The impacts of acid and nitrogen deposition on:

Sand dune habitats

Sand dune habitats are one of the most natural remaining vegetation types in the UK. They support over 70 nationally rare or red-data book species, and are a refuge for many species lost due to agricultural improvement of other lowland habitats. The open dune habitats in particular are important for a range of species: plants which are intolerant of competition; insects which require some bare soil for burrowing; and for threatened reptiles and amphibians such as the sand lizard, natterjack toad and great-crested newt.

Sand dunes are sensitive to many pressures, including: habitat loss, sea-level rise, climate change, agricultural improvement, tourist pressure, lack of management, and over-stabilisation. Nitrogen (N) deposition is thought to be a major contributor to over-stabilisation and species decline in UK dune systems.

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.

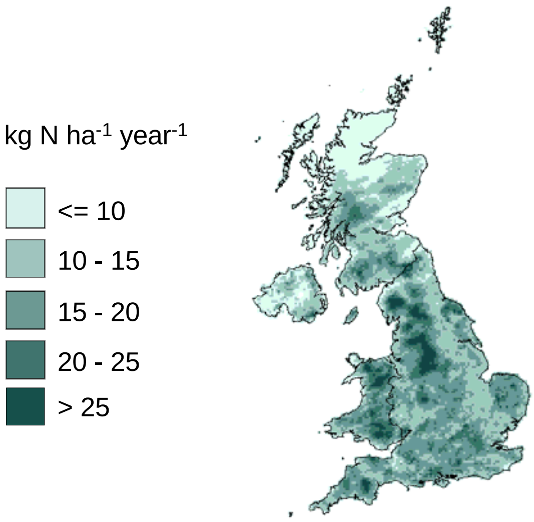

Fig 1a. Nitrogen (NOx + NHx) deposition measured 2003-2005

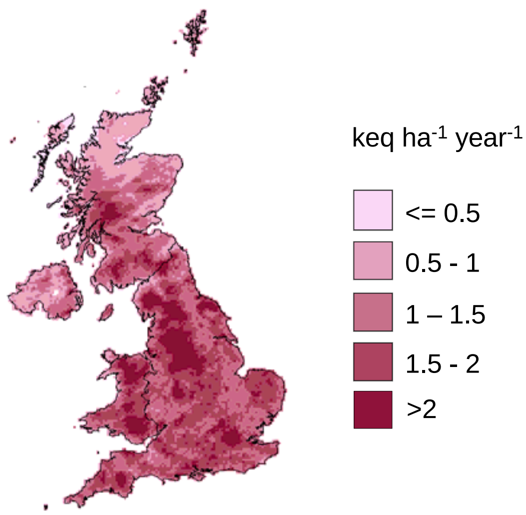

Fig 1b. Total acid deposition (S + NOx + NHx) measured 2003-2005

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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).

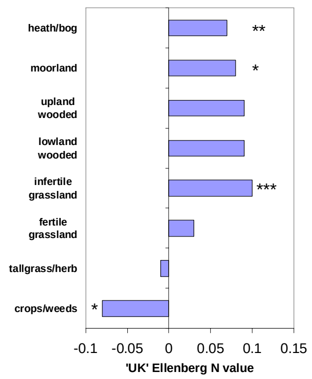


*Figure 2. The change in UK fertility score for different habitats between 1990 and 1998 taken from the most recent UK Countryside Survey (redrawn from Haines-Young et al., 2003). A low value is associated with low fertility and a high value with high fertility. Statistically significant changes are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

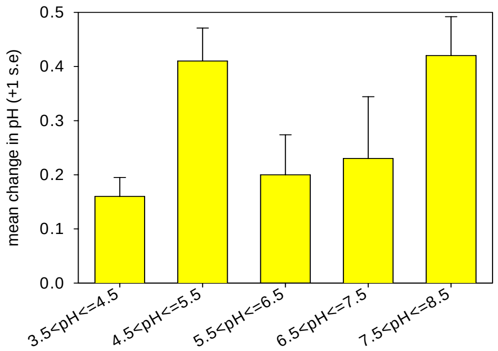


Figure 3. The increase in soil pH (0-15cm) from 1978-1998/9 at 767 sites across Great Britain (NEGTAP 2001)

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.

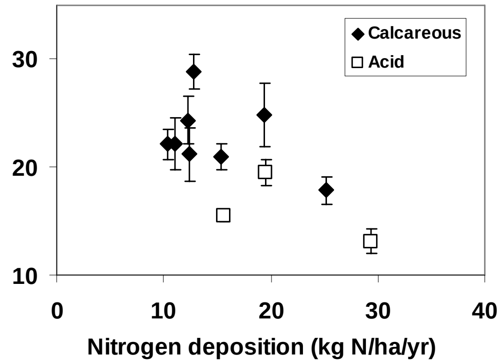
Emissions of nitrogen oxides and ammonia can lead to N enrichment (eutrophication). These problems can result in a loss of biodiversity in sensitive ecosystems because N-loving species benefit at the expense of other species of conservation interest that contribute so much to the character of semi-natural 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.

Current evidence for air pollution effects in sand dunes

Although physical processes, hydrology and succession have been extensively studied in sand dunes, research into air pollution effects in sand dunes is limited. A review on the effects of N deposition on sand dune habitats concluded that they were likely to be at risk of eutrophication. The greatest impact is likely to be on the early successional communities which are important for many of the sand dune rarities.

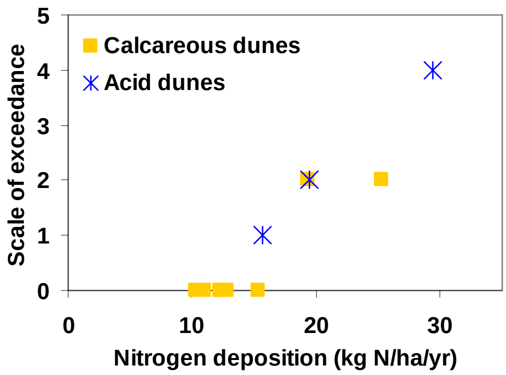
A survey approach of UK sand dunes along a gradient of N deposition showed significant correlations of vegetation, soil and groundwater parameters with increasing N deposition (Jones *et al*. 2004). In semi-fixed (open) dune habitats, cover of marram grass (*Ammophila arenaria*) and total biomass increased. In fixed dune grasslands, plant species diversity decreased (Figure 4) and biomass increased. Soil parameters showed surprisingly that the C:N ratio increased and available N decreased. Dissolved organic nitrogen (DON) concentrations in groundwater also increased. Experimental evidence from sand dune mesocosms in the Netherlands has shown an increase in cover of grasses and sedges and a decline in herbaceous species with increased N deposition (van den Berg *et al*. 2005). As a result of UK and Dutch studies, the suggested critical load range for sand dunes is 10 – 20 kg N ha^{-1} yr^{-1} (Figure 5).

Figure 4. Species richness, fixed dune grassland



Nitrogen retention in sand dune soils is poor, due to the low levels of organic matter. Nitrogen addition experiments in the Netherlands showed that leaching of N varied from 0 - 70 % of inputs (ten Harkel *et al.* 1998). A UK study under ambient N deposition, showed that total leaching losses of N varied from 15 – 65 % of inputs, mainly as DON. Losses were lowest in ungrazed vegetation on calcareous soils and were highest in rabbit grazed vegetation (Jones *et al.* 2005).

Figure 5. Critical load exceedance



Although much N is lost through leaching, enough is retained to cause adverse effects. An N manipulation experiment at Newborough Warren in North Wales (Plassmann, 2006) has shown that even low additions of N (within the critical load range) result in significant accumulation of N within the moss layer, which will be released to the rest of the soil-plant system as those moss shoots die. Phosphorus limitation is common in many UK dunes and may reduce vegetation responses to excess N deposition. However, as soil pH approaches pH 5, phosphorus becomes more available to plants, thus increasing the likelihood of adverse impacts of N deposition in more acidic systems.

In UK dunes, the main impact of N is that of eutrophication, and acid dune systems appear to be more sensitive to N inputs than calcareous dunes (Figure 5). Soil acidification as a result of acid deposition has relatively little impact in UK dunes because sand dune soils are generally well-buffered, with the exception of the few acidic dune systems. However, in the Netherlands where the sand usually has a lower initial carbonate content, both acidification and eutrophication have resulted in a decline of rare pioneer species in dune slacks sensitive to acidification (Sival & Strijkstra-Kalk, 1999).

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

Management can be used to mitigate the effects of N deposition. Both mowing and grazing tend to increase species diversity, and mowing (with removal of cuttings) removes N from the system. Managed grazing is frequently used to reduce the vigour of competitive species and to retain species of conservation interest. Natural grazers such as rabbits also play a key role, but need to be managed in conjunction with conventional grazing to allow for natural population fluctuations. Although the net removal of N by grazers is almost negligible, over an extended period of time rabbit grazing effectively reduces the soil N pool by slowing the rate of organic matter accumulation compared with ungrazed habitats. More extreme management (turf-stripping or topsoil inversion) can be used to remove nutrient-rich surface layers and re-create earlier successional habitats.

The effects of climate change and interactions with air pollution are uncertain. In many areas sea-level rise will result in loss of sand-dune habitat, and the corresponding rise in water table will increase the depth and extent of dune slacks. Early successional habitats, already impacted by N deposition, are most at risk. Climate change may increase or decrease mobility of dune systems, depending on the balance of rainfall, storminess, wind direction and wind speeds, and rising temperatures may affect the ranges of key 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

- NEGTAP (National Expert Group on Transboundary Air Pollution), 2001. Transboundary Air Pollution: Acidification, Eutrophication and Ground-Level Ozone in the UK. ISBN 1 870393 61 9. Available online at: http://www.nbu.ac.uk/negtap/
- Countryside Survey 2000 –http://www.cs2000.org.uk/
- Preston, C.D., Pearman, D.A. & Dines, T.D. (eds), 2002. *New Atlas of the British and Irish Flora.* ISBN: 0198510675
- Haines-Young, R., *et al.*, 2003. Changing landscapes, habitats and vegetation diversity across Great Britain. *Journal of Environmental Management*, **67**, 267-281
- Air Pollution Information System http://www.apis.ac.uk/

Key references

- Jones, M.L.M. *et al.*, 2004. Changes in vegetation and soil characteristics in coastal sand dunes along a gradient of atmospheric nitrogen deposition. *Plant Biology* **6**, 598-605.
- Jones, M.L.M. *et al.*, 2005. *Determining a nitrogen budget for Merthyr Mawr sand dune system*. Final Report for CCW.
- Plassmann, K., 2006. *Effects of grazing and nitrogen deposition on sand dune systems.* PhD Thesis, Bangor University
- Sival, F.P., Strijkstra-Kalk, M., 1999. Atmospheric deposition of acidifying and eutrophicating substances in dune slacks. *Water Air and Soil Pollution* **116**, 461-477.
- ten Harkel, M.J. *et al.*, 1998. Water and solute fluxes in dry coastal dune grasslands: the effects of grazing and increased nitrogen deposition. *Plant and Soil* **202**, 1-13.
- van den Berg, L.J.L. *et al.*, 2005. Effects of nitrogen enrichment on coastal dune grassland: A mesocosm study. *Environmental Pollution* **138**, 77-85.

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