The impacts of acid and nitrogen deposition on:

Blanket and raised bogs

The UK currently has 1.5 million hectares of blanket and raised bog, including 6000 hectares of lowland raised bog, a significant proportion of the worlds' resource. Bogs are an ancient, peat based ecosystem, representing thousands of years of organic matter accumulation, predominantly where rainfall is highest, in the west and north. Bogs support specialised plant communities, adapted and restricted to nutrient limited conditions that are sustained by the wet, often anoxic, acidic conditions which restrict decomposition. Bogs are priority habitats for nature conservation, valued for their specialised plant and bird communities and their ability to act as a sink for carbon. Large areas of bog were drained last century for agriculture and forestry, today increased atmospheric nitrogen (N) deposition, climate change, grazing and trampling threaten their existence.

The distribution of inputs of acidity and nitrogen across the UK

Energy production through combustion of fossil fuels results in the emission of nitrogen oxides (NO_x) and sulphur dioxide (SO_2) into the atmosphere. Food production also emits pollutants: ammonia (NH_3) from farm animal units, and both ammonia (NH_3) and nitrous oxide (N_2O) from intensive fertiliser use. These are transported in the atmosphere affecting air quality and rainfall chemistry across the UK. This pollutant deposition (Figure 1) 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.

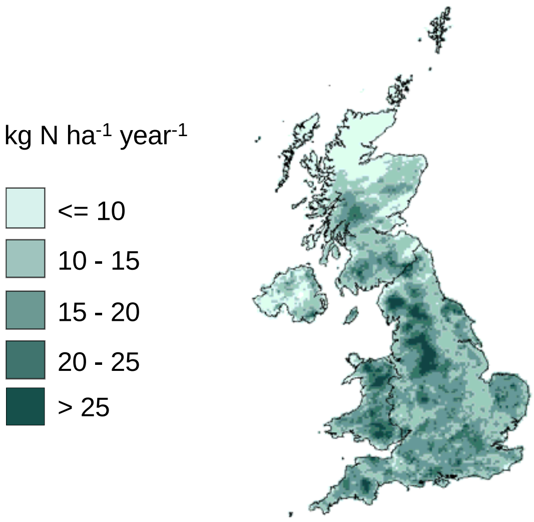

Fig 1a. Nitrogen (NOx + NHx) deposition measured 2003-2005

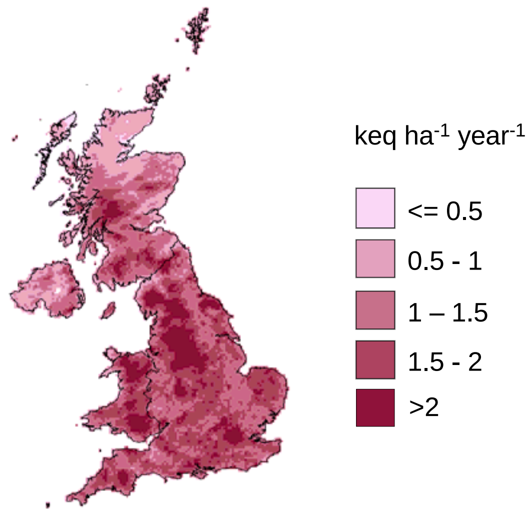

Fig 1b. Total acid deposition (S + NOx + NHx) measured 2003-2005

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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).

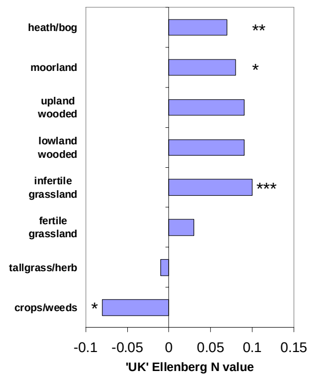

*Figure 2. The change in UK fertility score for different habitats between 1990 and 1998 taken from the most recent UK Countryside Survey (redrawn from Haines-Young et al., 2003). A low value is associated with low fertility and a high value with high fertility. Statistically significant changes are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

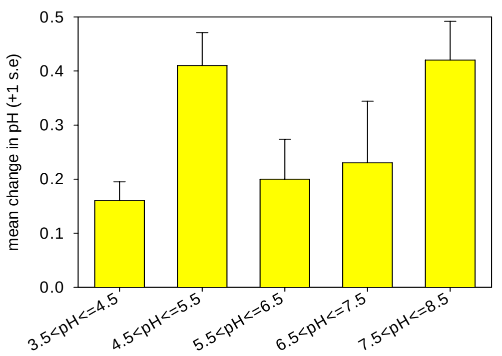

Figure 3. The increase in soil pH (0-15cm) from 1978-1998/9 at 767 sites across Great Britain (NEGTAP 2001)

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 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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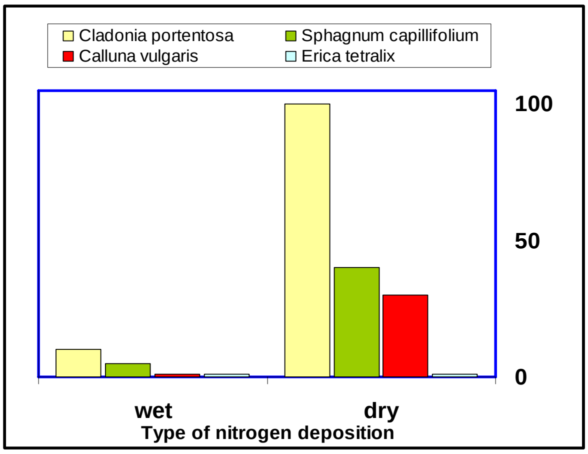
Current evidence for air pollution effects on bogs

Research on the effects of N deposition on bog ecosystems is limited, although there are many studies on responses of individual species of *Sphagnum* moss. In addition there is a large amount of field evidence from intensively farmed regions of the Netherlands and Denmark showing that high concentrations of gaseous ammonia and ammonium in precipitation have led to the loss of *Sphagnum* mosses, keystone species for the sustainability of acid bogs.

In the UK, the majority of bogs occur in the north-west where N deposition is predominately associated with the large amounts of precipitation. An experiment was established in 2002 at Whim bog in the Scottish Borders to assess the effects of wet deposited N at loadings comparable to those received by UK bogs (majority < 20 kg N ha^{-1} yr^{-1}), and compare them with those of released gaseous ammonia, simulating an agricultural point source.

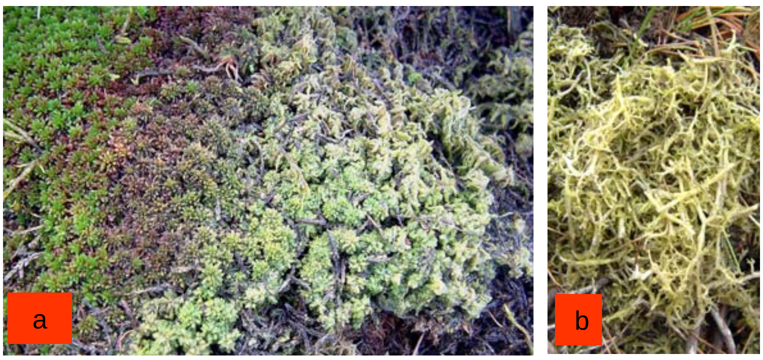
Aerial photograph of Whim bog nitrogen manipulation experimental site.

Additional N (~20 kg N ha^{-1} yr^{-1}) provided in precipitation for 5 years, on top of a background deposition of 8 kg N ha^{-1} yr^{-1}, has not yet caused significant changes in species composition, or species loss, among any of the functional groups, namely lichens, mosses, *Sphagnum* mosses, sedges or dwarf shrubs (such as bilberry, heather). There is evidence of increased growth and N accumulation, although these responses are species specific. Doubling this amount of N suggests that in the long-term, at current levels of deposition, hummock forming *Sphagnum* species such as *Sphagnum capillifolium* may be lost from those bogs in high N deposition areas. Ammonia at concentrations providing a similar N dose (~20 kg ha^{-1} yr^{-1}) is much more toxic, and affects more of the key species.



Percent damage caused by five years of added nitrogen, ca. 20 kg N ha^{-1} yr^{-1} in precipitation or as ammonia gas.

Nitrogen effects on bogs appear to be strongly influenced by climatic conditions which can predispose plants to detrimental effects of N and *vice versa*. Increased injury from spring frosts, winter desiccation, summer droughts and fungal pathogens have all been observed.



a) Stages of Sphagnum death and b) dead lichen (Cladonia portentosa) in response to increased nitrogen deposition.

However, invading species appear to be less of a problem than in other habitats, as mosses quickly colonise the exposed litter layer.

In the Whim experiment, N retention has been high to date, but increases in mineral N are measurable in the rooting zone which will have implications for a variety of microbial driven processes, such as greenhouse gas emissions and carbon sequestration.

Over this relatively short time scale changes in emissions of methane and nitrous oxide have been small, but longer term data are needed.

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

Drain blocking using pile and sheeting dams on the RSPB reserve at Forsinaird, Sutherland. Photograph by D. Norrie.

Redistribution of rainfall, in both time and space, could represent a real threat to bogs where regional climates are predicted to become drier and warmer. Research suggests that such changes will greatly exacerbate the detrimental effects of N deposition on bogs, and *vice versa*. Both *Sphagnum* species and *Calluna* (heather) are highly sensitive to desiccation stress. Climate change may also accelerate the breakdown of peat and lead to shifts in community ecology, with the ultimate loss of bog ecosystems. Management intervention by increasing the amount of water draining into bogs, and damming up drainage outflows could help offset a falling water table. Trampling causes long-term physical damage to bog vegetation which can be addressed through sensitive management.

On bogs where *Racomitrium lanuginosum*, woolly hair moss, is dominant, reducing the grazing pressure may help offset anthropogenic effects. Restricting the type of plants grown in close proximity to bogs, particularly tree species may help control invasive species.

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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