



RISING TEMPERATURES ON LAND AND SEA,
MORE INTENSE RAINFALL, ERRATIC SNOW
COVER – SCIENCE HAS SHOWN THAT THE
CLIMATE IS CHANGING IN SCOTLAND.
IDA MASPERO EXPLORES THE WORK BEING
UNDERTAKEN TO UNDERSTAND HOW OUR
NATIVE PLANTS AND WILDLIFE WILL COPE

TROUBLE BREWING

GAZING OUT FROM A SUMMIT PERCH in the Cairngorms or Northwest Highlands, the scale of the surrounding scenery seems almost unfathomable, as ridge upon ridge roll into the distance. Blasted by icy winds and covered in snow for at least half the year, Scotland's high mountain tops are a slice of the arctic tundra. Even in high summer, you may spot the odd glint of white – patches of snow compacted in hollows and gullies.

Vast and windswept this landscape may be, but at your feet during a summer walk in the hills you'll find a patchwork of colour and texture; a miniature world of dwarfed, dense vegetation adapted to cope with extreme conditions. On scree slopes and craggy outcrops, compact alpine flowering plants and ferns find a foothold. Delicate yet tough lichens creep between wind-clipped scrub, while mosses thrive in boggy spots and even where snow patches persist in summer. These high-altitude inhabitants are slow-growing, but up here they face little competition.

"Though small, arctic-alpine species help create that special mountain atmosphere, the feeling you get when you look out over the wilderness," comments Dr Chris Ellis,

lichen ecologist at the Royal Botanic Garden Edinburgh (RBGE). "They are often part of the reason why people climb mountains."

Scotland's high mountain ecology mimics arctic habitats found much closer to the Pole, such as in northern Scandinavia. Here in Scotland, many arctic-alpine plant species are at the southernmost edge of their range and it is for this reason that the fragile ecosystems of our montane zone are on the front line of the climate change challenge. Long degraded by overgrazing, arctic-alpine flora now face the threat of being bumped out of their secluded strongholds as the snow cover recedes and temperatures warm, allowing more vigorous plants to move in.

This is just one of the potential impacts of a changing climate on Scotland's wild places. Looking ahead, experts agree that the effects of climate change – some obvious, others very complex – pose probably the greatest challenge yet for our natural wealth. "We know we are already seeing changes due in part to a change in conditions as a result of man-made climate change," says Dr John Baxter, Policy and Advice Directorate Unit Manager at Scottish



Natural Heritage (SNH). “What we don’t know are the full knock-on implications of all these changes to individual species, to ecosystems and to food webs. But we are concerned – climate change will affect our natural heritage, our plants and animals.”

Now, a constellation of Scotland’s agencies and research institutes is rallying round and collaborating in a massive effort to understand and plan for the implications of climate change. They are measuring and analysing existing data, creating models to help predict change, surveying and monitoring populations of plants and animals – all in an effort to safeguard the future of those left vulnerable by the threat of a changing climate.

EMERGING TRENDS

The big climate debate no longer dwells on whether or not climate change is a reality – direct evidence from around the world is stacking up. In Scotland, climate change is evident from trends observed in land and sea temperatures, patterns of rainfall and persistence of snow cover, states the Scottish Environment Protection Agency (SEPA).

“We’re seeing less snow, or more erratic snow, and a change in the balance of rainfall between west and east – it’s getting wetter in the west and drier in the east,” summarises Professor Martin Price, Director of the Centre for Mountain Studies (CMS) in Perth. “But a key thing to note is that it’s not current and future changes in averages that are problematic – you can adapt to gradual change – it’s the greater likelihood of extreme events that pose a problem. We are facing a lot more high rainfall and high snowfall events and greater intensity of winds and storms.”

This picture of our already changing climate is backed up by *A Handbook of Climate Trends Across Scotland*, the result of a six-month study commissioned on behalf of SNH, SEPA, the then Scottish Executive, and the Forestry Commission. Trends highlighted in the report, published in May 2006, include an average rise in temperature of more than 1°C across Scotland (for all seasons) since 1961.

In the same period, the north and west have become much wetter in winter, with many more heavy rainfall events, while the snow season has shortened across the country, starting later and ending earlier, especially in the

north and west. The growing season has also extended, with 'spring' arriving earlier. And the surface waters of the seas around Scotland have warmed by up to 1°C over the last 20 years.

Indeed, says SEPA, climate change models suggest that temperatures in Scotland may rise up to 4°C by the end of the century, with consequences including milder and wetter winters, hotter and drier summers, more extreme weather events and rising sea levels. Baxter at SNH hints that the latest projections are even more worrying. "The newest climate change projections from the UK Climate Impacts Programme (UKCIP08) are due for publication in the early new year. That should give us a better idea of what challenges we may be facing, but the news is not good – it forecasts that the climate will change even faster than expected."

Signs are being noted that changes in our climate are already affecting the behaviour of Scotland's native plants and animals. Phenology – the study of the timings of recurring biological processes, such as budding, flowering and leaf fall in plants, and breeding and migration in animals – points to shifts in a number of species, particularly earlier spring events.

The report *Phenological indicators of climate change*, produced for SNH by the Centre for Ecology and Hydrology in 2006, compared phenological recordings with weather data, showing that these changes in 'nature's calendar' correlated with warmer air, water and sea temperatures. Out of more than 500 spring and summer events – wild birds laying eggs, the emergence of aphids and butterflies, and flowering of plants – it found that 74% appear to be happening earlier than they did



Trouble at the top: the state of snow beds on Scotland's high tops has a direct impact on specialist mosses such as *Polytrichum sexangulare* (top) and *Kiaeria glacialis* (bottom), as well as other high-altitude plants like the alpine lady-fern (*Athyrium distentifolium*, centre)



Snow beds on the slopes of Ben Macdui, Cairngorms (left); localised flooding at Dog Falls, Glen Affric (far right)



three decades ago. A quarter occurred “significantly” earlier.

So what does this mean? Certain moths and butterflies are arriving a few days earlier than they did 30 years ago, while dippers are laying their first eggs on average nine days earlier than they did 38 years ago. Other examples include the earlier arrival of aphids and marine plankton – both important building blocks in the food chains of their respective environments.

The obvious concern, says Baxter, is that food chains could become out of synch, as species respond at different rates to the effects of warming on land, air, freshwater and sea. “The knock-on consequences of one link in a chain being broken are largely unknown, and would put yet more pressure on species already under stress.”

ADAPTATION STRATEGIES

Phenology studies are already showing subtle shifts in the behaviour of certain plants and animals as they respond to a changing climate. But could a warmer, wetter Scotland with more erratic snowfall on the hills see some species disappear altogether?

Most experts agree that it will almost certainly cause some of the more specialised native plants and animals to move their range – generally northwards and upwards in altitude. “There may be some evidence of climate change impacts in the recently published *New Atlas of the British & Irish Flora*,” notes Dr Rob Brooker from the Ecology Group at the Macaulay Institute. “One of the identified trends is the expansion in range of southern species and the retraction of northern species. That might be interpreted as a consequence of climate change.”

SNH’s Baxter adds evidence of marine species, especially dwellers of the intertidal zone, already shifting their distribution in response to rising sea temperatures. SNH-funded returns to sites monitored since the 1950s have found mollusc, barnacle and seaweed species “either advancing or retreating northwards, sometimes by hundreds of kilometers – quite dramatic for organisms that don’t travel fast. In the marine environment, where we might expect things to happen slowly, they are actually happening quite quickly, and most likely due to a rise in sea temperature.”

The very building blocks of the marine food chain, plankton, are showing shifts too, warns Baxter: “Long-term plankton surveys conducted by the Sir Alister Hardy Foundation for Ocean Science provide good evidence for changes in the composition of important plankton types in the North Sea. The most notable is a massive decline in the distribution and abundance of a key northern species, *Calanus finmarchicus*. It’s been replaced in part by a southern species, *C. helgolandicus*, but in nowhere near as great an abundance. This change in balance could have drastic implications for Scotland’s marine system, and for commercial fish stocks.”

Turning attention to the uplands of Scotland, Macaulay’s Brooker notes: “One of the likely impacts of climate change on mountain systems is a marked decline in the number of snow beds that persist throughout the summer.”

The high plateau of the Cairngorms, the largest area of arctic mountain landscape in the British Isles, offers an insight into signs that this decline in snow patches is having an effect on a specialised habitat dominated by a miniature, tundra-type vegetation of mosses and liverworts (collectively called bryophytes). It is also the haunt of birds such as dot-

AN UNPREDICTABLE WORLD

THE CLIMATE CHALLENGE FOR RURAL COMMUNITIES

It’s not just Scotland’s plants, animals and ecosystems that must face the challenge of a changing climate. Direct and indirect impacts, and all the uncertainties they bring, are set to shape rural communities and the economic activities that support them – from farming and other land uses to tourism and adventure sports.

The future of winter sports, in particular, looks perilous. Professor Martin Price, Director of the Centre for Mountain Studies (CMS) in Perth, stresses that as climate change takes hold, it’s not so much the average rises in temperature as the increased variability and intensity of weather events that will pose a problem.

As a hill walker and cross-country skier, he speaks with feeling on the matter: “Even if your snow gauge is telling you you’re getting more snow, it’s not necessarily going to be where you want it, nor is it going to last. You could get a lot of snow, but if it warms up in three days’ time, the snow will all be gone.”

Sadly, Price does not offer a positive long-term forecast for Scotland’s ski centres. “I think we can safely say that the downhill skiing industry in Scotland has a limited future,” he comments. “Looking 10 or 20 years ahead, I suspect it will be marginal if existent, because of lack of snow and consistent sub-zero temperatures.”

Meanwhile, greater extremes in rainfall lead to increased risk of floods and landslides – with potential to disrupt rural communities and cut off road and rail access to more remote areas. “We are likely to see more floods, so we’ll need better ways of dealing with that increased flood risk,” says Price. “In the past, we tried to build defences, but now we’re looking at sustainable methods,

such as reinstating natural flood plains and planting trees.”

A pilot to develop and demonstrate more sustainable flood risk management begun at Glen Urquhart earlier this year as part of a three-year, European Commission-funded project called Clim-ATIC. CMS is leading the project, which also involves four other ‘northern periphery’ countries – Greenland, Finland, Norway and Sweden – and examines how rural communities can adapt to climate change.

“Clim-ATIC is taking climate change projections, which are on a national level and therefore general, and bringing them down to a very local level to work out what it actually means for different community groups, business sectors and land managers,” explains Clive Bowman, coordinator of Clim-ATIC and research fellow at CMS. “The other main part is setting up learning and demonstration projects to show how communities can go about adapting.

“The project is also keen to identify any potential economic advantage that these northern peripheral rural communities can gain from a changing climate. One of the short term advantages is that a warming could open up new opportunities for diversifying tourism, for land management and for growing different crops.”

Ultimately, agriculture, land management, transport and tourism are but some aspects of rural life and its economy that will need to adapt in the future. But the climate challenge is, of course, not the only factor. “We will have to get used to more variability, although climate change is not the only driver,” notes Price. “It will interact with all the other factors to produce a more unpredictable world.”



terel, snow bunting and the iconic ptarmigan, which feed on the insects living among the bryophytes and lichens.

“Scotland’s mountain tops are obvious places to monitor, because these plants have nowhere else to go. If they are being pushed up the mountain by the effects of a changing climate, they can only go this far north. In Scandinavia, they can go a little higher, but here in Scotland they are on death row,” explains Dr David Long, Head of Bryology at RBGE. “Lichens and bryophytes may not be flagship species or as charismatic as our most iconic animals, but they are very sensitive to climate change, and we feel they make better indicators. They also tell us a lot about habitat quality.”

Along with fellow bryologist Gordon Rothero, Long

has been surveying squares marked out on the ground – or transects – on the slopes of Ben Macdui in the Cairngorms, and Aonach Mor, Ben Dearg, Ben Alder and Ben Wyvis in the Northwest Highlands. These transects are small windows for their study of the specialised bryophytes that form the cornerstones of the snow bed habitat.

Building on Rothero’s surveys of snow bed bryophytes in the late 1980s, they are now monitoring their transects for changes in the bryophyte population – be it loss of species or new arrivals – as part of the Snowbed Monitoring Project, an SNH initiative with RBGE and the University of Bergen as collaborators.

“We now have enough data for initial findings and we expect to publish results within a year,” explains Long. “These will be quantitative statistics on the changes we’ve picked up.” The surveys are now being followed up with ongoing monitoring, which Long hopes will continue “over five, 10, 20 years, ad infinitum”.

Though reluctant to reveal the finer details of their findings at this stage, Long is happy to outline his concern about which communities and species are most vulnerable to climate change at this stage. “The impact of climate change on the bryophytes and other lower plants which characterise these areas will affect the whole snow bed ecosystem,” he comments. “Our preliminary results indicate that these communities are already being colonised by larger flowering plants that threaten to replace characteristic mosses and liverworts.”

As Long points out, while people may not necessarily notice the loss of specific lichens and bryophytes, they will detect any resulting effect on creatures that depend on such lower plants. “This could happen if the ground-cover flora changes so radically that there is no longer food for them,” he emphasises.

UNCERTAIN FUTURE

It is very hard to know exactly what the future holds for these habitats, but long-term monitoring by dedicated experts will provide a better scientific understanding. “At the moment we cannot put a timescale on the survival of particular species in climate change scenarios,” admits

The loss of tundra-type vegetation could spell trouble for mountain species such as ptarmigan (right)



FURTHER READING

NATURE’S CALENDAR

www.naturescalendar.org.uk

Discover more about phenology and get involved by helping to survey and monitor seasonal events

SCOTTISH ENVIRONMENT PROTECTION AGENCY

www.sepa.org.uk/climate

Information about the science of climate change and how it applies to Scotland

SCOTTISH NATURAL HERITAGE

www.snh.org.uk

Trends, advisory notes and guidance for decision-makers, communities and businesses

THE CENTRE FOR MOUNTAIN STUDIES

www.cms.uhi.ac.uk

The CMS focuses on the sustainability of communities in mountain regions, with adapting to climate change a major theme

CLIM-ATIC

www.clim-atic.org

This project explores how northern rural communities can adapt to and even gain from climate change

THE SCOTTISH GOVERNMENT

www.scotland.gov.uk/Topics/Environment/Climate-Change

Policy relating to climate change, including Scotland’s Climate Change Programme called Changing Our Ways

THE SCOTTISH CLIMATE CHANGE IMPACTS PARTNERSHIP

www.sccip.org.uk

The SCCIP aims to help businesses and organisations adapt sustainably to climate change by providing information, resources and training

ROYAL BOTANIC GARDEN EDINBURGH

www.rbge.org.uk/science/plants-and-climate-change

A round-up of RBGE’s research relating to climate change, including its phenology project

THE MACAULAY INSTITUTE

www.macaulay.ac.uk/climatechange

The Macaulay Institute is researching climate change impact on the ecology, soils, hydrology and land use of Scotland

Bryologist Gordon Rothero surveys the bryophytes present in a transect for the Scottish Snowbed Monitoring Project (below)





Long. "But that's part of the rationale for ongoing monitoring: to gauge the effects over time."

Also in the Cairngorms, a new study monitoring montane heath lichens recently began as part of a collaboration between RBGE and the Cairngorms National Park Authority. Like bryophytes, slow-growing montane lichens are prone to being pushed out by more vigorous flowering plants.

"Earlier this year, we completed predictive modelling to assess the likely response of certain lichen species to the climate scenarios envisaged for the UK by the Intergovernmental Panel on Climate Change (IPCC)," explains Chris Ellis at RBGE. "The results of our modelling, based on temperature and precipitation, show lowland species moving further north. They also show a threat to montane species, which simply have nowhere to move to."

"We have now started the monitoring project, which has to be long-term to be useful. Shifts in the Scottish climate are drivers of change. Now what we need to do is monitor over decades the response of vegetation to those drivers." And as Ellis points out, 20, 30 or 40 years sounds a long time in the life of a person, but in terms of vegetation, is pretty short. "These organisms have been in the landscape for thousands of years, so if things change in 20, that's extremely rapid," he adds.

In the end, predicting the scale of the impact of a changing climate on Scotland's native flora and fauna can, at this stage, only be an educated guess. Macaulay's Brooker remarks: "One can get into bet-hedging science – it's so hard to make firm predictions for individual species. There are good reasons to be concerned about certain mountain-top species, but whether one can make a firm prediction and say that those will become extinct due to climate change is a completely different matter."

The bigger picture – what changes we might notice on a landscape level when out exploring – is equally hard to forecast. "If you're considering how the landscape might change, you have to factor in human adaptation too: the potential for new crops, changes in grazing patterns, and shifts in policy and human activity," states Brooker.

"Apart from grazing on lower slopes, our high mountains are not heavily managed landscapes. However, for the valleys and lower lying areas, what our landscape is going to look like is very much dependent on the choices we make in response to – and in an attempt to deal with – climate change." ■

PHOTOGRAPHY: SCOTTISH NATURAL HERITAGE; ROYAL BOTANIC GARDEN EDINBURGH; CENTRE FOR MOUNTAIN STUDIES

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