Impacts of climate, grazing and pollution on structure and functioning of upland landscapes

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Introduction

The highlands of Scotland support unique plant communities and are the headwaters of important water resources. Whilst these ecosystems represent the least disturbed environments in Britain, their biodiversity and functioning are threatened and impacted by multiple drivers including nitrogen deposition, land management and climate change. Effective management requires strong underpinning science to understand and predict how different habitats will respond. Plant communities do not function as isolated units but are linked into the upland landscape as part of a mosaic, connected by flows of nutrients, water, resources and propagules, which adds to the challenge of predicting impacts on biodiversity and ecosystem services at the landscape scale.

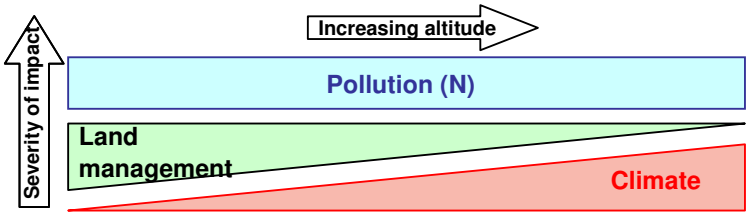
We are using an integrated research approach to studying the impacts of climate, N deposition and management, with experiments at a range of altitudes, coupled with catchment scale modelling to extend predictions to the landscape scale. Manipulation experiments enhance our understanding of 'driver' impacts through studies of key processes including above and below-ground community dynamics, nutrient cycling and hydrochemistry. Our catchment-scale monitoring focuses on characterising how the different communities within an upland-alpine landscape are linked and aims to build a model of catchment behaviour, which can use data from the experimental studies to explore scenarios of driver impacts and predict where they will have most effect.

These studies aim to provide decision-makers with a better understanding of upland biodiversity and ecosystem function so that appropriate policy and management measures can be taken at both European and national scales to ensure the sustainability of these ecosystems into the future.

Research projects

The project includes two experimental studies investigating driver impacts at the moorland-woodland interface (MOORCO) and in alpine heathland (Culardoch) and the catchment scale monitoring and modelling exercise (Allt a' Mharcaidh). In each experiment, the emphasis on the three selected drivers reflects their relative importance with altitude (Figure 1), with climate being most influential in high-altitude communities, while land management becomes more intensive as altitude decreases.

Figure 1 Hypothesised relative importance of key drivers with altitude.



MOORCO

Aim
To examine the impact of successional processes, N deposition and grazing on above- and below-ground biodiversity and ecosystem function, including soil C/N dynamics, using the moorland: birch/pine woodland interface as a model system.

Site information
We are using a combination of birch succession plots set up in 1970s-80s by John Miles and three new long-term experiments with birch and pine (set up in 2004/5), to explore how different components of the system change during succession from moorland to woodland. Treatments include tree species, deer grazing (+/-), N addition (0, 20 kg N ha^{-1} y^{-1}), litter type, and key plant species removals.

Measurements
Include: above and below ground vegetation dynamics, soil and soil water chemistry, soil fauna and soil carbon dynamics. Weather data is recorded by automatic weather stations.

Findings to date
- Tree colonisation affects not only vegetation, but also soil chemical and physical properties and soil fauna, with multi-way interactions driving change in ecosystem processes
- Changing grazing management and other factors can lead to divergent patterns of successional vegetation change, with knock-on impacts on other components of the system
- Several soil fauna groups increase in diversity from moorland to woodland but, importantly, some species can persist in both vegetation types.

Culardoch

Aim
To examine the interactive effects of N deposition, climate, burning and grazing on alpine biodiversity and ecosystem function. This project examines the effect of multiple drivers on diversity, composition and performance of alpine plant communities, impacts on mechanisms of carbon and nitrogen cycling, and nutrient budgets in soil and surface waters.

Site information
The site was established in 1999 in a *Calluna-Cladonia* heath (750m) in the Cairngorm mountains. Plots receive combinations of N addition (0, 10, 20 & 50 kg N ha^{-1} y^{-1}), fire (+/-) and grazing (+/-). In 2004 a warming treatment was added.

Measurements
Include: plant growth and composition, heather tissue chemistry, soil chemistry and soil water chemistry. Weather data is recorded by an automatic weather station, together with total N deposition measurements.

Findings to date
The first phase (1999-2004) focused on N deposition effects. Effects were rapid and included:
- A decline in lichen diversity.

- Increased winter damage in plants exposed to high N (50 kg ha^{-1} y^{-1}).
- Increased growth in dwarf shrubs.
- A shift from N to P limitation of growth.
- Almost immediate nitrate leaching into soil water with high N.
- Acidification of soil.

The second phase (2004-2011) will focus on the effects of climate and interactions with N deposition, grazing and burning.

Allt a' Mharcaidh

Aim

To integrate data from MOORCO and Culardoch with spatial data derived at a catchment scale. This study examines nutrient flows between plant communities, soil, soil solution and surface water along an altitudinal sequence from mountain top to forest edge. Major sources, sinks and transport pathways for carbon and nitrogen are investigated.

Site information

The Allt a'Mharcaidh is a tributary of the River Spey and is located in the western Cairngorms. There is a wealth of background data available for the catchment, with available records from the Environmental Change Network (ECN) site, and Acid Waters Monitoring Network (AWMN). Six new monitoring sites were established for the current project in 2004.

Measurements

Lysimeters, moisture and temperature sensors have been installed within the organic and mineral layers of the soil and atmospheric samplers collect rain and cloud water. Root dynamics are filmed during each survey.

Findings to date

Results indicate significant differences between the concentration and form of nitrogen at different sites, and between the organic and mineral horizons.

- Most nitrogen is retained by the vegetation and soil
- Stream concentrations are generally low in the warmer months and any ammonium (NH_4^+) entering the stream is nitrified.
- Pulses of nitrogen are observed during winter storm and snow melt events.

Future - upscale our observations to predict nutrient cycling for the whole catchment