The impacts of acid and nitrogen deposition on:

Lowland Heath

The UK currently has approximately 58,000 ha of lowland heath, representing 20% of the international total for this habitat. Lowland heathland occurs at altitudes of less than 300 m and is typically associated with nutrient-poor, often sandy soils. Both wet and dry heathlands are priority habitats for nature conservation and, in addition to supporting a diverse flora and fauna, heathlands also have a high amenity value. Lowland heaths are managed systems, requiring the regular removal of nutrients to maintain nutrient-poor conditions. However, since the late 19th Century, a decline in traditional management practices, together with changes in land use and increasing urbanisation, have resulted in the loss of large areas of heathland. More recently, elevated deposition of nitrogen (N) is thought to have contributed to widespread heathland decline throughout NW Europe.

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.

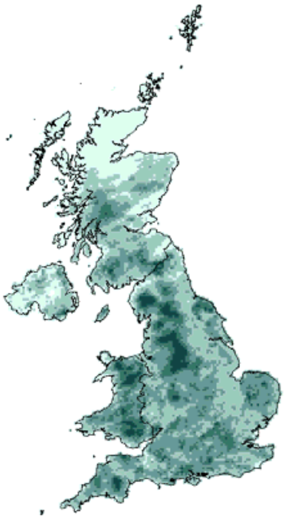

Fig 1a. Nitrogen (NOx + NHx) deposition measured 2003-2005

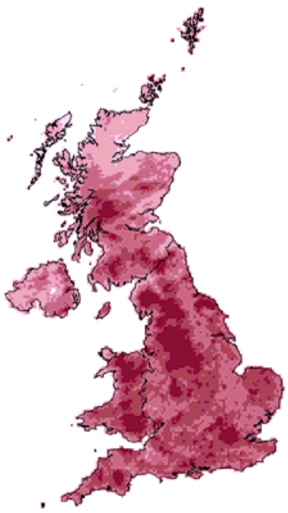

Fig 1b. Total acid deposition (S + NOx + NHx) measured 2003-2005

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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).

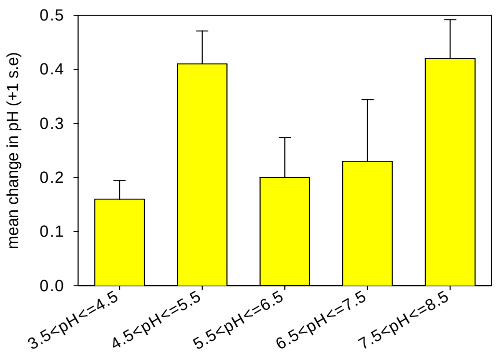

Figure 3. The increase in soil pH (0-15cm) from 1978-1998/9 at 767 sites across Great Britain (NEGTAP 2001)

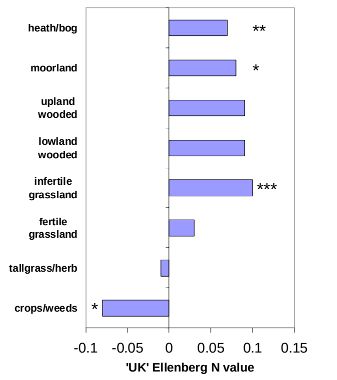

*Figure 2. The change in UK fertility score for different habitats between 1990 and 1998 taken from the most recent UK Countryside Survey (redrawn from Haines-Young et al., 2003). A low value is associated with low fertility and a high value with high fertility. Statistically significant changes are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

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 lead to N enrichment (eutrophication). These problems can result in a loss of biodiversity in sensitive ecosystems because N-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 all affect the balance of competition between species.

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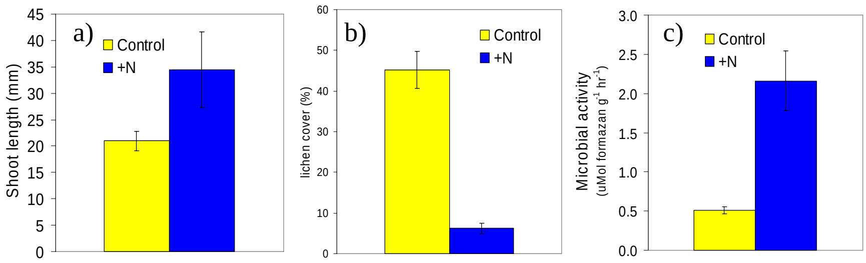
Current evidence for air pollution effects on lowland heaths

Experimental nitrogen addition at Thursley Common NNR

Research in the Netherlands, Denmark and the UK has demonstrated a variety of effects of N deposition, and to a lesser extent acidity, on the growth, chemistry and species composition of heathland vegetation and on nutrient cycling within heathland ecosystems. Results from long term manipulation experiments at lowland heaths in both north-west and southern England have shown that even relatively small increases in N inputs result in increased growth of heather (*Calluna vulgaris*) as well as earlier bud burst and higher foliar N concentrations. These changes are frequently associated with an increase in sensitivity to drought and frost as well as faster growth of the heather beetle, an insect which feeds exclusively on heather and which can be responsible for wide scale damage to vegetation.

In the Netherlands, elevated rates of N deposition have been responsible for increased dominance of the heathland grasses wavy hair grass (*Deschampsia flexuosa*) and purple moor grass (*Molinea caerulea*), at the expense of heather (Aerts & Heil, 1993). A recent nationwide survey has shown that the occurrence of the dominant heathland dwarf shrub species, and heathland habitat, have decreased significantly in the UK during the past 20 years (CS2000). However, whilst there is some evidence linking N deposition with a change in heathland community composition in Britain, field experiments have shown only a short-lived increase in grass species following prolonged periods of N addition (Wilson, 2004; Barker *et al*., 2004).



Effects of nitrogen addition (30 kg ha^{-1} yr^{-1}) on a) Calluna *growth, b) lichen % cover and c) soil microbial activity at Thursley Common heathland NNR (Surrey).*

Lichens and mosses are considered to be particularly sensitive to N deposition; heathland manipulation studies have shown negative effects of N on the performance and diversity of moss and lichen communities (Haworth, 2005; Carroll *et al.*, 1999).

Measuring the fate of added nitrogen in heathland soils

Although N deposition is the major pollutant issue for lowland heathland, acidity and high concentrations of ammonium ions have also been shown to have direct toxic effects on sensitive herbaceous species in Dutch heathlands (de Graaf *et al*., 1998). Whilst the effects of N deposition are most clearly seen above-ground, changes below-ground are also observed, with important consequences for plant nutrient and water relations. Typical below-ground responses include a reduction in *Calluna* root growth, a build up of soil N stores and changes in the rate of nutrient cycling.

The evidence to date indicates that a large proportion of N inputs is immobilised in the soil microbial biomass. Changes in microbial community composition and an increase in microbial activity are associated with accelerated rates of decomposition and faster nutrient cycling, factors which may favour the growth of more nutrient-demanding species, such as grasses, over slower growing dwarf shrubs, like heather. Current and future legislation will reduce emissions of nitrogenous pollutants, but little is known about the ability of semi-natural ecosystems to recover from the effects of eutrophication. Ongoing work at Thursley Common, a lowland heath in Surrey indicates that recovery will be a slow process, with the effects of earlier N inputs persisting for many years after additions cease.

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

Air pollution is not the only driver of ecosystem change; climate change is likely to have detrimental effects on heathland vegetation and alter nutrient cycling. Research has shown that N addition increases the sensitivity of heather to drought; climate change may result in even greater levels of drought injury, particularly in combination with elevated N deposition. Another important issue is that temperature is frequently a limiting factor for insect and microbial performance; warmer temperatures are likely to result in increased herbivory and faster nutrient cycling. Lowland dry heathlands typically occur on well drained, sandy soils, with limited water holding capacity. Predicted changes in summer rainfall and temperature may result in a greater frequency of uncontrolled summer fires, with detrimental effects on soil structure and seed bank, as well as heathland fauna.

Habitat management, in the form of controlled burning, turf cutting, mowing or grazing, is used as a tool to maintain low nutrient levels in lowland heaths. Recent results from both experiments and modelling studies indicate that frequent, intensive management (for example turf cutting or mowing with litter removal) is needed to retain nutrient-limited conditions at many heathland sites under current levels of N deposition.

Management burn of an experimental heathland plot

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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