Links between geodiversity and biodiversity on upland plateaux in Scotland: the importance of terrain sensitivity in managing change

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Introduction

Geodiversity is the complex variety of rocks, sediments, landforms, soils and geomorphological processes in an area. There are close links and dependencies between geodiversity and biodiversity in the uplands at different spatial and temporal scales (e.g. Haynes *et al*. 1998; Gordon *et al*. 1998; 2001; Jonasson *et al*. 2005). Upland habitats are generally of high value for nature conservation but are dynamic and often fragile. This dynamism and fragility result in part from the properties of the soils and vegetation, the active geomorphological processes and the extreme climate. It is crucial that management is based on understanding these links and the factors that determine their sensitivity since there is potential for irreversible changes on human timescales if geomorphological and ecological thresholds are crossed. This study has developed a quantitative geo-ecological approach to assessing terrain sensitivity to help inform integrated management of upland plateaux in Scotland.

Terrain sensitivity and landscape

The montane landscape is an intricate mosaic reflecting the interactions between deflation, frost activity in the soil, snow-lie patterns, hydrology, topography, micro-climate and vegetation patterns. Biodiversity is linked to the geomorphological heterogeneity of the landscape. Some plateau areas are inherently stable over long timescales, and are underlain by well-developed alpine podzols, indicating stability over thousands of years; others are inherently or episodically dynamic. Often there is a dynamic equilibrium that can be easily disturbed by human stresses (e.g. trampling, pollution, overgrazing), episodic geomorphological processes and long-term climate change. In some areas, a threshold has been crossed, leading to accelerated soil erosion and loss of montane habitats, for example on the Torridonian plateaux of the NW Highlands, such as An Teallach, Cùl Mór and Ben Mór Coigach (Ballantyne and Morrocco 2006). The underlying triggers, however, are still unclear. In the absence of mitigation strategies, there is the potential for wider catastrophic disturbance from human stresses on sensitive upland plateaux. Of particular concern is the potential loss of organic soils which are an important carbon store (Lilly *et al*. 2005).

Upland plateaux comprise mosaics of plant communities, regolith types and topographical features that form small-scale geocomplexes of widely differing sensitivity to stress. Assessment of this sensitivity has so far been largely qualitative (Thompson *et al*. 2001). Terrain sensitivity may be defined as a measure of the resistance and resilience of such geocomplexes to stress in terms of both geomorphological and ecological sensitivity. Robust measurement techniques have now been developed for two components of the mechanical response of the terrain to applied physical stress (Morrocco 2005): the tensile and shearing strengths of the

vegetation mat, and the shear and compressional strengths of the underlying regolith. Measurements have been made on 10 plateau areas across Scotland.

Results

Results show that the terrain sensitivity of high Scottish plateau surfaces is highly variable, both on and between individual plateaux. Local and regional variations in environmental conditions, including human pressures, produce an intimate mosaic of stable, robust or sensitive areas.

There are significant differences in shearing resistance between and within different plant communities on all plateaux, and between some of the same communities on different plateaux. This is due to differences in their species composition, the proportional representation of dominant species and their physiological condition, and the underlying soil types. Generally, grass-dominated (particularly *Nardus*-dominated) communities tend to be most robust, and communities dominated by bryophytes and prostrate *Calluna vulgaris* are typically most sensitive to mechanical stress.

There is also large variability within and between plateaux in the response of the substrate to mechanical stress, due to local factors such as grain size. On all plateaux, soils at greater depths are generally more robust than near-surface soils. Peat is the most sensitive substrate type, closely followed by other organic-rich soils, though the latter are often strengthened by an abundance of roots. Clast-supported substrates are the most robust of all substrate types.

Assessment of the responses of different geocomplexes on upland plateaux has allowed the development of a terrain sensitivity classification based on the shear strength of the vegetation cover and the substrate (Morrocco 2005). This should help to inform the management of such areas and also the development and testing of erosion risk modelling (Lilly *et al*. 2005).

Conclusions

Mountain environments are episodically dynamic in response to natural climatic and geomorphological trigger events and human activities, with potential for irreversible changes in sensitive areas. Terrain sensitivity analysis can help to predict vulnerable areas that may require targeted management. This needs to be informed by understanding of the links between climate, geomorphological processes, terrain sensitivity and ecological processes. Linking geodiversity and biodiversity in this way as part of an integrated geo-ecological approach is consistent with the ecosystem approach in conservation management, which emphasises the functional integrity of ecosystems and maintenance of natural processes.

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