Natural England.
Appendix 10 to Ex 2 MATTON 14

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Interpretation of evidence of nitrogen impacts on vegetation in relation to UK biodiversity objectives
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4.5 Management options to reduce the future impacts

It has long been recognised that management may affect the sensitivity of ecosystems to N (UBA 2004). Management, in particular the removal of biomass, litter and nutrient elements by grazing or cutting, is known to strongly affect the relative competitive ability of species. Thus even under relatively large rates of N deposition, appropriate management can reduce the competitive advantage of fast- and tall-growing species and consequent loss of small growing species (Bakema *et al* 1994). Examples of approaches include: increased grazing pressure to reduce the expansion of nitrophilic species, increased removal of above-ground biomass or top soil and thus N, topsoil inversion in neutral grassland to relocate soil N to below the main rooting zone and canopy removal to increase light levels.

Many management processes result in the direct export of N thus slowing the rate of N accumulation which over time leads to change in ecosystem structure and function. The amount of N removed in standard management practices have been calculated as part of one method for calculating critical loads for a range of habitat types. This approach (called the Steady State Mass Balance Method) aims to estimate the amount of N which can be stored in different components of the ecosystem without causing ecosystem change. The calculation also allows for removal of N under what is considered non-damaging conditions. Values are derived from studies where biogeochemical studies have quantified N pools and fluxes in systems considered undamaged by N deposition. The methods for the calculation in the UK are consistent with the UNECE Mapping Manual (UBA, 2004), although wherever possible model inputs are based on UK data from UK databases or site-based studies. Examples of values include: removal of N by tree harvesting in deciduous woodlands (30 kgN/ha/yr) and managed coniferous woodlands (15 kg N/ha/yr); heathland, acid grassland, montane and bogs management (3 kgN/ha/yr); unmanaged woodlands (0 kgN/ha/yr) and calcareous grassland management (51 kgN/ha/yr) (Hall *et al* 2003). Whilst values in excess of this can be reported for fertilised or high deposition areas, these are the values considered appropriate and sustainable for non-impacted systems. As can be seen, with the exception of calcareous grassland and woodlands, these values are generally small relative to deposition values for much of the UK. Thus the level of management required to significantly mitigate inputs of N ca.5-10 kgN/ha/yr (variable depending on habitat) may be greater than normally recommended for the maintenance of features of interest. This is particularly relevant for nutrient poor upland habitats such as heathland and acid grassland.

Many studies which have recommended increased intensification of management have failed to monitor the impacts on the full range of species and functions but rather focussed on dominant species and measures such as nitrate leaching (e.g. Hardtle *et al* 2006). This can result in conflicts as a result of the management requirements of different taxa. For example, mowing and grazing increase the plant species richness of abandoned calcareous grasslands, whereas the maintenance of diversity of the insect community might depend on allowing areas of taller vegetation or scrub (Bakker and Berendse 1999). There are now several UK studies which suggest there is a risk that the level of management required to remove sufficient N or control competitive species will in itself be damaging to the features which are desirable to protect e.g. lichens and dwarf shrubs. One example of this is

available for an acid grassland site where the levels of grazing required to remove N to any significant extent caused a decline of desirable species (Emmett *et al* 2004). Indeed, inappropriately intense levels of management are thought to have contributed to damage observed for several habitats initially assigned solely to N deposition e.g. *Racomitrum* heath, calcareous grassland and heathland (as cited in Negtap 2001). Therefore, it is important to be clear about the conservation objectives and targets, so that appropriate management practices can be implemented. This will prevent the tendency for the management practices themselves to become the conservation goal, rather than the community being restored.

In more nutrient-rich lowland habitats such as hay meadows and calcareous grasslands, offtake rates will help to reduce the accumulation of N. However, it should be recognised that any biomass removal involves the removal of other nutrients such as base cations and phosphorus. In acid-sensitive systems increased intensity of management and accelerated removal of base cations could result in increased risk of acidification and phosphorus deficiency both of which have been clearly demonstrated in experimental and gradient studies (RoTAP in prep).

When considering more intensive management options in severe cases of N enrichment which involve the removal of top soil, the composition of the seed bank needs to be considered as many seed banks include non-target species and those with a wide ecological amplitude (Bakker and Berendse 1999). As these authors point out, the areas with the greatest potential for restoration are those with a short history of N deposition (similar to restoration following agricultural intensification) but it requires reduced ongoing N inputs to occur in tandem. Hence, for successful restoration management of most plant species and plant communities, an overall strong decrease of atmospheric deposition is a prerequisite. Measures to achieve this objective can be successful only when they are taken at a national or European scale (Bakker and Berendse 1999).

There are no known management options for reducing the direct effects of ammonia critical levels on vegetation but an awareness of the highly variable spatial nature of ammonia deposition at a 1km scale and exploitation of the potential scavenging effect of some vegetation such as tree shelter belts (Theobald *et al* 2001) are both tools which may help reduce damaging effects of N deposition at a local scale. However, care needs to be taken to manage any buffer or shelter belts to ensure N scavenged from the atmosphere, thus protecting target vegetation, does not just transfer to soils and freshwater systems (e.g. capture by tree canopy leading to enrichment of the soil and increased nitrate leaching).

In summary, management clearly provides some protection to semi-natural systems when applied at appropriate intensities. However, there is risk of conflict between different conservation targets, and many management options put in place will be compromised if ongoing N deposition remains above the critical load. The desired outcome may be: (a) management options for restoration with an agreed end point, (b) ongoing management to offset continuing chronic inputs of N and/or (c) management options to reduce N transfers. Further theoretical, experimental and modelling work could help understand the interlinkages between management options proposed for single issues such as N deposition to ensure a whole ecosystem approach i.e. covering all ecosystem services and the interaction with other drivers of change such as climate change. Managing for any single issue (e.g. carbon, N, acidity or biodiversity) or for any single driver of change in isolation may result in unintended and undesirable outcomes. Ultimately, a reduction in emissions and deposition of N is the most desirable approach due to the absence of unintended consequences.

Such an approach would stop further accumulation of N and thus protect areas where accumulation levels have not resulted in species change to date. In areas where species change has already occurred, the approach will minimise further species change or loss as indicated by the different thresholds for species above the critical load indicated in Tables

4.2-4.5. The figures in Stevens *et al* (2011) indicate an increasing number of species being protected for every kilogram of N deposition removed in the long term. It is likely recovery back to pristine conditions, or at least a less N-enriched state, will be slow due to the difficulty of removing N from the soil pool, but N is likely to be stored in more unavailable stores over time and ongoing leaching will reduce the N stored to some extent. However, there are few experimental studies to enable this to be quantified. Modelling approaches are being developed which provide information on rate of change of habitat suitability, but dispersal and other factors then have to be factored in. Currently, there are no reliable estimates of recovery rates for the four habitats which are the subject of this report, although the limited experimental evidence available suggests bryophytes and lichens are likely to be the fastest to respond, as well as a reduction in nitrate leaching (Emmett *et al* 2004; Mitchell *et al* 2004; UKREATE 2007; UKREATE 2010).