. Where projections have been quantified at the Northern Ireland scale these have been applied.

**Understanding the Valuation Rankings**

Valuations are based on projections for the Medium emissions scenario, central estimate (p50) for the 2050s with no socio-economic changes.

Valuations are ranked as Low (L), Medium (M) or High (H), based on a logarithmic scale of increasing value.

A negative ranking signifies a cost (or financial loss); a positive ranking signifies a saving (or financial benefit).

In general, the following ranges are applied: Low is less than £10 million per year; Medium is £10 to £100 million per year; and High is over £100 million per year. However, there are exceptions; for example, if a large proportion of a business that is vital for the sustainability of a region is affected then this would result in a High ranking even if the total cost was less than £100 million per year.

It is important to note that the valuation exercise has only been undertaken for those risks that have been identified as being sufficiently important to assess as part of this first risk assessment for Northern Ireland. Furthermore, it has not been possible to provide monetary valuation for some risks. Therefore, the sum of the valuations does not provide the total cost in human welfare terms of projected climate change. The valuation exercise only provides a means of identifying the relative significance of these selected risks.

**B.3 Natural Environment**

A large proportion of the climate change risks to the natural environment relate to biodiversity and ecosystem services. The task of valuing these risks remains
challenging. Whilst much attention has been directed towards the analysis and valuation of the loss of biodiversity\textsuperscript{161}, there is little theoretical and empirical published valuation literature that considers biodiversity in the context of climate change. Therefore, the monetary valuation method adopted for biodiversity and ecosystem services differs from the rest of the CCRA. Details of the method can be found in the Biodiversity sector report.

**Terrestrial**

The results under this section all come from the Biodiversity sector and are based on informed judgement. Given the generally indirect ways in which these impact on human welfare, these estimates are considered to have a low level of confidence.

As a consequence of this uncertainly, and in the absence of better empirical evidence, it is inappropriate to scale these results on any basis.

Table B.1 draws together all the monetary estimates by use of a cost ranking. There is low confidence in the monetisation surrounding the risks relating to the terrestrial natural environment.

**Table B.1** Monetary valuation of climate change impacts on the natural environment (terrestrial) – Medium emissions scenario (p50; 2050s); no population change

<table>
<thead>
<tr>
<th>Impact</th>
<th>Metric</th>
<th>Valuation Ranking</th>
<th>Confidence Ranking</th>
<th>Estimation Method</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in soil organic carbon</td>
<td>BD8</td>
<td>-M</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risks to species and habitats due to drier soils</td>
<td>BD1</td>
<td>-L</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risks of pests (inc. invasive non-native species) to biodiversity</td>
<td>BD3</td>
<td>-M</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of diseases to biodiversity</td>
<td>BD4</td>
<td>-M</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Species unable to track changing ‘climate space’</td>
<td>BD5</td>
<td>-M</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changes in species migration patterns</td>
<td>BD9</td>
<td>-M</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generalists species more able to adapt than specialists</td>
<td>BD11</td>
<td>-L</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental effects of climate mitigation measures</td>
<td>BD6</td>
<td>-L</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wildfires due to warmer and drier conditions</td>
<td>BD12</td>
<td>-L</td>
<td>L</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note:* - signifies a negative impact or loss; + signifies benefits or cost reductions.

\textsuperscript{161} See the international effort co-ordinated by the UN – The Economics of Ecosystems and Biodiversity (TEEB, 2010) – and nationally – The UK National Ecosystem Assessment (UKNEA, 2011).
Freshwater

The risks in this sector come from the Biodiversity and Water sectors, and all risks that have been assessed are based on informed judgement. Similar to the risks identified in the terrestrial section above, and for the same reasons, these estimates are all considered to have low confidence.

From the results given in Table 5.2, changes in species migration patterns and climate change effects on water quality have the highest cost rankings. However, all risks in this Table have low confidence for monetisation, and other risks may well justify a similar or higher cost ranking. It should also be noted these risks are all identified as having a high impact/consequence for Northern Ireland, even though this section identifies a much lower value attached to human welfare in absolute terms.

Table B.2 Monetary valuation of climate change impacts on the natural environment (freshwater) – Medium emissions scenario (p50; 2050s); no population change

<table>
<thead>
<tr>
<th>Impact</th>
<th>Metric</th>
<th>Valuation Ranking</th>
<th>Confidence Ranking</th>
<th>Estimation Method</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risks of pests (inc. invasive non-native species) to biodiversity</td>
<td>BD3</td>
<td>-M</td>
<td>L</td>
<td></td>
<td>Based on informed judgement in UK Biodiversity sector report</td>
</tr>
<tr>
<td>Changes in species migration patterns</td>
<td>BD9</td>
<td>-M</td>
<td>L</td>
<td></td>
<td>Qualitative risk assessment based on results in UK Sector report. Ranking given here only relates to small number of indicator species. Total effects likely to be much greater.</td>
</tr>
<tr>
<td>Biodiversity risks due to warmer rivers and lakes</td>
<td>BD10</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Based on informed judgement in UK Biodiversity sector report</td>
</tr>
<tr>
<td>Lower summer river flows (Q95)</td>
<td>WA2</td>
<td>-L</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential decline in water quality</td>
<td>WA9</td>
<td>-H</td>
<td>L</td>
<td></td>
<td>Scaled from UK level analysis (WA7) but considering that water balance (determining water quality) unlikely to be very significant</td>
</tr>
<tr>
<td>Decline of native freshwater fish species</td>
<td></td>
<td>-L</td>
<td>L</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: - signifies a negative impact or loss; + signifies benefits or cost reductions.

Coastal and Marine

Changes in species migration are suggested to constitute the highest ranked cost. Whilst changing migration patterns imply that there are likely to be a mix of species that gain and lose as a result of climate change, and an accompanying array of associated welfare effects that are location-specific, the welfare impacts are likely to be most immediately in the form of amenity effects, but in parallel with longer lasting changes in regulating and supporting systems. However, the confidence uncertainty is very low.
The climate change-induced impacts of Harmful Algal Blooms (HABs) and Jellyfish (risk metric MA1) are not currently quantified, and have therefore not been assessed. However, studies of the costs of HABs in other contexts suggest that these costs may be relatively low in the Northern Ireland case. Based on data to 1998, ECOHARM identify an impact on UK of HABs on mussel aquaculture of between €2.54 and €5.28 million. This does not account for climate change, but it may give an indication of the potential scale of the costs.

Other impacts include effects on recreational users and tourists. The ECOHARM study uses a contingent valuation survey to elicit preferences and showing impacts of between €215 and €1,524 million for the whole of Europe. Clearly the impact on Northern Ireland would be a very small fraction of this. The ECOHARM study does not consider the impact of climate change explicitly, so these costs may be likely to increase in future.

For ocean acidification costs, we took the results of the UK level analysis and adjusted the values for the size of shellfish catch (MMO, 2010) in Northern Ireland, using the relative catch of the three largest ports in Northern Ireland. This gives the cost estimates shown in Table B.3.

**Table B.3 Mid-point annual costs of ocean acidification – with no socioeconomic change**

<table>
<thead>
<tr>
<th></th>
<th>£ million</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shellfish</td>
</tr>
<tr>
<td>2020s</td>
<td>1</td>
</tr>
<tr>
<td>2050s</td>
<td>7</td>
</tr>
<tr>
<td>2080s</td>
<td>15</td>
</tr>
</tbody>
</table>

The complexity of the valuation of the shift in fish species cannot be understated; even in the case of using petrol and labour costs for some (e.g. plaice) the shift moves the catch closer to UK ports, while for others the catch is moved further away. The analysis also highlights the potential for species shift across international boundaries, with associated implications for fishing quotas. For the UK level analysis, expert judgement was used to estimate that this cost would be low (between £1 to £9 million per annum), as the shift seems to be towards the UK ports for plaice and cod, whereas sole and haddock are generally moving further away from the UK. It seems appropriate to suggest that the costs for Northern Ireland would also be low.

For the case of invasive species, the UK level analysis considered the case of the eradication of the Carpet Sea Squirt from marinas in the UK, suggesting that the costs could rise to £72 million for the whole of the UK by the 2080s. Given that 3% of berths are in Northern Ireland, this suggests costs of up to £2.2 million for Northern Ireland by the 2080s. This does not consider increases in numbers of berths, which may occur if incomes increase and so demand for recreational boating increases.

Based on the above, it is possible to summarise the likely impacts of climate change on the marine sector in Northern Ireland as shown in Table B.4. The uncertainties associated with these valuations vary. For most risks the confidence is considered in the estimates is considered to be low. For increases in the spread of invasive species the confidence is considered to be high, but this is only true for the cost of the Carpet

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162 Based on a visual inspection of coordinates.
Sea Squirt. Further work is needed on a number of these areas to come up with more robust estimates of the likely consequences.

Table B.4  Monetary valuation of climate change impacts on the natural environment (coastal and marine) – Medium emissions scenario (p50; 2050s); no population change

<table>
<thead>
<tr>
<th>Impact</th>
<th>Metric</th>
<th>Valuation Ranking</th>
<th>Confidence Ranking</th>
<th>Estimation Method</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk to species and habitats due to coastal evolution.</td>
<td>BD2</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Based on results in Biodiversity sector report</td>
</tr>
<tr>
<td>Risk to coastal habitats due to flooding</td>
<td>BD7</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Based on results in Biodiversity sector report</td>
</tr>
<tr>
<td>Changes in species migration patterns</td>
<td>BD9</td>
<td>-M</td>
<td>L</td>
<td>Informed judgement</td>
<td>Qualitative risk assessment based on results in UK Sector report. Ranking given here only relates to small number of indicator species. Total effects likely to be much greater.</td>
</tr>
<tr>
<td>Decline in marine water quality due to sewer overflows</td>
<td>MA2</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Low impact likely because of existing measures to reduce health impacts</td>
</tr>
<tr>
<td>Increased Ocean acidification</td>
<td>MA3</td>
<td>-L to -M</td>
<td>L</td>
<td>Market Prices</td>
<td>Based on shellfish, molluscs and aquaculture only. Adjustment based on shellfish fishery.</td>
</tr>
<tr>
<td>Changes in fish latitude/centre of gravity (cod, haddock)</td>
<td>MA4</td>
<td>+/-L</td>
<td>L</td>
<td>Market Price / Informed judgement</td>
<td>Assumes species do not cross national boundaries</td>
</tr>
<tr>
<td>Distribution of marine alien / invasive species</td>
<td>MA6</td>
<td>-L</td>
<td>H</td>
<td>Market Price / Informed judgement</td>
<td>Carpet sea squirt only</td>
</tr>
</tbody>
</table>

Note: - signifies a negative impact or loss; + signifies benefits or cost reductions.

B.4 Agriculture and Forestry

Agriculture

Based on an assessment of the changing yields of grassland hay and silage, grassland productivity is noted as the highest ranked cost for Agriculture for Northern Ireland. With the change in monetary value due to climate change of between £53m and £335m by the 2050s, this is given a high cost ranking, with a high level of confidence in the estimates.

Flooding of agriculture land in Northern Ireland is estimated as being low cost. This draws on the results of the UK level analysis, which applied the estimated costs of one flood event to value future flood risks to agriculture.

Waterlogging, assessed as the change in the number of unworkable days on land (see Appendix C), is considered to be low cost by the 2050s.

For pests and diseases, the UK level analysis examined two crop impacts, but the results suggested little or no impact of climate, probably due to the use of pesticides in
response to increased pest prevalence. However, it was not possible to value this metric, and no results are therefore given. The remaining impacts for Agriculture were also considered to have a poor or weak evidence bases, and these were therefore not quantified.

A summary of the expected scale of damages to agriculture in Northern Ireland for agriculture is given in Table B.5.

Table B.5 Monetary Valuation of climate change impacts on agriculture – Medium emissions scenario (p50; 2050s); no population change

<table>
<thead>
<tr>
<th>Impact</th>
<th>Metric</th>
<th>Valuation Ranking</th>
<th>Confidence Ranking</th>
<th>Estimation Method</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in wheat yield (due to warmer conditions)</td>
<td>AG1a</td>
<td>+L</td>
<td>M</td>
<td>MP</td>
<td>Includes land use and price scenarios</td>
</tr>
<tr>
<td>Changes in potato yield (due to combined climate effects and CO₂)</td>
<td>AG1c</td>
<td>Neg</td>
<td>L</td>
<td>Informed judgement</td>
<td></td>
</tr>
<tr>
<td>Flooding of agricultural land</td>
<td>AG2/FL4</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td></td>
</tr>
<tr>
<td>Livestock pests and diseases</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Changes in grassland productivity</td>
<td>AG10</td>
<td>+H</td>
<td>H</td>
<td>Market Prices</td>
<td>Assumes hay/silage use, and constant grass price.</td>
</tr>
<tr>
<td>Waterlogging</td>
<td>-</td>
<td>-L / +L</td>
<td>L</td>
<td>Informed judgement</td>
<td></td>
</tr>
</tbody>
</table>

Note: - signifies a negative impact or loss; + signifies benefits or cost reductions.

Forestry

To estimate the damage costs due to Red Band Needle Blight, the UK estimates were scaled by area of pine forests. The damage costs in the UK level analysis reflect a range of values for ecosystem services in forests, assuming a 10% damage to services caused by the impacts of the pathogens. It should be noted that the scaling assumption is a strong one since it assumes an even coverage of impact across the UK and similar species. However, in the absence of alternative evidence we adopt it here. The annual costs for Northern Ireland may be up to £0.14 million by the 2080s.

Table B.6 Estimated change in damage costs due to Red Band Needle Blight in Northern Ireland

Note: Values are £ million/year, using 2010 prices, no uplift or discounting, assuming current forest stock (no future socio-economic change)

<table>
<thead>
<tr>
<th>UKCP09 scenario</th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>0.00</td>
<td>0.06- 0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>Medium</td>
<td>0.00</td>
<td>0.06- 0.14</td>
<td>0.02</td>
</tr>
<tr>
<td>High</td>
<td>0.00</td>
<td>0.06- 0.14</td>
<td>0.02</td>
</tr>
</tbody>
</table>

To estimate the damage costs due to Green spruce Aphid, the UK estimates were scaled for the relative size of forest in Northern Ireland. This gives estimates of the
costs as shown in Table B.7, based on the market price of lost productivity. Other ecosystem services were judges to be limited and were not assessed.

Table B.7  Estimated Change in damage costs due to green spruce aphid in Northern Ireland
Note: Values are £ million/year, using 2010 prices, no uplift or discounting, assuming current forest stock (no future socio-economic change)

<table>
<thead>
<tr>
<th>UKCP09 scenario</th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>0.00-0.06</td>
<td>0.00-0.06</td>
<td>0.06-0.28</td>
</tr>
<tr>
<td>Medium</td>
<td>0.00-0.06</td>
<td>0.00-0.06</td>
<td>0.06-0.28</td>
</tr>
<tr>
<td>High</td>
<td>0.00-0.06</td>
<td>0.06-0.28</td>
<td>0.00-0.28</td>
</tr>
</tbody>
</table>

The impact of yield loss due to drought was valued, as in the sectoral study, on the basis of market prices for soft and hard wood. The impact in Northern Ireland was not modelled in the UK level analysis, so the effect was assumed to be similar to that in Wales, which was modelled. This leads to estimated costs as shown in Table B.8 of around £0.2 million per year by the 2080s depending on the scenario considered.

Table B.8  Value of forest yield loss due to drought in Northern Ireland
Note: Values are £ million/year (no future socioeconomic change)

<table>
<thead>
<tr>
<th>UKCP09 scenario</th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>0.00</td>
<td>0.09</td>
<td>0.18</td>
</tr>
<tr>
<td>Medium</td>
<td>-0.03</td>
<td>0.05</td>
<td>0.13</td>
</tr>
<tr>
<td>High</td>
<td>0.03</td>
<td>0.13</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Based on the assessment carried out for the UK, monetary estimates considering drought effects on Sitka spruce only are considered to be a low benefit, though with a low level of confidence.

An overview of the scale of costs associated with climate change in Northern Ireland is given in Table B.9. Of those impacts where a valuation was possible, the costs are considered low. However, these costs are quite uncertain, particularly in relation to the costs of red band needle blight and the impacts of drought. As a consequence the valuation ranking should be seen as more robust than the monetary estimates given in the previous tables that – if taken at face value suggest spurious accuracy.
Table B.9  Monetary valuation of climate change impacts on forestry – Medium emissions scenario (p50; 2050s); no population change

<table>
<thead>
<tr>
<th>Impact</th>
<th>Metric</th>
<th>Valuation Ranking</th>
<th>Confidence Ranking</th>
<th>Estimation Method</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest extent affected by red band needle blight and green spruce aphid</td>
<td>FO1</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement / Non-market Values / Market Price</td>
<td>Red band needle blight and green spruce aphid only. Transferred to NI Irish area based on forest cover.</td>
</tr>
<tr>
<td>Loss of forest productivity due to drought</td>
<td>FO2</td>
<td>-L</td>
<td>L</td>
<td>Market Price</td>
<td>Consider future climate on current forest cover and land-use, no autonomous adaptation (forest management). Note wider ecosystem services not considered.</td>
</tr>
<tr>
<td>Increase of potential yield of Sitka spruce</td>
<td>F04b</td>
<td>+L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Based on UK assessment.</td>
</tr>
<tr>
<td>Wildfires due to warmer and drier conditions</td>
<td>BD12</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Based on informed judgement in UK Biodiversity sector report</td>
</tr>
</tbody>
</table>

Note: - signifies a negative impact or loss; + signifies benefits or cost reductions.

B.5 Business and Services

Risk metric BU4 addresses the exposure to insurance companies as a result of flooding to commercial buildings. These have not been estimated in the physical risk assessment for Northern Ireland. However, scaling on the basis of commercial activity in Northern Ireland relative to England, and assuming the same flood risk, the total expected annual damages attributed to this risk in Northern Ireland is estimated to be £10m, £20m and £30m for the 2020s, 2050s and 2080s, respectively under the Medium emissions scenario. Additional business interruption costs in Northern Ireland are estimated to be negligible.

On the basis of these results, it is estimated that the combined domestic and commercial claims in Northern Ireland could double by the 2020s (Medium emissions scenario, p50), increase by almost three-fold by the 2050s and increase between three and four times by the 2080s. This equates to an additional average annual total claim for flood related damage of the order of £6m, £12m and £16 million in the 2020s, 2050s and 2080s, respectively.

However, the UK level analysis for the business sector describes the overall impact to the industry as unclear, being determined by the balance of pay-out following an event versus the cost of products to consumers (i.e. cost of premiums). Therefore, the risk is fundamentally one of how well the industry understands weather risk (and how this may vary as climate changes). The evidence suggests that the insurance industry is adapting to the challenges arising from climate change.

The BU6 metric is concerned with the impact of increasing flood risk on mortgage lending revenues as a function of market changes and the important issue of asset devaluation in the event of the loss of insurance cover. Scaling the quantitative results from England, as detailed in the Flooding and Coastal Erosion Sector Report, on the basis of population, the scale of the non-mortgageable residential property value at risk, relative to the 2008 baseline, has been estimated to be £90m, £140m and £180m for the 2020s, 2050s and 2080s respectively. However, it should be highlighted that the values given are total asset values and so is likely to be much higher than the
incremental welfare change associated with this impact. As a consequence of a simple scaling, medium cost ranking has therefore been applied to this risk metric.

Table B.10 highlights that, on the basis of the risks considered, flood risk is likely to be the most significant to business, most particularly in relation to the implications for insurers. It should be highlighted, however, that impacts on the insurance sector, together with the potential failure to mainstream climate change, a potentially large risk that is too uncertain to assess, should not be seen as welfare impacts. Rather, they indicate sectors of business vulnerability to climate change and serve to indicate the need for adaptation action.

Table B.10 Monetary valuation for climate change impacts on Business and Services – Medium Climate scenario (p50; 2050s); no population change

<table>
<thead>
<tr>
<th>Impact</th>
<th>Metric</th>
<th>Valuation Ranking</th>
<th>Confidence Ranking</th>
<th>Estimation Method</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monetary loss due to tourist assets at risk from flooding</td>
<td>BU2</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td></td>
</tr>
<tr>
<td>Risk of restrictions in water abstraction for industry</td>
<td>BU3</td>
<td>-L</td>
<td>M</td>
<td>Non-market Values</td>
<td>Scaled from UK level results. Double-counting with WA8b.</td>
</tr>
<tr>
<td>Risk of business disruption due to flooding</td>
<td>BU4</td>
<td>-M</td>
<td>H</td>
<td>Market Price</td>
<td>Scaled from UK level results. Double counting with FL7. Should not be interpreted as welfare impact.</td>
</tr>
<tr>
<td>Mortgage provision threatened due to increased flood risk</td>
<td>BU6</td>
<td>-M</td>
<td>H</td>
<td>Market Price</td>
<td>Scaled from UK level results. Double counting with FL6. Should not be interpreted as welfare impact.</td>
</tr>
<tr>
<td>An expansion of tourist destinations in the UK.</td>
<td>BU8</td>
<td>+M</td>
<td>L</td>
<td>Informed Judgement/ Market Price</td>
<td>Scaled from UK level results.</td>
</tr>
<tr>
<td>A decrease in output for businesses due to supply chain disruption</td>
<td>BU9</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td></td>
</tr>
<tr>
<td>Loss of staff hours due to high internal building temperatures</td>
<td>BU10</td>
<td>-L</td>
<td>L</td>
<td>Market Price</td>
<td>Scaled from UK level results.</td>
</tr>
<tr>
<td>Opening of Arctic shipping routes due to ice melt</td>
<td>MA5b</td>
<td>+M</td>
<td>L</td>
<td>Informed judgement</td>
<td>Positive effects from opening of N-E and N-W passage.</td>
</tr>
</tbody>
</table>

Note: - signifies a negative impact or loss; + signifies benefits or cost reductions.
B.6 Infrastructure and Buildings

**Infrastructure**

Risk metric WA5 is estimated using market prices; the cost rankings of the remaining risks are based on informed judgement.

There are a number of risk metrics concerned with damage to transport infrastructure resulting from the projected increases in frequencies in extreme weather events under climate change. On the basis of the UK level analysis, it is possible to identify cost rankings for these risks for Northern Ireland. For landslide risk on the road network, the cost ranking is low in the 2050s, but may increase to a medium cost for the Medium and High emissions scenarios p90 projections in the 2080s (though zero for the p10 projections). For cost of carriage repairs due to high summer temperatures, the cost ranking is considered to be low under all climate scenarios, across the three time periods.

The risk metrics concerned with water relate to the issue of meeting water demands, given changing supply conditions under climate change. Table B.11 spatially disaggregates the results on the basis of Northern Irish UKCP09 river basins and shows the impacts of climate change alone on water supply deficits (£ million/year) in each of these UKCP09 basins, when population is held constant at current levels. From these results it is clear that the deficits are relatively small, the largest being borne in the North East Basin. These deficits are exacerbated under projected increases in future populations. Note, however, that there is considerable uncertainty, as reflected in the range of results under the different climate change scenarios in a given time period.

Table B.11 Annual Water Supply-Demand deficits in the Northern Irish UKCP09 regions, considering climate change impacts on Deployable Outputs,

<table>
<thead>
<tr>
<th>Region</th>
<th>Time Period</th>
<th>low emissions</th>
<th>medium emissions</th>
<th>high emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>p10 (wet)</td>
<td>p50 (mid)</td>
<td>p90 (dry)</td>
</tr>
<tr>
<td>North Western Ireland</td>
<td>2020s</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2050s</td>
<td>0.0</td>
<td>0.0</td>
<td>-0.7</td>
</tr>
<tr>
<td></td>
<td>2080s</td>
<td>0.0</td>
<td>-0.4</td>
<td>-1.3</td>
</tr>
<tr>
<td>Neagh Bann</td>
<td>2020s</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2050s</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2080s</td>
<td>0.0</td>
<td>0.0</td>
<td>-0.9</td>
</tr>
<tr>
<td>North Eastern Ireland</td>
<td>2020s</td>
<td>0.0</td>
<td>-0.1</td>
<td>-0.7</td>
</tr>
<tr>
<td></td>
<td>2050s</td>
<td>0.0</td>
<td>-0.8</td>
<td>-1.7</td>
</tr>
<tr>
<td></td>
<td>2080s</td>
<td>-0.3</td>
<td>-1.2</td>
<td>-2.3</td>
</tr>
<tr>
<td>Northern Ireland</td>
<td>2020s</td>
<td>0.0</td>
<td>-0.1</td>
<td>-0.7</td>
</tr>
<tr>
<td></td>
<td>2050s</td>
<td>0.0</td>
<td>-0.8</td>
<td>-2.5</td>
</tr>
<tr>
<td></td>
<td>2080s</td>
<td>-0.3</td>
<td>-1.6</td>
<td>-4.5</td>
</tr>
</tbody>
</table>

The population affected by water supply-demand pressures (risk metric WA6) does not provide quantitative estimates of the additional risks relating to non-connected households and business, nor the WTP that businesses may have above that reflected in the supply cost. As a result, it is not possible to make quantitative estimates of the welfare costs associated with these risks. Therefore, informed judgement has been used to estimate the potential order of magnitude that this risk metric implies, additional to the costs estimated for the public water supply-demand deficits (risk metric WA5). It
is judged that since these two groups of water consumers may be sizeable, the cost ranking across Northern Ireland is likely to be low to medium.

The risk metric relating to energy use, (EN2 - increase in cooling demand) is based on market prices applying DECC energy price projections to previous estimates of increased energy use from climate change in the UK. Based on this analysis, and scaling results for Northern Ireland, this generates a low cost ranking by the 2050s.

Those metrics relating to infrastructure damage due to extreme weather events, (EN1 and EN10) rely on informed judgement, in the absence of a quantitative physical risk assessment. Although the energy infrastructure at risk of flooding is considered too uncertain to assess, the results related to the reduction in transmission efficiency (EN10), indicate potentially high impacts. However, based on the estimated costs to address the risks scaled from the UK analysis to the Northern Ireland analysis, this is considered to have low costs with low confidence on the results.

Table B.12 summarises the results for infrastructure in Northern Ireland. It shows that there are noticeable welfare impacts associated with transport energy provision. However, the uncertainty associated with these rankings, compounded by the lack of available quantitative evidence in relation to the majority of risks considered, suggests that the full range of results, as indicated, need to be considered in planning adaptation.

**Table B.12 Monetary valuation of climate change impacts on Infrastructure – Medium emissions scenario (p50; 2050s); no population change**

<table>
<thead>
<tr>
<th>Impact</th>
<th>Metric</th>
<th>Valuation Ranking</th>
<th>Confidence Ranking</th>
<th>Estimation Method</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in energy demand for heating</td>
<td>BE9</td>
<td>+H</td>
<td>M</td>
<td>Informed judgement</td>
<td>Based solely on UK-wide assessment.</td>
</tr>
<tr>
<td>Landslide risks on the road network</td>
<td>TR2</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Road sector only. Qualitative risk assessment.</td>
</tr>
<tr>
<td>Cost of carriageway repairs due to high summer temperatures</td>
<td>TR4</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Road sector only. Repair costs (adaptation cost)</td>
</tr>
<tr>
<td>Scouring of road and rail bridges</td>
<td>TR6</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Based solely on UK-wide assessment.</td>
</tr>
<tr>
<td>Change in household water demand</td>
<td>WA4</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>The welfare impact derives from the supply-demand imbalance captured in WA5</td>
</tr>
<tr>
<td>Reduction in water available for public supply</td>
<td>WA3</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>The welfare impact derives from the supply-demand imbalance captured in WA5</td>
</tr>
<tr>
<td>Public water supply-demand deficits</td>
<td>WA5</td>
<td>-L</td>
<td>L</td>
<td>Market Price</td>
<td>Supply costs used. These equate to adaptation costs and are used to proxy welfare costs, only.</td>
</tr>
<tr>
<td>Population affected by water supply-demand pressures</td>
<td>WA6</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Metric largely covered by WA5. Cost ranking based only on possible impacts on households not connected to mains, and businesses with high WTP not captured in WA5.</td>
</tr>
<tr>
<td>Risk Category</td>
<td>Metric</td>
<td>Impact</td>
<td>Informed judgement</td>
<td>Monetary Valuation</td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>--------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Combined sewer overflow spill frequency</td>
<td>WA10</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td></td>
</tr>
<tr>
<td>Low impacts due to existing winter peak capacity in the UK (thus within summer reserve margin). Does not include potential issues of summer maintenance regime, or summer peak (extremes).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy demand for cooling</td>
<td>EN2</td>
<td>-L</td>
<td>L</td>
<td>Market Price</td>
<td></td>
</tr>
<tr>
<td>Low impacts due to existing winter peak capacity in the UK (thus within summer reserve margin). Does not include potential issues of summer maintenance regime, or summer peak (extremes).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy transmission efficiency capacity losses due to heat - over ground</td>
<td>EN10</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td></td>
</tr>
<tr>
<td>Adaptation cost (cost of upgrading)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of restrictions in water abstraction for energy generation</td>
<td>EN4</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td></td>
</tr>
<tr>
<td>Potential disruption to shipping due to rough seas</td>
<td>MA7</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td></td>
</tr>
</tbody>
</table>

Note: - signifies a negative impact or loss; + signifies benefits or cost reductions.

**Buildings and the urban environment**

Increased subsidence risk due to rainfall changes (risk metric BE2) has been assessed based on market prices; the cost rankings of the remaining risks are based on informed judgement. All results have been scaled to the Northern Irish context from the UK level analysis.

The quantitative results for subsidence risk (BE2) are identified as being negligible or low. The risk metric (BE3) relating to the overheating of buildings may lead to potentially high costs, from reduced productivity and lost work time, which could plausibly be of the order of tens, or even hundreds of £ millions annually by later time periods. This is based on the size of the working population potential impacted, combined with the unit value of a day of lost productivity (£150/day on average). However, particular care is needed in interpreting these changes, because of the possible private sector autonomous response to climate change. In the face of rising temperatures, companies would be likely to adjust the working environment (e.g. through air conditioning), to avoid falls in productivity and in direct response to occupational health legislation/guidance. The indicative results above are, therefore, an over-estimate of the actual costs likely to occur in the future, although, of course, they do not take account of the costs of autonomous adaptation.

The remaining risks identified in this section are considered to have a low negative impact for Northern Ireland by the 2050s, although with a low level of confidence.

Table B.13 summarises the monetary valuation relating to the built environment for Northern Ireland.
Table B.13 Monetary valuation for climate change impacts on the Built Environment – Medium emissions scenario (p50; 2050s); no population change

<table>
<thead>
<tr>
<th>Impact</th>
<th>Metric</th>
<th>Valuation Ranking</th>
<th>Confidence Ranking</th>
<th>Estimation Method</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overheating of buildings</td>
<td>BE3</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Assumes no autonomous adaptation or use of cooling (energy), thus values (left) are considered high for actual future baseline. Values loss in workers productivity. Strong overlap (double counting) with increased energy use metric.</td>
</tr>
<tr>
<td>Increased subsidence risk due to rainfall changes</td>
<td>BE2</td>
<td>-L</td>
<td>M</td>
<td>Market Price</td>
<td>Qualitative risk assessment.</td>
</tr>
<tr>
<td>Effectiveness of green space for cooling</td>
<td>BE5</td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td></td>
</tr>
<tr>
<td>Loss of staff hours due to high internal building temperatures</td>
<td>BU10</td>
<td>-L</td>
<td>L</td>
<td>Market Price</td>
<td></td>
</tr>
<tr>
<td>Rainwater penetration / damage</td>
<td></td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td></td>
</tr>
<tr>
<td>Condensation, damp, mould, algal/fungal growth in buildings</td>
<td></td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td></td>
</tr>
</tbody>
</table>

*Note:* - signifies a negative impact or loss; + signifies benefits or cost reductions.

B.7 Health and Wellbeing

With the exception of the emergency response metrics, all risk metrics in this section have been estimated using market prices and non-market values. Apart from the emergency response to climate events, all results have been scaled to the Northern Irish context from the UK level analysis on the basis of population.

Table B.14 shows the monetary value of additional mortality impacts from heat under the three time slices, given current population, i.e. in the absence of future socio-economic change for Northern Ireland. No acclimatisation or increased adoption of air conditioning is assumed. It is clear from the table that as climate change develops over the course of the century the size of the heat-related mortality risks increase significantly, so that the welfare cost in the 2080s is at least four times higher than that in the 2020s, whilst doubling between the 2050s and 2080s.

Table B.14 Valuation of Life Years Lost (heat) for the Medium emissions scenario, principal population scenario

*Note:* Values are £m, annual, using 2010 prices, no acclimatisation

<table>
<thead>
<tr>
<th></th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Northern Ireland</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
</tr>
</tbody>
</table>
The results for HE2 (heat-related morbidity) and HE4 (mortality ozone impacts) show the risk to be of a similar scale to HE1, attracting a low cost ranking. This is also the case for HE6 (reductions in cold-related morbidity), though in this case they constitute a benefit.

The monetary value of reduced mortality impacts from cold under the Medium emissions scenario, in the 2050s, using the principal population growth for Northern Ireland, has been estimated as between £5 and 30 million. No acclimatisation is assumed. It is clear that the benefits identified under this metric outweigh those under HE1 and HE2.

The monetary totals for climate-induced flood related deaths (HE3) are presented in Table B.15 for Northern Ireland. Current levels of flood defences are assumed in the risk assessment. The welfare impacts of these fatalities increase further into the future, and across the climate scenarios from low to high. It is notable that the range of uncertainty expressed by the results across the probability distribution function (p10 - p90) within a given emission scenario is substantial, the latter being at least a factor of four greater than the former in the 2020s.

Table B.15 Monetary value of Annual Additional Flood Related Deaths due to Extreme Event Flooding and Storms
Note: Values are £m, annual, using 2010 prices, current population

<table>
<thead>
<tr>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Med.</td>
</tr>
<tr>
<td>p10</td>
<td>p50</td>
<td>p50</td>
</tr>
<tr>
<td>Med.</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>p50</td>
<td>p90</td>
<td>p50</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Med.</td>
</tr>
<tr>
<td>p10</td>
<td>p50</td>
<td>p50</td>
</tr>
<tr>
<td>Med.</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>p90</td>
<td>p50</td>
<td>p50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Med.</td>
</tr>
<tr>
<td>p10</td>
<td>p50</td>
<td>p50</td>
</tr>
<tr>
<td>Med.</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>p50</td>
<td>p90</td>
<td>p50</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Med.</td>
</tr>
<tr>
<td>p10</td>
<td>p50</td>
<td>p50</td>
</tr>
<tr>
<td>Med.</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>p90</td>
<td>p50</td>
<td>p50</td>
</tr>
</tbody>
</table>

Table B.16 shows the valuation of additional flood related injuries due to extreme events such as flooding and storms (HE7), assuming current population. The table shows that the climate sensitivity changes the size of the results by up to a factor of 5 within and across climate scenarios.

Table B.16 Monetary Valuation of Additional Flood Related Injuries due to Extreme Event Flooding and Storms
Note: Values are £m, annual, using 2010 prices, current population

<table>
<thead>
<tr>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Med.</td>
</tr>
<tr>
<td>p10</td>
<td>p50</td>
<td>p50</td>
</tr>
<tr>
<td>Med.</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>p50</td>
<td>p90</td>
<td>p50</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Med.</td>
</tr>
<tr>
<td>p10</td>
<td>p50</td>
<td>p50</td>
</tr>
<tr>
<td>Med.</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>p90</td>
<td>p50</td>
<td>p50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Med.</td>
</tr>
<tr>
<td>p10</td>
<td>p50</td>
<td>p50</td>
</tr>
<tr>
<td>Med.</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>p50</td>
<td>p90</td>
<td>p50</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Med.</td>
</tr>
<tr>
<td>p10</td>
<td>p50</td>
<td>p50</td>
</tr>
<tr>
<td>Med.</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>p90</td>
<td>p50</td>
<td>p50</td>
</tr>
</tbody>
</table>

Table B.17 summarises the monetary valuation relating to health and well-being for Northern Ireland.
<table>
<thead>
<tr>
<th>Impact</th>
<th>Metric</th>
<th>Valuation Ranking</th>
<th>Confidence Ranking</th>
<th>Estimation Method</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer mortality due to higher temperatures</td>
<td>HE1</td>
<td>-L</td>
<td>M</td>
<td>Non-market Values</td>
<td>Assume no acclimatisation. Do not include urban heat island and heatwave impacts. Do not include benefits of cooling associated with rising energy costs</td>
</tr>
<tr>
<td>Summer morbidity due to higher temperatures</td>
<td>HE2</td>
<td>-L</td>
<td>L</td>
<td>Non-market Values / Market Price</td>
<td>Assume no acclimatisation. Do not include urban heat island and heatwave impacts. Adaptation costs (medical treatment costs)</td>
</tr>
<tr>
<td>Decline in winter mortality due to higher temperatures</td>
<td>HE5</td>
<td>+L</td>
<td>M</td>
<td>Non-market Values</td>
<td>Assume no acclimatisation</td>
</tr>
<tr>
<td>Decline in winter morbidity due to higher temperatures</td>
<td>HE6</td>
<td>+L</td>
<td>L</td>
<td>Non-market Values / Market Price</td>
<td>Same as HE1</td>
</tr>
<tr>
<td>Extreme weather event (flooding and storms) mortality</td>
<td>HE3</td>
<td>-L</td>
<td>L</td>
<td>Welfare impact cost Non-market Values</td>
<td>Assumes current flood protection levels</td>
</tr>
<tr>
<td>Extreme weather event (flooding and storms) injuries</td>
<td>HE7</td>
<td>-L</td>
<td>L</td>
<td>Non-market Values / Market Price</td>
<td>Adaptation costs equate to medical treatment costs</td>
</tr>
<tr>
<td>Mortality/morbidity due to summer air pollution (ozone)</td>
<td>HE4</td>
<td>-L</td>
<td>L</td>
<td>For 2020s &amp; 2050s Informed judgement; For 2080s Non-market Values</td>
<td>Same as HE1</td>
</tr>
<tr>
<td>Emergency response to grassland and forest fires</td>
<td></td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Qualitative risk assessment.</td>
</tr>
<tr>
<td>Emergency response to climate events (including flood)</td>
<td></td>
<td>-L</td>
<td>L</td>
<td>Informed judgement</td>
<td>Qualitative risk assessment.</td>
</tr>
<tr>
<td>Increase in algal or fungal/mould growth in buildings affecting respiratory conditions</td>
<td></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Not assessed</td>
</tr>
</tbody>
</table>

**Note:** - signifies a negative impact or loss; + signifies benefits or cost reductions.
Appendix C  Waterlogging

With rainfalls projected to increase significantly in the winter months (between 2 and 35% increase in mean winter precipitation by the 2080s, see Table 2.9), there is the potential for an increased frequency and extent of waterlogging of high grade (floodplain) agricultural land. This would impact negatively on agricultural productivity (Johnson et al., 2009), as well as forestry, although warmer drier summer periods would be expected to reduce periods of waterlogging during these periods. Changes in levels of waterlogging would also impact on work on construction sites, and present both opportunities and threats to biodiversity.

Waterlogging has been represented by the proxy measure of workable days on the land for this indicative analysis. Workability of the land and access to it are the practical issues of concern for farmers and foresters, rather than waterlogging per se (although it is recognised that waterlogging can of itself damage crops and trees). For this indicative study, two representative sites have been investigated with typical soil characteristics provided by Alex Higgins at the Agri-Food and Biosciences Institute (AFBI) in Belfast:

- Soil 1: Brown Earth on Red Limestone Till (under Winter Barley cultivation)
- Soil 2: Surface water gley class 2 on Basalt Till (under Winter Barley cultivation)

The workable limit of the land has been defined on the basis of a literature review, and particularly Cooper et al. (1997), which defined the workable limit to be 110% of Field Capacity (FC) for its modelling study based on Scottish soils. Field Capacity is the amount of water which can be held in a soil against the force of gravity and is usually stated as a percentage. We have adopted this definition for this study.

The WASIM model (Hess and Counsell, 2000) was selected for use in this study. Wasim can simulate a daily soil moisture balance for a range of soil, crop, climatic and field management conditions, can be readily adapted for use in large modelling ensembles for investigating climate change uncertainty and is appropriate for indicating the likely direction and magnitude of climate change impacts.

The soil characteristics for the two study sites are shown in Table C.1 based on the typical data provided by Alex Higgins, apart from the curve number value which was adopted from tables corresponding to ‘cultivated land with/without conservation treatment’.

<table>
<thead>
<tr>
<th>Table C.1 Parameter values used to represent the soil types in the WASIM model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil 1</td>
</tr>
<tr>
<td>% water at saturation</td>
</tr>
<tr>
<td>% water at field capacity</td>
</tr>
<tr>
<td>% water at PWP</td>
</tr>
<tr>
<td>Hydraulic Conductivity (m/day)</td>
</tr>
<tr>
<td>Curve Number ( a measure of the proportion of runoff)</td>
</tr>
</tbody>
</table>
Daily baseline precipitation data were downloaded from the Hadley Centre regional precipitation data website\textsuperscript{164} and monthly temperature data were downloaded from the Met Office UKCP09 baseline data website\textsuperscript{165}, with the Oudin (2005) formula used to calculate potential evapotranspiration. For future climatology, nineteen samples of monthly change factors were selected for each epoch (2020s, 2050s, and 2080s) and emission scenario (Low, Medium, and High) based on ranking all 10,000 values available, by totalling winter rainfall (October – March) and identifying the scenarios at each 5% probability level (e.g. from the 5\textsuperscript{th}, termed p05 to the 95\textsuperscript{th}, termed p95).

Each simulation was run for the period 1960-1990, to allow one ‘warm-up’ year to minimise the influence of initial conditions, with the following outputs (averages over 1961-1990 period) used in the analysis presented below:

- average date of first unworkable day of autumn (i.e. water content at or above 110% of field capacity);
- average date of last unworkable day of spring;
- average number of unworkable days per year.

The average number of workable days per year includes those days during the winter when the soil moisture content temporarily drops below the threshold used (i.e. 110% of field capacity). The number of unworkable days per year was used to rank the results for each emissions scenario/decadal period and the results corresponding to the p10, p50 and p90 probability levels are presented below to provide an indication of the range of results across all simulations.

**Results**

**Soil 1**

The trend for this soil is towards an increase in the length of the ‘summer’ period when soil moisture is maintained below the 110% field capacity threshold. This trend generally becomes stronger further into the future and as a result of increases in emission concentrations, with the change in the start of the unworkable period in autumn more pronounced than the change in the end of the unworkable period in spring (Figure C.1). This impact is attributed to the general tendency towards projected increases in temperatures and decreases in precipitation during the summer period.

\textsuperscript{164} http://www.metoffice.gov.uk/hadobs/hadukp/data/download.html
\textsuperscript{165} http://www.metoffice.gov.uk/climatechange/science/monitoring/ukcp09/download/daily/time_series.html
With regards to the average number of unworkable days per year (Table C.2), the results indicate a trend towards an increase in the total number of unworkable days per year into the future and as emission concentrations are increased. This increase in unworkable days is concentrated in the winter, with the proportion of days with soil moisture below the 110% field capacity (i.e. workable) during winter tending to decrease, which is attributed to the tendency towards increased winter precipitation present in the climate change projections.

Table C.2  Average number of unworkable days per year, for representative soil type 1 - Baseline 1961-90 is 27 days (probability levels are of results, not of climate inputs to the model)

<table>
<thead>
<tr>
<th></th>
<th>Low emissions</th>
<th>Medium emissions</th>
<th>High emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10 p50 p90</td>
<td>p10 p50 p90</td>
<td>p10 p50 p90</td>
</tr>
<tr>
<td>2020s</td>
<td></td>
<td>25 30 35</td>
<td></td>
</tr>
<tr>
<td>2050s</td>
<td>24 31 35</td>
<td>26 33 39</td>
<td>27 32 36</td>
</tr>
<tr>
<td>2080s</td>
<td>27 33 39</td>
<td>27 32 40</td>
<td>29 34 42</td>
</tr>
</tbody>
</table>

The sensitivity of the results, in terms of the trends in predicted impacts, to changes in model parameters was explored as part of this study and whilst changes in absolute results were recorded, the direction and magnitude of the trends remained consistent.
Soil 2

The results for soil 2 are the same as those for soil 1. The trend is towards an increase in the length of the ‘summer’ period when soil moisture is maintained below the 110% field capacity threshold. This trend generally becomes stronger further into the future and as a result of increases in emission concentrations, with the change in the start of the unworkable period in autumn more pronounced than the change in the end of the unworkable period in spring (Figure C.2). This impact is attributed to the general tendency towards projected increases in temperatures and decreases in precipitation during the summer period.

![Figure C.2 Mid values and selected extremes of the unbroken workable period for soil 2]

**Notes:**
Emissions scenarios (Low, Medium, High) are denoted by the first letter after the epoch (2020s, 2050s and 2080s).
Period of workable days (short, medium and long periods) are based on the ranges presented, not the absolute extremes.

Again, the results indicate a trend towards an increase in the total number of unworkable days per year into the future and as emission concentrations are increased. This increase in unworkable days is concentrated in the winter, with the proportion of days with soil moisture below the 110% field capacity (i.e. workable) during winter tending to decrease, which is attributed to the tendency towards increased winter precipitation present in the climate change projections.
Table C.3  Average number of unworkable days per year, for representative soil type 2 - Baseline 1961-90 is 41 days (probability levels are of results, not of climate inputs to the model)

<table>
<thead>
<tr>
<th></th>
<th>Low emissions</th>
<th></th>
<th>Medium emissions</th>
<th></th>
<th>High emissions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
<td>p10</td>
<td>p50</td>
<td>p90</td>
</tr>
<tr>
<td>2020s</td>
<td></td>
<td></td>
<td></td>
<td>37</td>
<td>42</td>
<td>47</td>
</tr>
<tr>
<td>2050s</td>
<td>35</td>
<td>42</td>
<td>47</td>
<td>37</td>
<td>44</td>
<td>51</td>
</tr>
<tr>
<td>2080s</td>
<td>37</td>
<td>43</td>
<td>47</td>
<td>37</td>
<td>43</td>
<td>50</td>
</tr>
</tbody>
</table>

Conclusions

The key conclusions from this study are that climate change can be expected to have the following impacts across both study sites:

- An increase in the unbroken period of workability between spring and autumn;
- An increase in total unworkable days associated with a decrease in the proportion of workable days in winter.

The magnitude of these impacts is relatively small, but tends to increase further into the future and as a result of increased emission concentrations.

Acknowledgements

The assistance of Dr Allan Lilly at the James Hutton Institute is especially gratefully acknowledged, as is the help of Dr Fiona Burnett in outlining the crop development of winter barley. Alex Higgins at AFBI must be thanked for providing the typical soil type characteristics for Northern Ireland. Dr Tim Hess, Cranfield University, also provided support in adapting Wasim to support large ensemble simulations.
Appendix D  Preliminary Flood Risk Assessment for Northern Ireland

A Preliminary Flood Risk Assessment (PFRA) looking at current and future flood risk in Northern Ireland was completed in December 2011, to meet the requirements of the Floods Directive (2007/60/EC). The PFRA was based on available or readily derivable information and assessed the adverse consequences of flooding from all sources of flooding on human health, economic activity, cultural heritage and the environment. The Directive also requires member states to use the PFRA as the basis for identifying Significant Flood Risk Areas (SFRAs).

The Floods Directive was transposed into Northern Ireland legislation under the Water Environment (Floods Directive) Regulations (Northern Ireland) 2009. The legislation requires the completion of the preliminary flood risk assessment by December 2011, flood risk and flood hazard maps for significant risk areas by December 2013 and flood risk management plans by 2015. Supported by statutory authorities including Northern Ireland Water, DOE Roads Service, Planning NI and local councils, the aim of the Directive is to manage the adverse consequences that flooding has on human health, the environment, cultural heritage and economic activity on a catchment wide scale.

In order to identify the SFRAs for Northern Ireland, strategic flood models for rivers, surface water runoff (pluvial flooding) and the sea have been developed to identify which geographic areas are prone to flooding and how they are likely to flood under current conditions and in the future (up to 2030) with climate change. These models have been used to produce flood outlines that illustrate the extent of flooding for a range of return periods. The protection from existing flood defences has been excluded from the modelling, as protected areas still remain at risk.

The following Annual Exceedance Probabilities have been used to produce the flood outlines:

<table>
<thead>
<tr>
<th>Source</th>
<th>Annual Exceedance Probabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rivers (fluvial)</td>
<td>10% 1% 0.1%</td>
</tr>
<tr>
<td>Sea</td>
<td>10% 0.5% 0.1%</td>
</tr>
<tr>
<td>Surface Water (pluvial)</td>
<td>3.3% 0.5% 0.1%</td>
</tr>
</tbody>
</table>

These flood outlines have been used to calculate the potential consequences of flooding. These consequences are represented using a set of Flood Risk Indicators, which include:

- Number of different property types flooded;
- Economic damage arising from flood damage;
- Number of people at risk;
- Vulnerability of people at risk;
- Number of key infrastructure assets flooded;

167) http://www.dardni.gov.uk/riversagency/index/eu-floods-directive/the_european_floods_directive-fabout_fd/the_european_floods_directive-stage_3.htm
168) http://www.dardni.gov.uk/riversagency/index/eu-floods-directive/the_european_floods_directive-about_fd/the_european_floods_directive-stage_4.htm
- Areas of designated environmental sites flooded;
- Number of IPPC\textsuperscript{169} sites flooded, and
- Lengths of roads/railways flooded.

The Strategic Flood Map (SFM) for Northern Ireland illustrates the areas throughout Northern Ireland that have flooded from rivers and the sea in the past and those that are estimated to be prone to flooding currently and in the future. They also provide additional information on the location of existing flood defences and highlights the areas that benefit from these defences.

As part of the PFRA around 50 SFRAs have been identified and maps illustrating the location and extents of these areas will be available when the PFRA is published. These will enable a more accurate valuation of the potential economic damages to these assets and enable the identification of any Cat 2 assets\textsuperscript{170}.

The PFRA takes into account flooding from all sources including rivers, the sea, surface water runoff (also known as pluvial flooding) and impounded water bodies (such as dams and reservoirs). However, unlike the rest of the UK, Northern Ireland does not have specific legislation for the management of reservoir safety and as a consequence there is insufficient ‘available or readily available’ information to conduct a robust assessment of the risk from this source. Therefore, DARD, Rivers Agency has produced a separate strategic assessment to scope the potential adverse consequences from flooding by impounded water bodies and proposes to address the assessment and management of this risk through the introduction of a Reservoir Safety Bill. Rivers Agency has recently established a team to progress the development of this legislation.

The PFRA has determined the location and extent of the potential future flood hazards for each source of flooding for a range of return periods using a range of predictive flood inundation models developed by Rivers Agency for each source of flooding. To support the PFRA process a GIS based application was developed to combine the flood outlines for each of the sources with a wide range of receptor datasets including, for residential and non-residential property, transportation infrastructure (road, rail, air and sea ports) and key infrastructure assets (electricity, gas, water supply/waste, hospitals, GP Practices, Care Homes, Police Stations, Fire Stations etc).

The production of SFM is an important first step in a process that will lead to the development of flood risk management plans for all areas across Northern Ireland that are estimated to be at potential significant risk of flooding. However, due to the inherent uncertainties in the flood modelling techniques and data used to produce this national snapshot of our flood prone areas, the SFM is not sufficiently accurate to determine the flood risk to individual properties or specific point locations. The second generation flood hazard and risk maps that will be produced for the Areas of Potential Significant Flood Risk shall be much improved with less uncertainty as these will be derived from predictive models, developed in accordance with best practice.

The three River Basin Districts draft plans will be ready for public consultation by December 2014. The plans will set out Northern Ireland’s objectives, measures and an action plan for managing flood risk. The plans will focus on prevention, protection and preparedness, and will address all aspects of flood risk management.

\textsuperscript{169} Integrated Pollution Prevention and Control

\textsuperscript{170} Cat 2 is defined by the Cabinet Office’s Criticality Scale for National Infrastructure as ‘Infrastructure whose loss would have a significant impact on delivery of essential services leading to loss, or disruption, of service to tens of thousands of people or affecting whole counties or equivalents.'
Appendix E  List of gaps in knowledge

### Natural Environment - Terrestrial

| NEW | Asynchrony between species breeding cycle and food supply | Limited for and against disrupted relationships. Little observed data and difficult to judge the impact of mismatches |

### Natural Environment - Freshwater

| BD6 | Environmental effects of climate mitigation measures | Not assessed | Not possible to analyse the impact of renewable energy impact on biodiversity due to a lack of knowledge on the spatial plans for mitigation measures and uncertainty on the distribution of biodiversity |
| NEW | Algal growth | Not assessed | Influenced by a range of variable and lack of data available for projections |

### Natural Environment - Coastal and marine

| NEW | Risk of Harmful algal and jellyfish blooms due to changes in ocean stratification | Too uncertain | Complexity of interactions. Warming of waters around Northern Ireland is likely to be unaffected by climate change however, there may be an increase in stratification. These two variables may act together or oppose resulting in a high uncertainty |
| NEW | Decline in marine water quality and risk to human health | Too uncertain | Relies on the spread of pests and diseases in the marine environment. The response of pest and diseases is very uncertain and may be influenced by a range of factors. |
| BD6 | Risk of human illness due to marine pathogens | Too uncertain | Not possible to analyse the impact of marine renewable energy impact on biodiversity due to a lack of knowledge on the spatial plans for mitigation measures and uncertainty on the distribution of biodiversity. |
| NEW | Eutrophication of sea loughs | Not assessed | Eutrophication depends on a number of factors including temperature, rainfall and human actions and land use. There is high uncertainty on the influencing factors and how they interact. |
| NEW | Plankton Blooms | Too uncertain | Not possible to analyses the changes in plankton abundance due to changing water temperatures. Uncertainty on increasing water temperature means that assessments are not possible. |
### Agriculture

| AG3 | Risk of crop pests and diseases | Too uncertain | Pests and diseases cannot be strongly correlated with a single climate driver. The impact of pest and diseases on crops has been controlled by human intervention through history and this has a strong impact on the chances of future outbreaks. |
| AG6 | Water demand for livestock | Not assessed | Flooding and water table analysis not undertaken for NI due to a lack of data. |
| NEW | Saltwater Intrusion | Too uncertain | Limited data for carbon storage and the change in agricultural land use. Uncertainty on the extent of the magnitude of GHG emission on agricultural changes. |
| NEW | Increase in GHG emissions | Not assessed | No data on the volume of water used for livestock. Not possible to make projections |

### Forestry

| NEW | Windthrow and storm damage | Too uncertain | High uncertainty on the projections of extreme cold events |
| NEW | Snow and frost damage | Not assessed | Climate change models highly uncertain on storm and wind projections therefore related metrics have not been assessed. |

### Business

| NEW | Changes in UK trading patterns | Too uncertain | Relies on a range of outside factors and may change independently of climate change. The opportunity for trade depends on international trade agreements and frameworks as well as an investment in foreign infrastructure. |
| BU1 | Climate risks to investment funds | Not assessed | Management processes may exacerbate the risk of Climate change, and the response of the financial sector to climate change is unknown |
| BUS | Loss of productivity due to ICT disruption. | Too uncertain | Impacts related to individual business planning and readiness. Impacts of extreme events and storms can impact on ICT but these are of high uncertainty |
| NEW | SMEs and micro-SMEs | Too uncertain | Have many differences compared to the rest of the UK and it is uncertain on how the differences will change with climate impacts. Influenced by a range of outside variables |
| NEW | Underestimation of decommissioning liabilities and end of life costs | Not assessed | Lack of data |
| NEW | Seasonal interruptions to construction activities (winter) | Not assessed | No data to assess this risk and influence of local variations. |
| NEW | Key workers unable to get to work due to extreme events | Not assessed | Uncertainty on extreme event occurrences and little research into the impacts on such events on business operations |
### Infrastructure

| BU5 | Loss of productivity due to ICT disruption | Too Uncertain | Impacts related to individual business planning and readiness. Impacts of extreme events and storms can impact on ICT but these are of high uncertainty |
| NEW | Reliance on imported fossil fuels | Not assessed | Lack of suitable data for assessment. Relies of global trade and resources and change supply chain and subsequent disruption risk |
| EN1 | Energy infrastructure at significant risk of flooding | Not assessed | Unknown exposure of power stations to current and future flood risk |
| FL11b | Sub-stations at significant risk of flooding | Not assessed | Flood risk analysis not available for consideration and assessments |
| FL12a/b | Hospitals and schools at significant risk of flooding | Not assessed | Flood risk analysis not available for consideration and assessments |
| TR1/FL8 | Disruption to road traffic due to flooding | Not assessed | Flood risk data not available for CCRA analysis |
| TR6 | Rail buckling risk | Not assessed | Only important during high temperatures aren’t project to occur as often in Northern Ireland as the UK |
| NEW | Flooding of critical infrastructure (water) | Not assessed | Flood risk data not available for CCRA analysis |
| NEW | Failure of water impoundment structures | Not assessed | Flood risk data not available for CCRA analysis |
| NEW | Algal growth in raw water supply sources | Not assessed | Lack of suitable data and large range of influencing factors to be considered |
| NEW | Change in reservoir yields for public water supply | Not assessed | Lack of suitable data for assessment |
| NEW | Key workers unable to get to work due to extreme events | Not assessed | Uncertainty on extreme event occurrences and little research into the impacts on such events on business operations |

### Buildings

<p>| BE1 | Urban Heat Island effect | Too Uncertain | Greatly influenced by local factors and unclear relationship to human health |
| BE4 | Flood Damage to cultural heritage | Not assessed | Flood risk data not available for CCRA analysis |
| FL13 | Ability to obtain flood insurance for residential properties | Not assessed | Flood risk data not available for CCRA analysis |
| FL15 | Flood risk for Scheduled Ancient Monument sites | Not assessed | Flood risk data not available for CCRA analysis |
| FL6a | Residential properties at significant risk of flooding | Not assessed | Flood risk data not available for CCRA analysis |
| FL7a | Non-residential properties at significant risk of flooding | Not assessed | Flood risk data not available for CCRA analysis |</p>
<table>
<thead>
<tr>
<th>FL12a/b</th>
<th>Hospitals and schools at significant risk of flooding</th>
<th>Not assessed</th>
<th>Flood risk data not available for CCRA analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEW</td>
<td>Coastal erosion to cultural heritage</td>
<td>Not assessed</td>
<td>Flood risk data not available for CCRA analysis</td>
</tr>
<tr>
<td>NEW</td>
<td>Pest infestations</td>
<td>Not assessed</td>
<td>Unclear how much spaces are vulnerable to pest infestation due to climate change</td>
</tr>
<tr>
<td>NEW</td>
<td>Waste management</td>
<td>Not assessed</td>
<td>Unclear to what extent climate change may impact on waste and landfill</td>
</tr>
</tbody>
</table>

**Health**

| NEW     | Fuel poverty (people affected)                          | Too Uncertain | Fuel poverty linked to climate and independent factors and the interaction is poorly understood |
| NEW     | Winter air pollution                                   | Not assessed  | Little evidence to quantify risk |
| NEW     | Cold weather working/travelling                        | Not assessed  | Little research into the impact of cold weather working and travelling and the impact on business and health |
| HE9     | Sunlight/UV exposure                                   | Too Uncertain | Strong coloration to social behaviour and population demographics |
| NEW     | Vector-borne diseases                                  | Not assessed  | Lack of research into impact due to climate change |
| NEW     | Food-borne diseases                                    | Not assessed  | Lack of research into impact due to climate change |
| FL1     | Number of people at significant risk of flooding       | Not assessed  | Flood risk data not available for CCRA analysis |
| FL2     | Vulnerable people at significant risk of flooding      | Not assessed  | Flood risk data not available for CCRA analysis |
| FL12a/b | Hospitals and schools at significant risk of flooding  | Not assessed  | Flood risk data not available for CCRA analysis |
| HE10    | Effects of floods/storms on mental health              | Not assessed  | Flood risk data not available for CCRA analysis |
| MA2b    | Risks of human illness due to marine pathogens         | Not assessed  | Little research into the relationship between pathogens and climate change and human health |
| NEW     | Increased immigration                                   | Not assessed  | Poorly understood link between possible increases in immigration and climate change, and the risk this will have on human health |
| NEW     | Transport and communications network failure           | Not assessed  | Little research into the relationship with human health and climate change |
| NEW     | Pollen and allergens                                    | Not assessed  | Insufficient quantitative research for establishing a link with climate change |
| NEW     | Demand for emergency medicine                          | Not assessed  | Linked to social factors and can disproportionally affect population group. Little research on this currently |
| NEW     | Medicine efficacy                                      | Not assessed  | Related to temperature increases which are projected to be less than needed to have an affect |