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Adaptation of Native Woodlands in Scotland[1] Issues Paper

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1. Aims and purpose

This paper takes forward the outputs from a workshop in August 2012[2] which sought to review the evidence base for management options for Scottish native woodlands in light of climate change. The paper sets out the main issues in order to stimulate further discussion and promote agreement about what the priorities should be for further policy-making, management and research.

It describes key issues around what we currently know about 1) the consequences[3] to native woodlands of climate change, 2) their capacity to respond, and 3) possible management strategies.

It is acknowledged that potential management strategies themselves have risks. Decisions on which options to take in different circumstances need to be based on a conceptual framework, underpinned where possible by sound scientific evidence. This paper proposes such a framework and how it may be applied.

The paper invites response to some specific questions. Comments are also welcome on any aspect of the paper. The workshop identified the need for a further in-depth review of management options, and a meeting to review this study is anticipated in autumn 2013.

2. Main issues

2.1 What do we know about effects of climate change on native woodlands: climate change scenarios and ecosystem responses

There is policy and scientific consensus that climate change will cause native woodland ecosystems to change. UKCP09 and other projections are a strong basis for evolving policy. But decision making using these projections needs to be founded on a clear position on the level of risk considered acceptable.

For some parts of the native woodland ecosystem, current projections do not go far enough into the future. For example, we may not know enough to be able to predict how climate change will impact on the survival of populations of long-lived trees. Decision making with respect to these species may be more challenging because of this.

We now know from single species models a reasonable amount about how some of our individual tree species are likely to change in different parts of Scotland. We can predict the tree species whose range or 'climate space' is likely to change with the changing climate. Modelling so far predicts: the northerly expansion in range of oak,

[1] Here we define native woodlands as those composed predominantly of native tree species. They include 'semi-natural' and 'ancient woodland' types, and occupy approximately 133,000 hectares in Scotland.

[2] Please see http://www.climatexchange.org.uk/adapting-to-climate-change/adaptation-native-woodlands-scotland/

[3] Risk is used here as in the UK Climate Change Risk Assessment, i.e. the product of likelihood and consequence of impacts or effects. It can be positive as well as negative.

beech, ash; and the northerly expansion of hornbeam and lime except in the oceanic west. Predictions indicate that native (Caledonian) pine woodlands may suffer under future climates, and upland birch woods may also decline in area[4].

Forest Research's Ecological Site Classification decision support system incorporates climate change projections and has already identified the vulnerability of some native tree species (e.g. to drought and waterlogging). We can also use species-specific mapping of climate change risks for some native species (e.g. native pinewoods and ash) to identify habitat vulnerability.

However, we know much less about how trees growing in intimate species mixtures will interact and respond to climate change in native woodlands which are managed as semi-natural ecosystems; and also about other components of the woodland ecosystem, in particular how interactions between ecosystem components (floral and faunal species) will be affected by climate change. We are therefore in a comparatively weak position to give precise and certain guidance on adaptation; instead we must develop advice on management which acknowledges and builds on uncertainty (see below).

Question: What are the key knowledge gaps in our understanding of the risks of climate change to native woodlands? What work is being done to address these gaps? What further work is needed?

2.2 What do we know about native woodlands *capacity* to adapt to climate change

In many places in Scotland the potential for tree growth will be higher for many native and non-native species, but in other areas there will be physical challenges to some species in their current sites. The adaptive capacity of tree populations is large, though not limitless. It depends on genetic factors and a recent review has stressed the high potential of evolutionary response to climate change in tree populations[5] . Existing diversity, gene flow and natural selection are the most important genetic factors for adaptation to climate change. Where there is high within-population diversity, effective gene dispersal and consistent and abundant regeneration via seedlings, there should be a high potential for tree populations to adapt. However, we don't know the rate of local adaptation relative to climate change – how quickly natural selection will act to produce an adapted population. Populations will be required to respond within one to ten generations to changes such as: more frequent and more extreme climatic events; altered average climatic parameters; as well as associated changes in the challenges presented by competing tree species, weeds, pests and pathogens[6] . Nor do we know the key factors driving natural adaptation, e.g. soil moisture, and their effects on plant and tree physiology. The impact of non-local gene flow for adaptation is unknown. We should recognise and evaluate phenotypic adaptive capacity as well as genetic, e.g. how far can plants adapt to increasing windiness and rainfall in heir own lifetimes?

[4] Berry, P., Onishi, Y. and Paterson, J. (2012). Understanding the implications of climate change for woodland biodiversity and community functioning. Synthesis of the key findings. Unpublished Report to the Forestry Commission.
[4] Ray, D., Wainhouse, D., Webber, J. and Gardiner, B. (2008). Impacts of climate change on forests and forestry in Scotland. Report for Forestry Commission Scotland. www.forestry.gov.uk/pdf/scottish_climate_change_report.pdf/$FILE/scottish_climate_change_report.pdf
[5] Alberto, F.J., Aitken, S.N., Alía,R., González-Martínez, S.C., Hänninen, H., Kremer, A., Lefèvre, F., Lenormand, T., Yeaman, S., Whetten, R. and Savolainen, O. (2013). **Potential for evolutionary responses to climate change – evidence from tree populations.** Global Change Biology 19, 1645–1661.
[6] Lefèvre, F., Boivin, T., Bontemps, A., Courbet, F., Davi, H., Durand-Gillmann, M., Fady, B., Gauzere, J., Gidoin, C., Karam, M-J., Lalagüe, H., Oddou-Muratorio, S. and Pichot, C. (2013). Considering evolutionary processes in adaptive forestry. Annals of Forest Science DOI 10.1007/s13595-013-0272-1

Other factors are also significant. Current biological pressures which are likely to increase with climate change include: deer (populations of which will themselves be influenced by climate change and land use changes associated with responding to climate change); and some pests and diseases (for example, green spruce aphid and red band needle blight). Herbivore pressure is easier to control but it must be recognised that in some cases, negative effects of pests and diseases may be impossible to arrest – native woodlands so affected may change irrevocably. Changes in wider land use, e.g. in response to improved land capability for agriculture, will also affect adaptive capacity such as gene flow.

2.3 Our adaptation objective

The adaptation objective should determine the choice of appropriate management strategy. However, choice of management strategy for short term objectives may have long term consequences on resilience e.g. over selection for a single trait such as drought tolerance could impact on the population's ability to adapt to different challenges which arise in the future. Maintaining ecosystem resilience and ecosystem function may be the most realistic long term objective. But which management option we take will also affect other objectives in the short term – whether for habitat or species conservation or for a wider range of ecosystem services. So objectives need to be clear and trade-offs need to be considered, possibly as part of a wider cost-benefit analysis.

The ecosystem services framework (e.g. the National Ecosystem Assessment (NEA)) is useful because it helps to rationalise the relative importance of biodiversity and nature conservation as examples of a wide range of ecosystem goods and services that native woodlands deliver – it is important to recognise the other benefits (e.g. carbon sequestration, recreation) that they provide which may be dependent upon different types of intervention than those solely devoted to conservation objectives. We need to explore the economic values of the benefits and losses associated with climate change, and the costs of different strategic and management approaches.

2.4 Adaptation measures

There is a strong measure of agreement within the policy and science community that good woodland management can do much to mitigate the impacts of climate change on native woodland. Strong, up-to-date guidance exists for managing forests for biodiversity[7], and 'Woods for Nature' has been an important Forestry Commission Scotland Programme for several years.[8] The challenge is to encourage native woodland owners to put management plans in place that have clear and agreed aims, and are founded on processes of modern understanding, engagement and consensus-building.

However, a significant public perception is that *non* intervention is good for nature. Attitudes to intervention are often dependent on a philosophical standpoint with respect to what 'native' means. Emotional attachment can be a strong influence on attitudes. Policy makers and scientists need to explain why suitable intervention is actually good for biodiversity and woodland health.

The SNH 'Adaptation Principles'[9] contain a range of options for management which are applicable to native woodlands. In support of these, a range of options for management were put forward at the Workshop. These include:

[7] The Forests and Biodiversity Guidelines (Forestry Commission, 2011)
[8] Forestry Commission Scotland Woods for Nature Programme (http://www.forestry.gov.uk/pdf/fcs-woods-for-nature.pdf/$FILE/fcs-woods-for-nature.pdf)
[9] http://www.snh.org.uk/pdfs/publications/corporate/Climatechangenaturescotland.pdf

(a) 'No-regrets' actions, such as:
- Reducing other pressures on ecosystems, habitats and species, such as controlling grazing by deer, or reducing risk of wildfire;
- Testing, monitoring and evaluation of adaptive management and management interventions, based on current knowledge. For example, the testing of purposeful diversification in an area of native woodland and comparing this approach to an area where reactive adaptation is promoted;
- Giving nature space to adapt: through, thinning of stands and promotion of habitat connectivity[10]and networks of native woods (enhancing networks in lowland areas is regarded as particularly important);
- Increasing native woodland area through new planting.

(b) 'Assisted migration' – moving tree species in order to locate them in suitable future climatic conditions suggests more purposeful assistance at a regional/national scale. However, it is not accepted as necessary by some ecologists, and it may pose risks of maladaptation to current conditions as well as pathogen transfer if plants (even seeds) are used.

(c) There is a need to consider genetic diversity at a range of levels. This implies ensuring a wide genetic base. However, there is not yet scientific agreement on how this is best achieved. Options range from maximising opportunities for local populations to adapt, to more deterministic intervention, for example using non-local genetic material or genetic manipulation. Promoting adaptive capacity has strong support - giving the genetic resource a chance to evolve, by increasing turnover through regeneration, and by producing new genotypes on which natural selection can act. To secure new cohorts of seedlings regularly, herbivore pressure needs to be controlled and space and light provided for seedling regeneration.

It is important to note that all these options involve trade-offs between ecosystem services.

2.5 Decision making under uncertainty: what conceptual frameworks and techniques can we borrow from other fields?

(a) Flexible adaptation pathways (FAP)

To build climate resilience, climate change adaptation should allow for flexible responses to changing climate conditions. Flexible adaptation consists of implementing actions or infrastructure that stakeholders can adjust or shift over time in response to new climate science and evidence from ongoing monitoring, as well as implementing shifts in policies and strategies to respond to emerging climate threats and opportunities more effectively[11]. Fundamental elements of a FAP approach relevant to adaptation in native woodlands include:

- We shouldn't try to predict what will happen but take a risk management approach;
- To deal with uncertainty means taking a flexible, adaptive approach; e.g. maintain genetic diversity to allow populations to evolve in an unpredictable future, i.e. resilience;
- Uncertainty is integral to dealing with climate change and taking a resilience approach acknowledges this;
- We need to accommodate change;
- There is a need to identify tipping points;
- Planning needs to consider both short and long-term objectives.

[10]The science in support of this objective/outcome is by no means incontrovertible, but there are other drivers for adopting it where appropriate (e.g. landscape, recreation). In contrast, other ecosystem disservices should be seen as possible from unconditional application of this approach (e.g. increased fire risk, spread of pests and pathogens).

[11] www.climatexchange.org.uk/documents/adaptation_flexible_pathways.pdf

The adaptation principles set out by SNH represent 'adaptation pathways' – ranging from low to high risk options.

There may be difficulties in applying a tightly-defined FAP approach because of a comparative lack of scientific evidence about natural adaptive capacity of native woodlands and the complexity (perhaps impossibility) of quantitatively defining 'tipping points/thresholds'. However, the FAP approach could provide a useful loose framework to aid logical thinking about some of the critical issues relating to adaption in native woodlands. The principles of a FAP approach can help us to accept and understand the need to work with uncertainty, using responses that work reasonably well across a wide range of circumstances even if they do not work optimally well for any single outcome.

The FAP approach also emphasises the need to take into account the amount of time it would take for an adaptation pathway to be effective in reducing risk to an acceptable level. With native woodland management, timescales will be quite long – although gene flow and natural selection are shorter-term. Applying lessons from the FAP approach, we should use existing and developing knowledge of the current adaptive capacity of native woodlands to:

- Better understand what is an acceptable level of risk for native woodlands in terms of adaptation;
- Better monitor change and if possible set some thresholds for moving from one adaptation pathway to another – this might be quite qualitative (rather than quantitative as set out in a standard FAP) and based upon where exceeding a threshold would lead to a critical loss of ecosystem functions;
- Make more explicit use of the existing adaptation principles for biodiversity as flexible adaptation pathways and better map these for native woodlands in particular; e.g. providing space for more gene flow (more connected landscapes), more natural tree lines, more frequent cohorts (to allow for more successful natural selection).

If we can define un-/acceptable levels of risk and thresholds then we could potentially identify at what point we move from a low risk adaptation pathway (or principle) (e.g. reducing pressure from deer grazing) to a more high risk adaptation principle (e.g. translocation). With more research (e.g. along the lines of that done to look at genetic diversity in Scots Pine) and with good monitoring in place there would be a knowledge base from which to start to map out a plan of action, focussing on particularly vulnerable species and areas.

Question: Does the Flexible Adaptation Pathways approach, together with a range of management options, provide a helpful conceptual framework to base our selection of management options on? How can this be developed further, and tested?

(b) Management Decision Support tools

Forest Research has developed a range of woodland management support tools over several decades[12]. These include:

- Vulnerability and site sensitivity mapping tools;
- Tools to control a range of risks;
- Probabilistic climate projections to understand the likelihood of hazards.

Many of these tools can be harnessed to explore, understand and make management decisions for native woodland in the face of projected climate change for Scotland.

[12] http://www.forestry.gov.uk/fr/INFD-7NKFMQ

3. Filling key evidence gaps, further research and planned actions

There are several important ongoing workstreams which will improve our understanding of native woodlands and their adaptation to climate change. Some of the most important are listed below:

- The Native Woodland Survey for Scotland[13], due for completion in 2013. It provides opportunities for scenario building or modelling responses to various factors upon a national spatial inventory of current composition and condition of native woods. Beyond this, it is important to develop plans for monitoring changes in native woodland condition, in association with the National Forest Inventory;
- Relevant programmes within Forest Research are directed towards (a) the evaluation of future scenarios in forests and wooded landscapes and their impact on the provision of ecosystem services, (b) assessment of the geographic distribution of adaptive variation, using provenance trials based in birch, rowan, ash and Scots pine, (c) further development of Ecological Site Classification and other decision support tools, (d) research on the role of habitat connectivity;
- ClimateXChange research under the Adaptation Workstream, developing a risk based framework, underpinned by UKCP09 (and future) climate change projections, in order to identify the most vulnerable and most resilient native woodland types – a study exploring the utility of flexible adaptation pathways will be undertaken in 2013.

Other research projects considered at the Workshop to be worthy of further development and possible funding include:

- Re-use of existing tree provenance trials for information on adaptive behaviour;
- Further development of the response of functional traits to climate change in woodland ecosystems;
- Further fundamental woodland genetic research;
- Study and monitoring of 'new' and potentially 'future-proofed' native woodland.

In addition to research, it is intended to publish some broad principles, with links to supporting information and tools, to support managers of semi-natural/conservation woodlands as well as to guide broader policy and integration into wider land use, and to explore how these principles can be incorporated into woodland adaptation demonstration sites.

Question: What further guidance and Knowledge Exchange would help managers of native woodlands?

[13] http://www.forestry.gov.uk/nwss