Scenarios of the future – Scotland Under Climate Change

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Setting : Hills and Moors

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SUMMARY
This report considers the possible impacts of climate change from low and high emissions scenarios for the year 2025. If there are no dramatic policy, social, economic or environmental changes, with climate change occurring as indicated in the scenarios, there will probably be no major noticeable effects on hill and moor habitats. However, currently degraded habitats may continue to degrade, such as through substrate erosion. Any major increases in current degradation, or new large-scale and easily observed changes will probably be attributable to alterations to management regimes brought about by other driving forces, such as CAP reform. In addition, extreme events may have a very unpredictable and profound impact, depending on their frequency and intensity, and deserve further consideration. Even in the absence of other drivers and extreme events and with no apparent change in hill and moor habitats, there will still be a climate-induced ‘momentum’ for change slowly building up in all communities that will exert increasing effects as the century progresses.

INTRODUCTION

Three-fifths of the land area of Scotland is covered by hills and moors, often collectively referred to as upland, and defined as the land above or beyond enclosed farmland or croftland.[1] In these areas the main habitat types are blanket bog, wet heath, dry heath, acid grassland, montane heath, montane scrub and alpine. Although these habitats show altitudinal zonation, the strong east-west and north-south climatic gradients in Scotland mean that their elevational limits (with the exception of the high mountain alpine zone) vary with location[2].

OVERALL IMPACTS ON THE HILLS AND MOORS

The main effect of predicted climate change[3] on the habitats of the hills and moors will be a shift in climate space for species northwards by up to several hundred kilometres and uphill by several hundred metres (derived from[4]). This will result in pressure for movement, already being seen in mobile species such as insects,[5] with butterflies often cited as the prime example.[6, 7] For sessile species such as plants, it can be difficult to predict migration rates[8], but it seems likely that the required rates are much greater than many species can manage.

A shift in seasons is also likely to continue – spring is already 5 days earlier than in the 1960's,[9] and this is seen in the earlier arrival of migrant birds. There are already also changes in the phenology of plants,[10] such as a trend towards earlier flowering, most noticeable in herbaceous early flowerers. This will result in all habitats of hills and moors 'greening' earlier.[10] Leaf-fall in autumn may be delayed.[11] Possible changes in synchronicity between species may result from both phenological changes and species movement, with particular impacts on species linked as hosts or food sources. It is unlikely that there will be many completely new invasive species,[12] but some species present in lower habitats or currently found further south may start to spread north or upwards. Some established problem species such as bracken[13] may be favoured by climate changes. Others may be unaffected[14] or adversely affected ; for example, rhododendron prefers wet soils,[15] and dry summers may restrict its spread.

The drier and warmer summers may continue the already noted increase in frequency, size and severity of uncontrolled fires,[16] and drought effects may become more common later in the year. This may have severe impacts in areas already subject to pressures such as overgrazing and inappropriate burning, and which are already showing effects such as loss of vegetation cover and erosion of the peat or soil. There is also likely to be an increased incidence of extreme weather such as high precipitation events,[3] although a trend in decreasing average snowlie is expected to continue, by approximately 9 days by 2025.[17] Due to the short timescale considered, the effects of the high emissions scenario will very likely be similar to those for the low emissions scenario. The following proposed impacts are therefore applicable to both scenarios, but the frequency, intensity and severity of impact may be greater in the high emission scenario.

Habitat boundary changes. Changes due to the pressure for species and habitat movement will manifest first and most obviously at the habitat boundaries in the hills and moors. At the lower altitudinal boundary of the dry heath and grassland habitats, there may be an increase in both spontaneous natural regeneration and planned tree planting. Natural regeneration will be site specific, but will mainly be by birch, Scots pine, juniper and rowan, responding to a continuing decrease in management by fire and grazing. New planting, as part of a projected increase in forest cover over Scotland,[18] will be of a

variety of species, with some on ground currently considered marginal. Species invasion is also more likely at the southern/lower edge of all habitats. However, factors other than climate change (such as propagule dispersal and invasibility of habitats) will also control and may partially inhibit movement of habitat boundaries.[19]

Blanket bog. There is likely to be little visual change to many blanket bogs, in particular those that are currently in good condition and hydrologically intact. The MONARCH modelling project indicates that although some bog species may lose some climate space, others will be stable or even gain climate space (such as the key *Sphagnum* species).[20] The earlier spring will be apparent in the flowering of species such as cotton-grass. Already degraded sites (those overburnt, overgrazed, or drained) may suffer from summer drought which, when combined with increased winter rainfall may lead to increased erosion[12] and very visible deterioration. There may be greater impacts from late summer/autumn fires, in particular during drought years when the *Sphagnum* moss layer has dried out, leading to substrate loss or instability, lack of plant establishment, and subsequent peat erosion (perhaps countered slightly by fewer frost-days in winter resulting in less frost heave). Patches of bog habitat may therefore appear degraded or even devoid of vegetation for substantial periods. Peat stabilisation may become an important issue, perhaps partly driven by carbon output concerns. However, the greatest transformations in this habitat may be due to other land use impacts.[21]

Wet heath. It is suggested that increased winter rainfall may eventually allow wet heath to expand onto dry heath in some areas.[20, 21] However, as the predicted winter rainfall to 2025 is within natural variability for most of Scotland,[3] this is unlikely to occur within the timescale of this report. This habitat is predicted to remain 'structurally intact,[22] with no changes in visual appearance due directly to climate change. A more substantial effect is likely to be through the effects of late summer and autumn fires (when the habitat has dried out) exacerbated by subsequent increased winter rainfall. As with blanket-bog, these factors may combine to result in increased erosion of the peaty soils. This may be a major problem in already degraded areas where there is less vegetation to hold the soil together, and on steeper slopes where runoff can cause severe gullying and erosion.

Acid grassland. The earlier flowering of some herbaceous plants may be noticeable. Climate change and continued deposition of nitrogen may result in a change in the competitive balance favouring grass over heather and allowing some habitat expansion.[23] This competitive balance will also be determined by the intensity and seasonality of grazing, and the type of grazing animals involved. For example, grass is favoured over heather under intense and/or winter grazing. Changes in temperature, evapotranspiration and number of frost days may aid bracken invasion or an increase in density where already established.[13]

Dry heath. Earlier, warmer and wetter springs can result in good conditions for heather beetle outbreaks. Climate change is already being anecdotally blamed for the current increase in beetle damage across Scotland. The severity of such outbreaks may increase if the heather is also stressed due to climatic or competitive changes, or if a change in burning regimes results in an increase in degenerate heather which may be more vulnerable to attack. Large areas of heather clad hillsides may therefore appear periodically unhealthy or dead. In some areas continued nitrogen deposition and increased decomposition due to warming may lead to invasion by grass. Likewise,

bracken invasion may also increase.[13] With drier and warmer summers, large uncontrolled summer fires will probably increase in frequency. Large areas burnt at once will change the appearance of the hills from a mosaic of different aged burns to large homogeneous areas; this will be detrimental to grouse populations. Overall, there may be areas where large burns dominate the landscape, although the habitat will still be dry heather moorland. Patchiness may result from heather beetle outbreaks, and there may be some changes at the edges of the habitat with more trees, bracken and grasses invading.

Montane scrub and ledge herb communities. As with all habitats of hills and moors there will be pressure for movement upwards in altitude, but the already small populations (and limited land area) may make this difficult. Invasion and hybridisation by other willow species may threaten some dwarf-willow species,[21] and more competitive species moving into the habitat may make regeneration *in situ* more difficult. Any spread of montane scrub and currently restricted tall herb ledge communities will be very dependent upon grazing regimes and competition from other species. Little change is predicted in these habitats, but again fires may be of concern, as these habitats are small in area and vulnerable to local extinction.

Montane heath. There will be greatly reduced climate space for this habitat, and although considered vulnerable, the actual impacts of climate change are unpredictable.[20] Any changes from invasion of this habitat by heather or other species (potentially displacing *Vaccinium* and *Empetrum*) may be counteracted by high winds maintaining the low vegetation structure.[12] Grazing regime will also be important in determining any changes. Although fire is currently not common or recommended in montane heath, the drier climate may result in more fires from lower altitude spreading into this habitat, leading to scarring of upper slopes and slow subsequent recovery.

Alpine. This habitat is restricted to a small area in the high mountains, so that any temperature rise will severely impact on available climate space. An overall upward shift in species distributions, similar to that seen in Norway[24] or Spain[25] will take place. In the latter case an upward isotherm shift of 240-280 m occurred for a 1.2-1.4 ºC rise in temperature, but there was much slower species movement indicating limited ability to adapt, or the influence of other factors (such as grazing). Many alpine plant species (being slow growers) may be subjected to pressure from more competitive species moving into the habitat from lower altitudes, but the process may be slow and the visual changes even slower. Localised and perhaps temporary increases in diversity may occur due to species movement into currently species-poor parts of this habitat[24]. Moss species associated with late-lying snow patches and flushes will be threatened, and eventual losses may be 'almost inevitable'.[21] Other species that are considered particularly at risk are the snow bunting due to its dependance on late snowbeds as a source of insect food, and Norwegian mugwort due to almost complete loss of suitable climate space.[20]

Society-driven effects. If snow cover in the high mountains decreases this is likely to have a high impact on snowsports, mountaineering and tourism.[17, 26] This would most obviously affect the ski industry, either moving resorts towards closure (as has already happened with Glencoe and Glenshee) or forcing them to try and attract other visitors (such as at Cairngorm). Although winter sports may suffer, the current increase in recreation in the hills is almost certain to continue, perhaps at an increased rate due to

'better' summer weather. Popular mountain paths will continue to erode and require pathwork, with the alpine, montane heath, and peat substrate areas being most vulnerable to damage. There will be pressure for more carparks and better road access. Given the government commitment to 'green' energy, an increase in the number and size of wind farms is likely and will continue to be a source of social conflict. Each of these is likely to lead to locally significant changes to the landscape that may outweigh any effects due to climate change.

Overall vision. Although there will be obvious movement of some species, and a 'blurring' at the boundaries of communities, habitats will not move in reaction to climate change within the timescale considered by this report. We will see the start of movement of constituent species and possibly some habitat fragmentation around the edges. Monitoring studies may detect some changes in community composition and processes, but the main species of the habitats are likely to remain *in situ*. There is therefore expected to be little overall change in outward visual appearance (and altitudinal zoning) of the hills and moors. However, many of the habitats are vulnerable to events such as fire and soil erosion that may be more common with predicted climate change (particularly in combination with the other drivers considered below), and which would lead to local, rapid, and perhaps very visual changes – and possibly slow subsequent recovery. All habitats will be on a trajectory of change which, although similar in the early stages for each emissions scenario, will result in increasingly greater ecological and visual effects (with more impacts under the high emissions scenario) as time goes on.

ALTERNATIVE DRIVERS OF CHANGE

Some drivers already operating may have increasing impacts with time (e.g. current grazing regimes, summer concentrations of ground-level ozone,[27] or nitrogen deposition). New drivers may also emerge. An extreme climatic event may completely overwhelm any climate-change impacts, perhaps even changing the direction of succession or change in a very different way. Extended drought may affect habitats over a wide spatial scale and last for several years. Alternatively, extreme events may be localised in time and space, such as storms causing bog-burst or landslips.

Legislation changes (driven by social, economic or envionmental factors) could drive land management changes, such as reform of the Common Agricultural Policy causing a drastic decline in sheep numbers. Likewise the economics of landuse in the Highlands could alter management, such as a decline in traditional estate management (less planned burning), or an increase in land managed for conservation. In the latter case, management may also be influenced by trends in management or advances in ecological knowledge, and by social awareness again leading to legislation changes. The changing patterns of land ownership across Scotland (with increased community ownership), may result in a greater diversity of management aims, making the upland landscape more heterogeneous. Finally, events or changes outwith Scotland may influence habitats and species, such as a change in Arctic breeding areas affecting overwintering migratory birds.[28]

It should be noted that these different drivers for change can interact in different ways and may combine with climate change in an additive or counteractive way. Indeed, such unknown interactions may result in the most severe impacts.[29] Given the potential for change arising from drivers such as those above, it is likely that such drivers may have greater impacts than climate change alone.

References

1 Anon. (2002). Natural Heritage Futures: Hills and Moors. Scottish Natural Heritage, Battleby.

2 Ratcliffe, D.A. and Thompson, D.B.A. (1988) The British Uplands: their ecological character and international significance. In: *Ecological Change in the Uplands*, M.B.Usher and D.B.A.Thompson, eds. Special Publication Number 7 of the British Ecological Society, Blackwell Scientific Publications, Oxford.

3 Hulme, M., Jenkins, G.J., Lu, X., Turnpenny, J.R., Mitchell, T.D., Jones, R.G., Lowe, J., Murphy, J.M., Hassell, D., Boorman, P., McDonald, R. and Hill, S. (2002). Climate Change Scenarios for the United Kingdom. The UKCIP02 Scientific Report. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich.

4 Cannell, M.G.R., Fowler, D. and Pitcairn, C.E.R. (1997). Climate change and pollutant impacts on Scottish vegetation. *Botanical Journal of Scotland* 49 (2), 301-313.

5 Burton, J.F. (2001). The responses of European insects to climate change. *British Wildlife*, 188-198.

6 Parmesan, C., Ryrholm, N., Stefanescu, C., Hill, J.K., Thomas, C.D., Descimon, H., Huntley, B., Kaila, L., Kullberg, J., Tammaru, T., Tennent, W.J., Thomas, J.A. and Warren, M.S. (1999). Poleward shift in geographical ranges of butterfly species associated with regional warming. *Nature* 399, 579-583.

7 Warren, M.S., Hill, J.K., Thomas, J.A., Asher, J., Fox, R., Huntley, B., Roy, D.B., Telfer, M.G., Jeffcoate, S., Harding, P., Jeffcoate, G., Willis, S.G., Greatorex-Davies, J.N., Moss, D. and Thomas, C.D. (2001). Rapid responses of British butterflies to opposing forces of climate and habitat change. *Nature* 414 (6859), 65-69.

8 Higgins, S.I., Clark, J.S., Nathan, R., Hovestadt, T., Schurr, F., Fragoso, J.M.V., Aguiar, M.R., Ribbens, E. and Lavorel, S. (2003). Forecasting plant migration rates: managing uncertainty for risk assessment. *Journal of Ecology* 91 (3), 341-347.

9 Menzel, A. and Fabian, P. (1999). Growing season extended in Europe. *Nature* 397 (6721), 659-659.

10 Fitter, A.H. and Fitter, R.S.R. (2002). Rapid changes in flowering time in British plants. *Science* 296 (5573), 1689-1691.

11 Sparks, T.H. and Menzel, A. (2002). Observed changes in seasons: An overview. *International Journal of Climatology* 22 (14), 1715-1725.

12 Hossell, J.E., Briggs, B. and Hepburn, I.R. (2001). Climate Change and UK Nature Conservation: A Review of the Impact of Climate Change on UK Species and Habitat Conservation Policy. Department of the Environment, Transport and the Regions, London.

13 Pakeman, R.J. and Marrs, R.H. (1996). Modelling the effects of climate change on the growth of bracken (*Pteridium aquilinum*) in Britain. *Journal of Applied Ecology* 33 (3), 561-575.

14 Willis, S.G. and Hulme, P.E. (2002). Does temperature limit the invasion of *Impatiens glandulifera* and *Heracleum mantegazzianum* in the UK? *Functional Ecology* 16 (4), 530-539.

15 Mejias, J.A., Arroyo, J. and Ojeda, F. (2002). Reproductive ecology of *Rhododendron ponticum* (Ericaceae) in relict Mediterranean populations. *Botanical Journal of the Linnean Society* 140 (3), 297-311.

16 Cannell, M.G.R., Palutikof, J.P. and Sparks, T.H. (2004). Review of UK Climate Change Indicators. Department for Environment, Food and Rural Affairs, London.

17 Harrison, J., Winterbottom, S. and Johnson, R. (2001). Climate Change and Changing Patterns of Snowfall in Scotland. The Scottish Executive Central Research Unit, Edinburgh.

18 Anon (2000). Forests for Scotland: Scottish Forestry Strategy. Forestry Commission, Edinburgh.
19 Dullinger, S., Dirnbock, T. and Grabherr, G. (2004). Modelling climate change-driven treeline shifts: relative effects of temperature increase, dispersal and invasibility. *Journal of Ecology* 92 (2), 241-252.
20 Berry, P.M., Vanhinsbergh, D., Viles, H.A., Harrison, P.A., Pearson, R.G., Fuller, R.J., Butt, N. and Miller, F. (2001) Impacts on terrestrial environments. In: *Climate Change and Nature Conservation in Britain and Ireland: Modelling natural resource responses to climate change (the MONARCH project)*, P.A. Harrison, P.M. Berry and T.P. Dawson, eds., UKCIP Technical Report, Oxford.
21 Hill, M.O., Downing, T.E., Berry, P.M., Coppins, B.J., Hammond, P.S., Marquiss, M., Roy, D.B., Telfer, M.G. and Welch, D. (1999). Climate change and Scotland's natural heritage: an environmental audit. Scottish Natural Heritage, Battleby.
22 Harrison, P.A., Berry, P.M. and Dawson, T.P. (2001). Climate Change and Nature Conservation in Britain and Ireland: Modelling natural resource responses to climate change (the MONARCH project): Summary Report. UKCIP, Oxford.
23 Whitehead, S.J., Caporn, S.J.M. and Press, M.C. (1997). Effects of elevated CO_2, nitrogen and phosphorous on the growth of two upland perennials: *Calluna vulgaris* and *Pteridium aquilinum*. *New Phytologist* 135, 201-211.
24 Klanderud, K. and Birks, H.J.B. (2003). Recent increases in species richness and shifts in altitudinal distributions of Norwegian mountain plants. *Holocene* 13 (1), 1-6.
25 Penuelas, J. and Boada, M. (2003). A global change-induced biome shift in the Montseny mountains (NE Spain). *Global Change Biology* 9 (2), 131-140.
26 Harrison, S.J., Winterbottom, R.C. and Johnson, S.J. (2001). A Preliminary Assessment of the Socio-Economic and Environmental Impacts of Recent Changes in Winter Snow Cover in Scotland. *Scottish Geographical Journal* 117 (4), 297-312.
27 NEGTAP (2001). Transboundary Air Pollution: Acidification, Eutrophication and Ground-Level Ozone in the UK. Centre for Ecology and Hydrology, Edinburgh.
28 Zockler, C. and Lysenko, I. (2001). Waterbirds on the edge: climate change impact on Arctic breeding waterbirds. In: *Impacts of Climate Change on Wildlife*, R.E. Green, M.Harley, M.Spalding and C.Zockler, eds. RSPB, University of East Anglia.
29 Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C., Erasmus, B.F.N., de Siqueira, M.F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., van Jaarsveld, A.S., Midgley, G.F., Miles, L., Ortega-Huerta, M.A., Peterson, A.T., Phillips, O.L. and Williams, S.E. (2004). Extinction risk from climate change. *Nature* 427 (6970), 145-148.