The impacts of acid and nitrogen deposition on:

Montane Heath

Montane heathlands comprise a range of dwarf-shrub, moss and lichen dominated communities occurring above the potential tree-line. They represent the most extensive remaining areas of near-natural habitat in the UK and are highly valued for the unique range of arctic and alpine species which they support. Montane areas form the headwaters of many river systems and play an important role in the regulation of water supply and quality for downstream uses such as drinking water and fisheries.
Montane moss and dwarf-shrub heaths are most common in Scotland, but have a restricted distribution south of the Scottish Highlands. They are thought to have declined over the last 50 years. There is also evidence of a loss of characteristic mosses and lichens and an increase in grasses. This is thought to be a result of past and current overgrazing combined with the effects of nitrogen (N) deposition and, increasingly, climate change (Thompson & Brown 1992).

The distribution of inputs of acidity and nitrogen across the UK

Energy production through the combustion of fossil fuels results in the emission of nitrogen oxides (NO_x) and sulphur dioxide (SO_2) into the atmosphere. Food production also causes pollutant emissions: ammonia (NH_3) from farm animal units and both ammonia (NH_3) and nitrous oxide (N_2O) from intensive fertiliser use. These pollutants are transported in the atmosphere affecting air quality and rainfall chemistry across the UK. This has resulted in acidification of soils and waters in acid-sensitive areas such as many upland habitats and has also contributed to N enrichment of semi-natural areas. Reductions in emissions due to policy control measures have resulted in lower quantities of sulphur and nitrogen oxides falling on different habitats but, due to increases in emissions from shipping, recovery has not been as fast as hoped for. Ammonia emissions increased sharply from the 1950s to 2000 and currently remain at these peak levels.

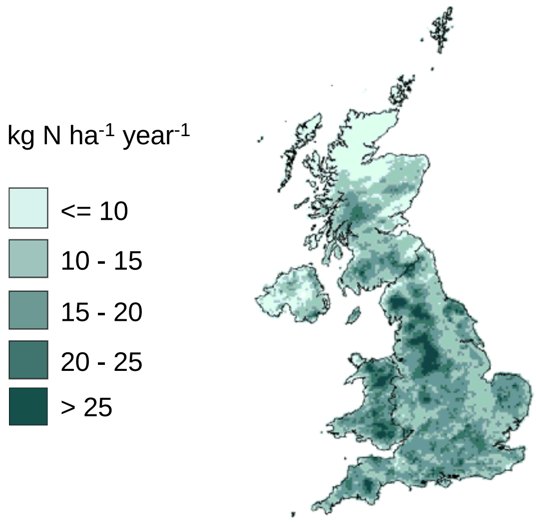

Fig 1a. Nitrogen (NOx + NHx) deposition measured 2003-2005

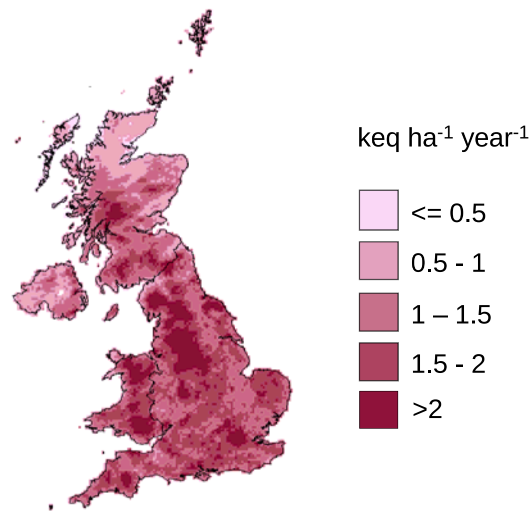

Fig 1b. Total acid deposition (S + NOx + NHx) measured 2003-2005

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Evidence of acidification and N-enrichment effects at the national scale

There are various sources of information which indicate vegetation, soils and waters have been affected by acidic and N deposition. A review of the evidence for the UK was brought together by the National Expert Group on Transboundary Air Pollution (NEGTAP) (http://www.nbu.ac.uk/negtap/home.html). The evidence for N enrichment of vegetation includes two national monitoring programmes – the Countryside Survey and the New Plant Atlas for the UK – which identified shifts in species composition towards more nutrient-demanding species in the latter half of the 20th century (Preston *et al*. 2002, Haines-Young *et al*. 2003) (e.g. Figure 2).

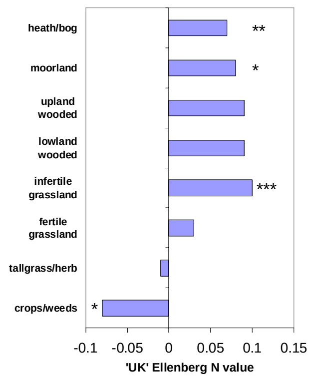

*Figure 2. The change in UK fertility score for different habitats between 1990 and 1998 taken from the most recent UK Countryside Survey (redrawn from Haines-Young et al., 2003). A low value is associated with low fertility and a high value with high fertility. Statistically significant changes are marked as * P<0.05, ** P<0.01, *** P<0.001.*

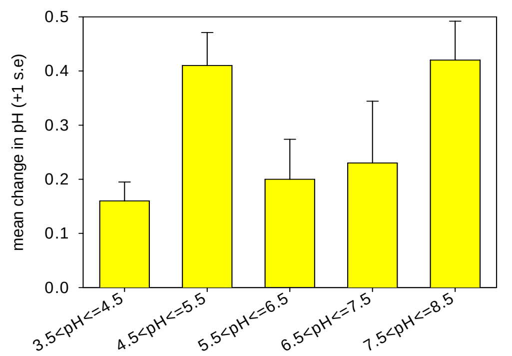

Figure 3. The increase in soil pH (0-15cm) from 1978-1998/9 at 767 sites across Great Britain (NEGTAP 2001)

Acidification of soils and waters recorded in some areas during the 20th century are now being reversed, reflecting the success of emission policies to reduce levels of acid deposition in the environment (e.g. Figure 3). There are still areas at risk, however, due to increases in sulphur emissions from shipping.

Why does air pollution affect our soils, vegetation and waters?

Although rainfall is naturally acidic, additional acidity either introduced directly by sulphur dioxide and nitrogen oxides or formed during the breakdown and uptake of ammonia has affected waters, soils and vegetation in the UK. The pH of lakes and rivers fell during the last century, in turn affecting populations of fish, invertebrates and water plant communities. Soils also became more acidic, affecting organic matter breakdown and soil nutrient balance. Soil acidification increases the solubility of some elements such as aluminium in the soil solution, which can be toxic to plant roots at high concentrations. Pollutants are also deposited to vegetation directly as gases, aerosols and in fogs and mists, and can cause direct damage to plants at high concentrations.

Emissions of nitrogen oxides and ammonia can also lead to N enrichment (eutrophication). These problems can result in a loss of biodiversity in sensitive ecosystems because nitrogen-loving species benefit at the expense of other species of conservation interest that contribute so much to the character of semi-natural habitats. This happens due to nutrient imbalances, increased susceptibility to climatic stress and higher levels of insect or fungal damage which affect the balance of competition between species.

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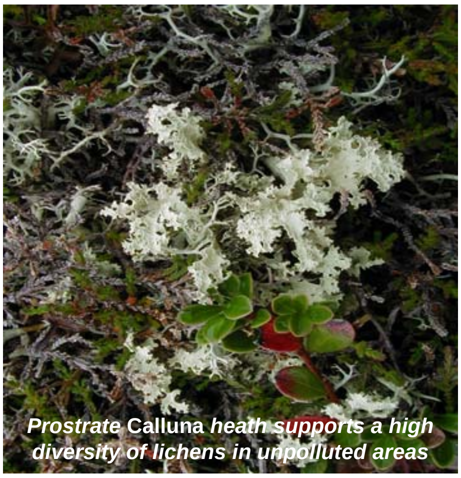
Current evidence for air pollution effects in montane heaths

The few studies which have been carried out in montane heathland ecosystems have focussed on two distinct communities: prostrate *Calluna vulgaris-Cladonia arbuscula* heath and *Carex bigelowii-Racomitrium lanuginosum* moss heath. The former is dominated by a carpet of prostrate dwarf shrubs with a diverse lichen community, while the latter is dominated by the montane moss *Racomitrium lanuginosum* (woolly hair moss) along with grasses and sedges. Both are climatically-determined 'climax communities' occupying large areas on exposed mountain summits and ridges in the UK.

South of the Scottish Highlands these communities are absent from many areas they occupied in the 1950s. Current summit vegetation in the southern Uplands, northern England and North Wales often consists of impoverished variants of these communities, with a reduced cover of mosses, lichens and dwarf shrubs, and a high prevalence of grasses. This degradation is thought to result from a combination of increasing N deposition (up to 56 kg N ha^{-1} yr^{-1} in montane areas of the UK) and high grazing pressures, both of which occurred over the period 1950-present. Separating the effects of these two factors is not easy and interactions between the two may substantially increase their impacts. Degradation of the ecosystem is not limited to effects on the plant community composition; studies on the Carneddau plateau in north Wales (Britton *et al.* 2005) have also shown reduced soil C:N ratios, loss of soil carbon from the most degraded areas and a high N content of both soils and plant tissues, compared with 'clean' sites in northern Scotland.

Degraded Racomitrium *heath in North Wales*

Both *Racomitrium* and *Calluna* have been shown to respond to N deposition by accumulating N in their tissues. Below 10 kg N ha^{-1} yr^{-1}, *Racomitrium* is able to use additional N supplies for growth but, as N deposition increases, excess N accumulates in the tissues. At very high levels of N deposition, the cell membranes of the moss become damaged, making them 'leaky', resulting in decreased growth and eventually shoot death (*Pearce et al*. 2003). The result is a reduced cover and depth of the moss mat and increased N availability in the soil as nutrients are released from decaying tissue. Reduction in moss cover may lead to soil erosion or allow expansion of grasses and sedges able to use the increased N supply. This in turn may decrease light availability to the moss, further reducing growth. Loss of the moss carpet and the thick organic layer below, which acts as both a sponge and a filter, may also have important consequences for hydrology and water quality downstream.



Prostrate Calluna *heath supports a high diversity of lichens in unpolluted areas*

In prostrate dwarf-shrub heaths in the UK and Scandinavia, N deposition has been shown to affect several aspects of community structure and function (Fremstad *et al.*, 2005). Nitrogen inputs as low as 10 kg N ha^{-1} yr^{-1} cause a reduction in the cover and species richness of the diverse lichen community associated with this habitat. *Calluna*, however, responds by increasing its shoot growth as long as phosphorus is not limiting. This community does not show the dramatic shift to grass dominance seen in lower altitude heaths, probably because of the limited amount of grasses present. Nitrogen addition also results in soil acidification and the associated loss of essential plant nutrients. Increased acidity mobilises toxic ions such as aluminium and heavy metals which are poisonous to terrestrial and aquatic life alike.

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How will climate change and management affect the impacts of air pollution?

The effects of air pollution on vegetation, soils and waters are not independent of other types of environmental change. Factors such as climate change and management may influence the sensitivity of ecosystems to air pollution. In some cases these will reduce damage while in other cases they may act to amplify effects. In montane heathlands two issues have been highlighted as being of major concern. These are the impact of domestic and wild herbivore populations and that of climate change. Studies in *Racomitrium* heath (van der Wal *et al.* 2003) have shown how grazing can enhance the negative effects of N deposition through trampling of the moss and deposition of dung, favouring grass growth. This interaction may be responsible for the degraded state of montane heaths south of the Highlands. Predicted future increases in drought frequency may also amplify N impacts. Montane habitats are exposed to extreme climates including the drying effects of high wind speeds during both summer and winter, and N deposition has been shown to increase drought sensitivity of key species. When also exposed to high levels of N deposition this can lead to increased winter injury in *Calluna* and reduced growth in *Racomitrium* (Jones *et al.* 2002).

Winter injury in *Calluna vulgaris* subject to high N load

UK actions being taken to help reduce air pollution

Protocols under the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP), have already led to substantial emissions reductions for sulphur dioxide and nitrogen oxides. As a result, acid deposition in the UK has declined by approximately 50% over the past 12 years, mainly due to reductions in sulphur emissions. Under the latest CLRTAP agreement (the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone) UNECE parties have agreed more stringent emission ceilings for SO_2 and NO_x as well as the first emission ceilings for NH_3, to be met from 2010. A major driver for agreement of these ceilings was the aim to reduce exceedance of critical loads for acidification and eutrophication across Europe. Critical loads are defined as the amount of acidity or nutrient N deposited on an ecosystem that, if exceeded, could lead to damage of that ecosystem. Critical loads are improved and refined as new data on ecosystem impacts become available. A recent update of UK critical loads has been undertaken and the report is available at: www.critloads.ceh.ac.uk .

Further Information

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