

# Climate change and the environment

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## Summary

Climate change poses a significant threat both to communities at risk of being flooded and to Scotland's plants and animals. All three types of flooding (adjacent to rivers, along the coastline and in towns and cities) are likely to become both more frequent and costly. Solutions will include limited engineered defences alongside more sustainable measures promoted by government, in partnership with individuals at risk. Climate change means that we will all have to learn to live with floods. Government will need to increase spend on flooding infrastructure, while individuals will need to take more personal responsibility for making their properties more resilient.

The threat posed by climate change to plants and animals extends from mountain tops down to the bottom of the sea-bed. It is likely that some individual species will disappear and new ones will emerge, but the majority will find a way to cope. Habitats that enable Scotland's plants and animals to thrive will also likely look different and be found in different locations. Landscapes will have quite different habitat associations, and some habitats as we know them will be lost locally.

In all cases, the impacts of climate change will occur alongside additional threats due to pollution, the more intensive use of land and sea, and the wider ways we use Nature's bounty. Nature-based solutions can mitigate many of the anticipated threats arising from climate change.

Success for particular species at given locations will depend on mobilising the efforts of individual citizen scientists and community groups, many working within environmental NGOs or with creative enterprises. At the strategic level, reviving Scotland's biodiversity will require a major uplift in investment by Government in work to revive nature, and not least in the organisations and partnerships best placed to implement this.

## The challenge posed by climate change

Climate change is already having a damaging impact on the natural environment via increased flood losses and changes in the habitats that support many plants and animals. These damaging impacts are set to worsen under likely climate change. In 2011 the Royal Society of Edinburgh's report *Facing up to Climate Change: breaking the barriers to a low-carbon Scotland* summarised projected changes in Scotland's climate, but not the likely impacts in terms of flooding and biodiversity. In this 'think piece', ten years on, we now have robust bodies of evidence to examine the likely impacts of climate change on the natural environment and ways in which some of these impacts can be reduced.

Throughout the 21st century, Scotland is expected to become warmer, with wetter winters and drier summers. More extreme events are also anticipated with more storms in the winter and more intense rainfall in the summer. As a result, both floods and droughts will become more frequent. Significant local sea level rise is also expected, and Scotland's surrounding seas are likely to become both warmer and more acidic. The impacts of these changes will be felt by all who live and work in Scotland in terms of increased flooding and also on the plants and animals that make up much of the natural environment.

## Climate change and sustainable flood risk management

Flooding arises in response to one of three processes. Firstly, river floods occur when a high flow locally over-tops the riverbank and spreads across the valley floor. Secondly, surface water floods occur when urban drainage systems are unable to evacuate flows generated by intense rainfall falling on impermeable surfaces such as roads and pavements. When this happens, localised ponding occurs, typically in streets and areas of housing, and this continues until the drainage system allows the water to drain away into the storm sewers. Thirdly, coastal floods occur when, during a period of high tide, a storm surge temporarily increases the local water level. On some occasions the local water level can be further elevated by storm waves driven onshore by the wind.

### Nature of the threat

The increased risk of flooding will threaten the properties and livelihoods of those who live alongside rivers, on the coast and even in our towns and cities. Protecting the people of Scotland from this risk will involve both costly engineering schemes but also changes in behaviour requiring all of us to "learn to live with floods". At present it is estimated that 284,000 homes, businesses and services are at risk of being flooded in Scotland. By 2080 it is likely that climate change will increase these numbers by a further 110,000 properties.

In addition, around 2,000 km of the road network and around 500 km of the rail network are currently exposed to flooding, plus around 20,000 hectares of agricultural land. Assets crucial for the health of the Scottish economy but located around the coastline are especially vulnerable to projected increases in coastal flooding and erosion. These sites include Important strategic infrastructure (e.g. the oil refinery at Grangemouth), key tourist assets (e.g. the Old Course at St Andrews) and Scotland's archaeological heritage (e.g. Skara Brae in Orkney).

### Learning to live with floods

The traditional approach for protecting people and places from flooding is to build engineered structures such as walls and embankments. Although many such structures have been built in the past (e.g. flood alleviation schemes for Perth in 2001 and Elgin in 2016) and are currently being built (e.g. in Dumfries), public funding will not be available to provide that level of protection universally – not least because, given climate change, the number of properties at risk is set to increase substantially. A worst-case scenario projects by the 2080s an increase of 90% for properties at risk of coastal flooding, 40% for river flooding and 25% for surface water flooding.

This likelihood of increased flooding in the future, especially that produced by intense localised storms that overwhelm existing urban storm water drains and sewers, has triggered a new approach to managing flood risk in Scotland. This is generally termed “sustainable flood risk management” and involves a mixture of actions which include traditional engineered structures alongside innovative solutions such as flood warnings, land use planning, river and catchment restoration, raising awareness, property level protection

and insurance. Underpinning many of these non-engineered actions is an explicit shift from solutions both provided and paid for by the state to actions initiated and owned by individuals and communities at risk. Increasingly, the state is looking for a partnership in which individuals and communities embrace the challenge of “learning to live with floods”.

The goal of “sustainable flood risk management” underpins the *Flood Risk Management (Scotland) Act 2009*, but many of the measures for delivering this are either still evolving or not yet fully implemented. These measures comprise:

- **Natural flood management** – this is a nature-based solution in which processes operating in the catchment are used to reduce runoff and slow down the flow. It includes planting woodlands, blocking drains in peatlands, damming upstream tributaries with woody debris, restoring wetlands, re-connecting river channels with their floodplains and re-meandering straightened channels. Whilst potentially effective for relatively frequent, low impact floods, these measures are unlikely to provide much protection from rare catastrophic floods.
- **Sustainable urban drainage (SuDS)** – these measures, described more fully in the section on ‘nature-based solutions’ below, are the urban equivalent of natural flood management adopted in rural areas. When combined at a city-wide scale with promoting biodiversity, they are also known as ‘blue-green city’ solutions. Implemented on a small scale in 2014 in the east end of Glasgow in advance of the Commonwealth Games, subsequent roll out has continued albeit localised and modest in scale.

- **Effective warnings** – many of the non-engineered solutions depend on accurate and timely flood warnings. This has significantly improved over recent years via the joint Scottish Environment Protection Agency (SEPA) / Met Office Flood Forecasting service. Most of Scotland’s major rivers and some key coastal communities now get at least 3 hours advance notice of a flood. But for this to be successful it requires a high uptake by those exposed to flooding, a willingness to take appropriate action and crucially a forecasting system that is highly trusted by its customers. It works best for those at risk from river and coastal flooding.
- **Emergency Action** – this comprises the immediate response to a flood by local authorities and the blue-light services. When coupled with accurate and effective flood warnings, emergency action can save lives and ensure that the most vulnerable are relocated to secure alternative accommodation. But it is not designed to deal with longer term trauma and social costs of flooding such as claiming against insurance, managing loss-adjustors and builders, temporary re-housing, and the impacts of flooding on an individual’s mental health and well-being.
- **Community flood groups** – assistance in meeting the needs of flood victims after the emergency services have withdrawn is available from the Scottish Flood Forum (SFF) a charity which supports self-help groups across Scotland. In addition to advising on insurance claims, the SFF encourages the development of community groups to increase local flood resilience in terms of training flood wardens, maintaining registers of the most vulnerable and promoting the use of property flood resilience.
- **Property flood resilience** – given adequate warning, measures to stop the water getting into a property (door guards, air brick covers, return valves in lavatories) can provide protection up to 0.6m of water for individual properties. When combined with resilience measures after a flood (laying concrete floors, moving electrical sockets up the wall, mounting kitchen appliances above floor level), losses can be significantly reduced in a subsequent flood. Despite strong promotion by the Scottish Government, to date uptake has been patchy reflecting concerns over costs, effectiveness, and potential negative impact on the property’s value on selling.
- **Insurance** – flood insurance is designed to cover the cost of replacing damaged buildings and contents. The recent development of Flood Re, a joint initiative between the UK government and insurers designed to make flood cover insurance more affordable, has only proved partially successful. In Scotland affordable policies under Flood Re are not generally available to low-income families living in rented accommodation. The resulting vulnerability raises a social justice issue, exacerbated by increased exposure to flooding given climate change.
- **Spatial planning** – prohibiting or severely restricting development in high flood risk areas is delivered via the Scottish planning system. In operation since 2007, this system has had considerable success. But it cannot address the historical legacy of earlier developments in high flood risk areas where reliance on some of the other measures noted above will continue to be needed.

## Protecting biodiversity and nature-based solutions to impacts of climate change

As Scotland becomes warmer, with wetter winters and drier summers, the ecological balance that enables plants and animals to thrive will alter. Much of this alteration will arise from changes in the processes that shape Scotland's mountains, rivers, coasts and sea-beds. In some cases, these changes may threaten the very survival of species and their habitats.

### **Climate change impacts: species**

The impact of climate change on species will be both direct and indirect. In terms of direct effects, higher rainfall will result in river spates that damage salmon spawning grounds. Less snow on Scotland's highest mountains will reduce the extent of montane species and extended droughts in summer will lower survival rates for juvenile animals and birds. For many species, rising temperatures are already having a widespread effect, with earlier arrivals and departures for summer migrant birds and lower breeding success for capercaillie. Similarly warmer and wetter winters mean that the numbers of some migrant birds have already declined with waders, such as the dunlin, wintering elsewhere.

Declining oxygen concentrations due to changes in water flow between the Arctic and Atlantic Oceans will make the North Sea almost uninhabitable for larger fishes, impacting food webs and fisheries productivity. As oceans become more acidic, the reduced strength of the limestone skeletons and shells of deep-sea corals, maerl (a purple-pink hard

seaweed) and shellfish will make them more vulnerable to predation and physical damage. Already rising surface temperatures in Scotland's seas and coastal waters have reduced sand eel populations, leading to lower kittiwake numbers, and may also have affected the survival of young salmon whose diet relies on sand eels.

Indirect impacts include birds no longer hatching in the spring when key insect species are available (e.g. wader species, such as golden plover), and flowers coming into bloom out of sync with their pollinators (e.g. some orchids and bees). The timing of autumn events is also changing with delays in leaf fall and the fruiting of fungi. Whilst some species have adjusted their life cycle to these seasonal changes, others struggle to do so and will either decline or shift their location northwards or to higher altitudes. An increase in the frequency of marine heatwaves is causing an increase in viral diseases in our coastal seas, affecting both marine life and human health. Rising ocean temperatures are decreasing the size of microscopic plankton, impacting the whole oceanic food chain. An even wider set of indirect effects will impact on plants and animals via interactions with pollution and habitat loss, making an effective response to climate change even more challenging.

In terms of winners and losers, Scotland will lose some of its species should the necessary climate no longer exist. For example, the Arctic charr, a cold-loving fish, could be lost from Scottish lochs, the capercaillie could disappear by the 2050s and the Scottish crossbill could become extinct. Rising sea temperatures have seen an increase in Northern hake in the North Sea and mackerel along the west coast. But some seabirds, such as Leach's storm petrel, great skua and Arctic skua, may become extinct in the UK due to rising temperatures.

As temperatures rise new species have been recorded such as the nuthatch, and diseases including the red band needle blight is already infecting the commercially important Corsican pine. Other recently introduced species, such as rhododendrons, thrive in warmer, wetter climates and may shade out native woodland plants. Whether or not a given species can cope with climate change depends on the quality, extent and connectivity of their existing habitat and whether they can move to new areas with suitable climate.

### **Climate change impacts: habitats**

The habitats for plants and animals will also undergo complex changes under climate change. As with species, some of these changes will be direct. For example, sea level rise is likely to result in the loss of coastal machair habitats throughout the Hebrides. Where local settings allow, sand dunes will migrate inland: but where coastal defences occur this habitat will locally be lost. Elsewhere the impacts will be more subtle as intricate ecological balances are disturbed. For example, Arctic-alpine habitats on mountain summits may have to move further north and/or to higher altitudes as they respond to rising temperature. On Ben Lawers, moss-heath communities are already being replaced by species-rich grasslands. But elsewhere, with wetter and windier summers Arctic-alpine habitats may be able to remain.

In Scotland's coastal seas, increases in temperature and acidity, and changes in water flow will result in the widespread loss of deep-sea coral reefs and maerl beds – home to thousands of other species. Given their very slow growth rates and sensitivity to climate change, maerl beds will prove especially vulnerable.

By contrast, some habitats such as seagrass meadows will benefit from the higher carbon dioxide levels of the future, locally enhancing seagrass-associated biodiversity.

Overall, whilst some habitats are likely to be lost, the most common response will be habitats adjusting to climate change. For example, in coastal waters the invasion of warm-water kelp species may change the structure of kelp forests, potentially reducing their biodiversity. In the uplands, pine woods may retain their tree cover but see heather replaced by grasses and bracken. In many cases the response to climate change may involve more than one impact. The replacement of heather by grass and bracken will reflect more nitrogen enrichment from increased rainfall as well as fewer frosts. Loss of maerl beds will reflect the impacts of human activities as well as climate change.

### **Nature-based solutions**

The impacts of climate change on species and habitats are best overcome through nature-based solutions. Not only are negative impacts reduced, but often multiple benefits are produced such as enhanced biodiversity, reduced flooding, lower temperatures, more carbon storage plus healthier lifestyles and positive mental well-being for people. A wide range of habitats can benefit from nature-based solutions:

- Removing trees and blocking drainage ditches raises water levels in damaged peatlands such as the Flow Country in Caithness. This means that the recent loss of carbon stored in the peat can be reversed, protecting one of Scotland's most important carbon stores and the key species that thrive in this habitat.

- Planting new native woodland not only improves biodiversity and stores of carbon but can also re-connect currently isolated woodland remnants. Similar goals can be achieved through localised re-wilding by allowing native woodlands to regenerate, as in the 'Cairngorms Connect' project. Here, a crucial reduction in red deer numbers, with reduced browsing and trampling, is actively promoting woodland regeneration.
- Planting trees along riverbanks provides shade and cooler water for vulnerable species. When planted along city streets the same cooling effect provides relief from higher summer temperatures.
- Allowing salt marshes to naturally regenerate along the coast offers an alternative to engineered defences against sea-level rise and increased flooding and coastal erosion. Salt marshes also provide valuable habitat for many wading birds.
- Replanting sea-grass meadows in coastal waters stores carbon and enhances the habitat for marine species including anemones, sea snails, starfish and crabs. Restoration and protection of such habitats will ensure that carbon also continues to be locked up.
- Nature-based solutions in urban areas such as reconnecting rivers with their adjacent floodplain, installing water storage ponds, planting green roofs, walls and parks with wild flowers and more trees will not only reduce flood risk but can also enhance local biodiversity. In addition, as these 'blue-green' cities are developed, new recreational opportunities will be created encouraging recreation, healthier lifestyles and promoting positive mental well-being.

Some of these nature-based solutions may compete with other land-use based measures designed to address climate change impacts. Where this is so, the relative merits of alternative proposals will need to be evaluated.

## Conclusion

Given the increased flood risk likely to arise from climate change, purely engineered solutions will be neither affordable nor sustainable. The alternative is a shift to “learning to live with floods” in which individuals and communities work in partnership with the state in managing flood risk. The state’s role is strategic – providing limited engineering-based protection, maintaining a nation-wide system of effective flood warning, ensuring that new developments are not located in high flood risk locations and encouraging nature-based solutions within catchments. The individual’s role is more tactical – protecting properties via appropriate flood resilience measures and flood insurance and, where appropriate, engaging with local community groups which aim to minimise flood losses by raising awareness.

Given the threats posed to Scotland’s plants and animals by climate change, urgent action is needed by Government, public bodies and, above all, by each of us as individuals. Nature-based solutions will form the basis for such action with environmental NGOs having a major role in raising awareness and promoting local monitoring of endangered species and habitats by informed citizen scientists. The state also needs to redouble its efforts to protect Scotland’s biodiversity by better resourcing NatureScot and SEPA (both charged with monitoring and protecting the natural heritage) and partnerships which provide key data, advice and impact at the local level. COP26 provides an opportunity to renew and ramp-up our efforts to protect Scotland’s valuable natural heritage and to harness nature-based solutions to mitigate some of the worst impacts of climate change.

*These think pieces are the personal views of the contributory authors. The views expressed are not necessarily those of the RSE but are intended to offer different perspectives on current issues.*

## Further reading

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