A FLUX-EFFECT RELATIONSHIP FOR ABOVE- AND BELOW-GROUND IMPACTS OF OZONE ON TWO SEMI-NATURAL GRASSLAND SPECIES

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Ranunculus acris and *Dactylis glomerata*, which are both common components of UK grasslands, were established in two-species communities in 14 litre pots filled with topsoil. Communities were either well-watered or reduced-watered and were exposed to eight ozone treatments in solardomes for 20 weeks, using an upland rural profile based on ozone concentrations in Snowdonia. In addition to the current background treatment, with a 24h mean ozone concentration of 34 ppb, there were six treatments with incremental additions to this profile, up to a maximum 24h mean ozone concentration of 90 ppb, and one treatment with a reduction in ozone concentration, with a 24h mean ozone concentration of 16 ppb. Stomatal conductance measurements were made on both species using a porometer (AP4, Delta-T) over a range of environmental conditions.

A stomatal conductance model was developed for each species using a Jarvis-type multiplicative approach. A strong relationship between stomatal conductance and soil water content was shown for both species, with *Ranunculus acris* maintaining stomatal conductance rates at lower soil water content than *Dactylis glomerata*. For *Dactylis glomerata* there was an increase in senescence with increasing ozone concentration, and the flux model indicated that differences in the extent of senescence between the reduced -watered and well-watered plants were related to differences in ozone flux (r^2=0.66). There was not a clear relationship between either ozone concentration or ozone flux and senescence (or visible injury) for *Ranunculus acris.*

The total biomass of *Dactylis glomerata* decreased with increasing ozone concentration, with the total biomass lower in the reduced-watered plants compared to those which were well-watered. The flux model indicated that differences in biomass between the reduced- and well-watered plants for a given ozone treatment were related to differences in ozone flux, with a linear relationship between ozone flux and total biomass (r^2=0.90). There was not a clear relationship between either ozone concentration or ozone flux and biomass for *Ranunculus acris* as this species was less sensitive to ozone. In both *Dactylis glomerata* and *Ranunculus acris*, reduced-watered plants had a greater root biomass compared to well-watered plants. Whilst root biomass increased with increasing ozone concentration for the less sensitive *Ranunculus acris* (r^2 = 0.7), there was a large decrease in root biomass with increasing ozone flux for *Dactylis glomerata* (r^2=0.88). Again, the flux model indicated that differences in biomass between the reduced- and well-watered plants were related to differences in ozone flux. Regardless of direction of effect, the roots were more sensitive to ozone than the shoots for both species.

These results highlight the importance of soil moisture as a modifying factor in the determination of flux-effect relationships. *Dactylis glomerata* showed negative effects on senescence and biomass (especially roots) with small increases in background ozone concentration and may even be affected by current UK ozone concentrations. In contrast, the less sensitive *Ranunculus acris* did not show a clear relationship between senescence or total biomass with either ozone concentration or flux.

This study has relevance for Defra policy as:

- Significant effects of ozone were found with small increases in background ozone concentration
- Differences in response of reduced- and well-watered *Dactylis glomerata* to ozone were explained by differences in ozone flux.
- Increasing background ozone reduced the capacity of plants to store carbon below ground; has the potential to further increase atmospheric CO_2 concentration .

- We wish to thank Defra and NERC for supporting this study

DEVELOPMENT AND PROVISIONAL EUROPEAN APPLICATION OF A MULIT-LAYER GRASSLAND OZONE FLUX MODEL

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The existing DO_3SE[1] grassland flux model was used to develop a framework for a multi-layer canopy model version. The introduction of five canopy layers allowed for the incorporation of variable LAI fractions, light penetration and O_3 concentration in assessments of O_3 flux to canopy components. The model was parameterised for productive grasslands based on two species (*Lolium perenne* and *Trifolium repens*) representing grass and legume plant functional types using available primary and secondary European data. The influence of N supply on O_3 flux was considered predominantly through variations in parameterisation of LAI and g_{max}. Attempts to use the model to derive reliable flux-response relationships proved difficult due to the limited number of appropriate experimental datasets. However, this work was important in identifying the need for modellers to work closely with experimentalists to ensure that data necessary for model parameterisation is collected during experimental studies.

A provisional application of the model was made at the European scale; results emphasised the potential of this modelling tool in enabling comparison of seasonal profiles of modelled canopy stomatal flux (Fst); accumulated stomatal flux (AFst) and AOT40 for climatically divers locations across both the UK and Europe. The effects of simulated management cuts are clearly apparent in the periodic instances of reduced Fst. While the model provided values of total O_3 deposition and surface resistance in the expected range, a thorough evaluation is required before a reliable application of the model could be made at the UK or European scale for policy formulation. However, the provisional modelling highlighted the importance of LAI both as a seasonal driver of total stomatal O_3 flux and deposition, as well as a key determinant of flux to different species within the canopy. Since this variable will be affected by factors such as soil water, management and N fertilization, future applications of the model will require a clear definition of the productive grassland system under investigation.

This study has relevance to Defra policy as:

- The development of this model allows an improved process based understanding of the threat that O_3 may pose to ecosystems in the UK
- The model allows for other factors such as enhanced N deposition and climate change to be considered in determining how O_3 impacts on grassland ecosystems may change in the future.

[1] DO_3SE: Deposition of Ozone and Stomatal Exchange Model

CHEMICAL OZONE REACTION ON LEAF SURFACES IDENTIFIED USING A NOVEL STABLE ISOTOPE APPROACH

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This study has relevance to Defra policy as:

- The novel stable isotope approach presented here identified the fate of ozone into cuticular waxes of leaf surfaces for the first time. Such direct measurements can inform parameterisation of non-stomatal ozone deposition onto leaf surfaces in ozone deposition models.

Tropospheric ozone poses a significant threat to crop yield, forest productivity and ecosystem carbon storage. Risk assessment of ozone impacts on vegetation is essential, since background ozone concentrations are expected to increase further during the next decades. A model (DO_3SE) has been developed to quantify and predict ozone deposition and stomatal flux, but some of its components, including non-stomatal deposition to leaf surfaces, are severely limited by current knowledge. A new approach with isotopically labelled ozone was applied[1,2] to trace ozone and its derivatives directly into leaf surfaces.

Garden pea (*Pisum sativum*, wildtype 406N) and a reduced wax layer mutant (*wel/wel* mutant 406G) grown in pots were exposed to 100 ppb ^{18}O labeled ozone for 10 hours during the photoperiod in an environment controlled chamber. The accumulation of ozone-derived ^{18}O, total wax content and composition of cuticular waxes of upper and lower leaf surfaces were determined. Significant ^{18}O-enrichment in cuticular waxes indicates that ozone deposition to leaf surfaces does not only result from physical degradation and reaction with biogenic volatile organic compounds (BVOCs), but also from chemical reaction of ozone with waxes in the cuticle. Estimates of non-stomatal ozone deposition velocity onto leaves based on these measurements will be compared to values reported in literature, and the implications for ozone models will be discussed.

[1]Subke *et al.* (2009). Rapid Commun. Mass Spectrom. DOI: 10.1002/rcm.3961
[2]Toet *et al.* (2009). New Phytol. DOI: 10.1111/j.1469-8137.2009.02780.x

HOW DOES RESOURCE AVAILABILITY AFFECT PLANT RESPONSE TO OZONE ?

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Despite a global increase in the rate of nitrogen deposition over the past several decades, growth of plants in many natural habitats is still primarily limited by low levels of soil nitrogen availability. However, experiments aimed at assessing the impact of tropospheric ozone on plants and plant communities typically use soils with high levels of nutrients and/or fertiliser additions. Since nutrient availability will affect productivity, metabolism and resource allocation, it is reasonable to expect that differing levels of nutrients, in particular nitrogen, will affect plant and ecosystem level response to ozone. Indeed, the few studies which have looked at this have provided some evidence that the magnitude of ozone effects is influenced by soil nutrient status.

During the past two years, we have carried out greenhouse and open top chamber experiments to test the hypothesis that soil nutrient limitation will exacerbate the effect of ozone on plant physiology and growth. The greenhouse study involved two levels of ozone (filtered air and 90 ppb) and two levels of soil fertility. Single species pots *of Circium arvense, Centaurea nigra, Holcus lanatus* and *Trifolium pratense* were exposed to ozone treatments 8 hours each day over a 40 day period. Results show a significant negative effect of ozone, and a positive effect of N, on biomass for all species except *H. lanatus*. This species had lower above- and below-ground biomass in ozone (compared to filtered air) at high N levels (-12.5%, -50%, respectively), but a higher biomass in O_3 at low N (+72% aboveground, +40% belowground). A similar interaction between ozone and nitrogen treatments was also seen for above-ground biomass in *T. pratense*, with a greater proportional reduction at high N.

A seven week ozone exposure experiment was carried out in a new Open Top Chamber Facility at Silwood Park, during summer 2008. Mixed (and single) species pots of *Plantago lanceolata, Trifolium pratense, Agrostis capillaries, Rumex acetosella, Lotus corniculatus* and *Festuca rubra* were exposed to four different target concentrations (filtered air, 40, 70 and 100 ppb). Pots were watered weekly with Hoaglands solution (with N additions of 0 or 50 kg ha^{-1} over the growing season). Preliminary results suggests that the detrimental effects of ozone may be greater at high nutrient levels. Although evidence from the literature is conflicting, the response to ozone of some plant species is clearly affected by soil nutrient availability.

Policy relevance:

- Plant community response to changing patterns of ozone exposure will depend on soil nutrient status
- Nitrogen deposition is likely to modify the effects of ozone on plant communities and ecosystem function

MODELLING SOIL MOSITURE TO DETERMINE OZONE FLUX TO EUROPEAN FOREST TREES

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The DO_3SE (Deposition of O_3 for Stomatal Exchange) model is an established tool for estimating ozone (O_3) deposition, flux and impacts to a variety of vegetation types across Europe. The DO_3SE model has been embedded within the EMEP photo-chemical model to provide a policy tool capable of relating vegetation damage to different O_3 precursor emission scenarios for use emission policy formulation. A key limitation of flux based risk assessments has been the necessary assumption that soil water deficits are not limiting O_3 flux; this was due to the unavailability of a rigorously evaluated method of modelling soil water deficits and their influence on stomatal conductance. Although this is not such an issue for agricultural crops where irrigation is common across Europe, it has posed serious limitations to the estimate of O_3 flux to forest trees.

This paper describes the continued development and evaluation of a method to estimate soil moisture and its influence on stomatal conductance for a variety of forest tree species that have recently been identified and parameterised for flux modelling to provide climatically relevant estimates of flux to this vegetation group across Europe. The soil moisture module uses the energy balance methods of the Penman-Monteith model to drive water cycling through the soil-plant-atmosphere system and empirical data describing stomatal conductance relationships with soil water status to estimate the biological control of transpiration. The module is parameterised for four different soil textures (sand, loam, silt loam and clay loam) according to their soil water holding characteristics.

The method has been evaluated against field data describing a variety of soil water parameters and stomatal conductance for Norway spruce, beech and Holm oak collected from 5 sites across Europe (extending from Scandinavia, through central Europe to the Mediterranean). Modelled estimates of soil moisture show a good agreement with observed data, with the timing and magnitude of soil drying events being captured well across all sites. Estimates become less accurate where the soil dries beyond the parameterised values. Sensitivity analysis shows that O_3 flux is most sensitive to changes in maximum stomatal conductance and rooting depth. These results suggest that this new module is capable of providing reasonable estimates of soil moisture and the subsequent influences on stomatal conductance and hence O_3 flux and risk for forest trees across Europe.

This study has relevance to Defra policy as:

- Tropospheric O_3 affects tree growth and subsequently forest community composition and biodiversity. Accurate flux modelling will aid the quantification of these impacts.
- O_3 deposition to forested ecosystems will affect atmospheric concentrations and air quality. Understanding O_3 deposition processes, particularly during drought conditions when ambient O_3 concentrations will tend to be higher, will be important for accurate estimates of air quality.

PAST, PRESENT AND FUTURE TROPOSPHERIC OZONE

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Tropospheric ozone is a ubiquitous global air pollutant, threatening human health and vegetation. Recent work[1] attributes 50,000 premature mortalities per year to current levels of European ozone, with the majority of deaths occurring outside Europe. One estimate[2] of global economic losses related to ozone damage to crops, pasture and forests over the 21st century is $8 trillion. Ozone is also a greenhouse gas, with increases in its concentration since 1750 causing a radiative forcing of about 21% of that from increases in CO_2. Policymakers are understandably keen to control ozone. Ozone has a lifetime of days to weeks, similar to many meteorological processes, including mid-latitude circum-hemispheric transit times. Consequently, ozone is strongly influenced by the weather and undergoes long-range transport. Ozone is not directly emitted, but forms by photo-oxidation of carbon monoxide and volatile organic compounds, catalysed by nitrogen oxides. Ozone's precursors have a variety of natural and anthropogenic sources, and the chemistry of its production and loss is complex. Downwards transport from the stratosphere is an important source of tropospheric ozone. Ozone strongly interacts with the biosphere – its major boundary layer sink is deposition to vegetation. To understand and explore the controls on ozone, we need models that include all these processes. Over the last 10-15 years, several groups around the world have developed such models, and there have been various international efforts to intercompare and evaluate global models (e.g., OxComp, ACCENT, HTAP, AC&C). I will summarise the progress made and the future outlook.

[1]Duncan et al (2008) The influence of European pollution on ozone in the Near East and northern Africa, Atmos. Chem. Phys., 8, 2267-2283
[2]Felzer et al. (2007) Impact of ozone on trees and crops, Comptes Rendus Geosciences, doi:10.1016/j.crte.2007.08.008

MECHANISMS OF EFFECTS OF ELEVATED OZONE EXPOSURE ON CARBON CYCLING PROCESSES IN TEMPERATE WETLANDS.

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This study has relevance to DEFRA policy as it links the major greenhouse gases carbon dioxide, methane and ozone, and how ozone may affect greenhouse gas sources and sinks in wetland ecosystems.

Background concentrations of ozone are predicted to increase over the next 50 years as worldwide emissions of ozone precursor compounds increase. Previous research has shown that elevated ozone has the potential to change plant growth and carbon cycling regimes in upland peat bogs which are considered to be an important sink for carbon dioxide. This study aimed to examine the mechanisms behind ozone-induced changes in carbon cycling through the use of ozone exposure of intact peat mesocosms in solardomes and $^{13}CO_2$ labelling of the mesocosms to trace carbon flow through the system. The potential methane production and consumption capacity of the peat were measured using laboratory based assays.

Since analysis of data was ongoing at the time of submission of this abstract, it is not possible to summarise results here. Latest results will be shown in the presentation.

COMBINED EFFECTS OF DROUGHT AND INCREASING OZONE ON SEMI-NATURAL UPLAND VEGETATION

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Dactylis glomerata and *Ranunculus acris* communities were exposed to well- and reduced-watered conditions together with increasing background ozone concentrations in the solardomes at CEH Bangor for 20 weeks during the summer of 2008. The eight ozone exposure treatments used followed a mean upland rural weekly profile from Snowdonia with incremental decrease of -20 and incremental increases of 12, 24,36,48,60 and 72 ppb, giving a mean ozone range of between 16 - 90 ppb for the season. The communities were cut back to 7cm at the end of week 12 to simulate a hay meadow cut.

Pre-harvest senescence was assessed visibly during weeks 1, 2, 4, 8, and 12 for both species. *Dactylis glomerata* showed a steady increase in senescence with increasing ozone exposure, with maximum senescence occurring in week 12. There was a less strong relationship between increasing ozone and ozone injury/senescence in *Ranunculus acris*, with maximum damage occurring between weeks 4-8, and some recovery apparent in week 12.

Stomatal conductance measurements were obtained throughout the season, under similar climatic conditions, using a Delta-T (AP4) porometer. The combined effects of increasing ozone and drought appear to have a direct effect on stomatal conductance with increasing ozone reducing the ability of plants to close their stomata under stress conditions. This trend was more apparent in *D. glomerata* than *R. acris*.
When severe water stress was imposed on non-senesced leaves from both species, leaves exposed to increasing ozone were less able to close their stomata in comparison to leaves exposed to current background levels suggesting that hormonal signalling, predominately ABA, may be being disrupted.

When exposed to high (70 ppb +) levels of ozone, abscised leaves fed with ABA were unable to restore stomatal functioning. This may be due to inhibition of ABA signalling and/or mechanical damage of the stomatal complex

Future work will include a detailed analysis of the mechanisms of injury by considering the role of ABA, ethylene and pH in influencing stomatal functioning under well- and reduced-watered conditions.

This study has relevance for DEFRA policy as:
Increasing background ozone may impair stomatal functioning reducing the ability of plants to respond to drought

* We are grateful to Defra and NERC for supporting this study

ASSESSING THE IMPACT OF GROUND LEVEL OZONE (O_3) ON CROPS IN SOUTH ASIA

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Experimental studies have indicated that current day surface O_3 concentrations in south Asia frequently result in yield losses of up to 30% for sensitive crops (e.g., wheat, rice, legumes). Modelling studies have also shown that the time of the year when O_3 concentrations are highest (March to July) coincides with the growing season of many important crops in this region. These studies also show that these high O_3 concentrations (of up to 70 ppb 7-hour growing season mean) are common across the Indo-gangetic plain region which is one of the most important crop growing regions in the world. Future global emission projections indicate that south Asia may become the most O_3 polluted region in the world by the 2030s.

This paper describes a provisional risk assessment for South Asia to estimate economic crop losses associated with ambient O_3 concentrations. Crops yield losses resulting from ground level O_3 were estimated using concentration-based dose-response indices characterizing O_3 dose as either (M7) or accumulated above a threshold of 40 ppb (AOT40) concentrations. The results indicate substantial yield losses across some parts of the region (e.g. for wheat, yield losses ranged from ~ 1 % to 60 %) with an average yield loss of ~ 10 % for the entire region, these results are comparable to the experimental evidence collected in South Asia. These yield losses were converted into production losses (based on FAO crop production statistics) from which economic losses were estimated in relation to the crop commodity price. Economic losses for South Asia were estimated to be in the region of US$ 4 billion per year for 4 staple crops (wheat, rice soybean and potato) with India suffering the greatest loss of ~ US$ 3 billion. The largest losses were found in the agriculturally important Indo-gangetic plain where the implications of these economic losses for food security need careful consideration.

In view of this future work will consider how O_3 induced changes in supply will affect both consumer- and producer-crop price and implications for agricultural livelihoods and consumer accessibility to nutritionally important foodstuffs. Work will also concentrate on developing flux based methods for yield loss assessment, extending the use of flux models developed in Europe to South Asia through the parameterisation of these models for wheat growing under South Asian (and specifically Indian) conditions. This parameterisation is being developed with a view to incorporating a module capable of estimating leaf level O_3 flux into an existing photo-chemical oxidant model MATCH to assess the yield losses resulting from O_3 flux to wheat in India.

This study has relevance to Defra policy as:

- This would aid Defra's participation in the Global Science and Innovation Forum (GSIF), as a part of the strategic framework to improve the coordination of the UK's engagement in international science and innovation.

TWENTY YEARS OF NITROGEN ADDITION TO AN UPLAND HEATH: WHAT HAVE WE LEARNED?

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As part of a NERC thematic programme on air pollution, a nitrogen fertilisation experiment was started in May 1989, under the guidance of Professor John Lee, on heather moorland near Ruabon in north Wales. The original aims were to examine the changes in growth, nutrition and physiology of heather plants in response to monthly additions of ammonium nitrate solutions. However, within a few years we became interested in wider aspects of community structure and ecosystem properties and results of the project started to be useful in informing the European critical loads guidelines for heathlands. The initial experiment expanded in 1998 with establishment of a lot more larger plots to include phosphate treatments and later on to explore the consequence of stopping nitrogen additions. This important experiment has survived this long due to a string of funding from NERC and Defra and the University but most importantly because of the enthusiasm and hard work of a series of exceptional PhD students and post-doctoral researchers to whom this talk is dedicated.

This study has relevance to Defra policy as:

- Nitrogen speeds up the heather growth cycle
- Nitrogen makes plants more vulnerable to climate stress
- Bryophytes and lichens are most seriously affected by Nitrogen
- Availability of phosphate interacts strongly with impacts of Nitrogen
- Burning management can have beneficial effects on the community but might cause increased nitrogen leaching

IT ISN'T EASY BEING GREEN: INVERTEBRATES, PLANTS AND POLLUTION IN URBAN GREEN SPACES

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This investigation looks at invertebrates, with particular focus on carabids and woodlice, and plants in urban green spaces in Bracknell, Berkshire, UK. The UK population is rising and more people are moving into urban areas. Thus as urbanisation increases urban green spaces may be the last reserves for biodiversity. Monitoring of vehicle emission levels, in urban areas in particular, is vital to allow predictions of change in vehicle pressure. Nitrogen dioxide (NO_2) is used in this investigation as a surrogate for vehicle emissions. NO_2 has been shown to influence plants, plant communities and invertebrates but other factors (including management, site age, fragmentation, surrounding land use and traffic density) also have important impacts. There are also significant difference in numbers and responses to different factors of plants and invertebrates away from the road edge. NO_2 levels commonly exceed critical levels in urban areas and this has important implications for conservation and human health. Urban green spaces clearly make a valid contribution to the ecological value of an area but are constrained by human influences. These results will be used to provide simple management recommendations to Local Authorities to improve and/or optimise green spaces for biodiversity.

Defra environmental policy relevance:

- This research highlights the value of urban green spaces as biodiversity reservoirs in built up environments.
- Information on the effects of roadside proximity and habitat management on plant and invertebrate communities can inform policy decisions on traffic management, pollution targets and management practices for the protection of urban biodiversity.

CHANGES IN FLORA OF CALCAREOUS GRASSLANDS IN UK

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Calcareous grasslands are floristically very rich ecosystems. These grassland ecosystems are generally N and P limited and found sensitive to increased N input. In this study we report on a vegetation survey undertaken in 2007-2008 on 40 calcareous grassland plots throughout the UK. We compare our results with a previous survey from the same plots from the period 1990-1993. In addition we will discuss the results of >100 plots from the 1990-1993 survey.

This study seeks to find evidence of impacts of nitrogen deposition in the field on (a) the lichen and bryophyte species composition and (b) the vascular plant species composition of calcareous grasslands. In addition we will relate the observed patterns and shifts in species composition to soil conditions and management using structural equation modelling. This will allow us to extract causal and non-causal effects on changes in species composition and loss of species.

NITROGEN DEPOSITION EFFECTS ON A MEDITERRANEAN ECOSYSTEM OF CENTRAL SPAIN: PRELIMINARY RESULTS OF A LONG-TERM FERTILIZATION EXPERIMENT

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We show preliminary results of a N fertilisation experiment on a kermes oak (*Quercus coccifera* L.) scrubland in Central Spain. After 18 months simulating N deposition according with 4 different future scenarios (0, 10, 20 and 50 Kg N. ha^{-1} yr^{-1} over background deposition) any change in moss or lichen cover has been detected. Neither the shrub *Rossmarinus officinalis* L. showed changes in growth or productivity associated with the treatments. However, lichens as *Cladonia foliacea* (Huds.) Willd. or *Squamarina lentigera* (Weber) Poelt, and the moss *Pleurochaete squarrosa* (Brid.) Lindb., considered as good indicator species of different natural soil conditions (pH and/or NO^{3-}), could be good candidates to respond to our N treatments. In Autumn 2008, the moss *P. squarrosa* showed a statistically significant increase in the concentration of photosynthetic and accessory pigments (neoxantin, lutein, chlorophylls a and b, total chlorophyll, β carotene/total chlorophyll, and VAZ cycle pigments) ($p < 0.05$) in 50 Kg N. compared with 0 Kg N scenario, while maximum photosynthetic efficiency of PSII (Fv/Fm) of *P. squarrosa*, measured at predawn, was marginally significant related with N deposition treatments (positive linear regression $R^2 = 0.152$; $p = 0.06$). Moreover, we obtained clear evidence of a dose related NO^{3-} accumulation in our field plots ($R^2 = 0.375$; $p < 0.01$), suggesting that our N treatments are susceptible to affect significantly ecosystem dynamics by making N no more longer limiting. Despite the short duration of the experiment, we have some evidences of a rapid response of this typically Mediterranean ecosystem to N addition, mainly through changes in physiological traits of mosses. With this experiment we expect to fill a gap of knowledge of the effects of this global change factor on Spanish Mediterranean ecosystems, which are typically limited by N, and to contribute to a better understanding of ecosystem response to N deposition in a global scale.

LONG-TERM VEGETATION CHANGE ON SNOWDON

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Long-established vegetation provides a sensitive integrated measure of the environment. Currently the effects of long-term environmental change on species composition, diversity and ecosystem functioning are poorly understood.

Due to high levels of precipitation in the uplands and high ionic concentrations in hill cloud, upland areas receive disproportionately large amounts of atmospheric nitrogen deposition compared to lowland areas. Nitrogen is a limiting factor for plant growth in most upland soils and their plant communities are therefore considered to be particularly vulnerable to atmospheric nitrogen deposition. There are many different ecological effects of nitrogen deposition, and these can lead to severe changes in species composition and to loss of diversity.

Snowdon has a long history of environmental research and as such provides an ideal opportunity to investigate the effects of long-term environmental change on vegetation. A repeat of a vegetation survey initially undertaken as part of the IBP Productivity of Grasslands study in 1968 was completed in the summer of 2008.

This study aimed to identify and quantify if any changes had occurred in the vegetation of the survey area. Significant changes in species composition, a loss of species richness and an increase in the grass: forb ratio were found. These results indicate that there may be an increase in the availability of nitrogen in the environment. However, an interaction between increased nitrogen availability and the effect of grazing is suspected to be driving the changes identified.

POLLUTION SWAPPING': FROM NITROGEN TO ALMOST EVERYTHING' .

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Concerns about environmental pollution, and resulting legislation, have tending to focus on single pollutants or issues, e.g. nitrate leaching, the EU Nitrate Limit and Nitrate Vulnerable Zones. Research suggests that policies and practices that focus so narrowly might reduce or solve the focal problem, but result in increases in other pollutants that can be as bad as, or worse than, the initial problem. As an example, the injection of animal wastes into soil to reduce ammonia emissions from surface spreading can lead to increases in nitrous oxide emissions. On a broader scale, farmers encouraged or forced by legislation, to change practice to reduce nitrate leaching may change their crops and practices in such a way as to increase the build up of phosphate in soil and the risk of loss to waters. The talk will present such examples and then broaden the discussion to the wider aspects of agriculture and the environment, including biodiversity. I will argue that integrated, systems-based assessments of land management are needed that facilitate decision making and lead to optimal solutions for sustainable farm systems. Single issue policies and politics must be avoided.

OZONE AND NITROGEN CONTROLS ON CARBON ALLOCATION WITHIN TWO SEMI-NATURAL PLANT SPECIES

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Ranunculus acris and *Dactylis glomerata* were separately exposed to a factorial combination of eight ozone concentrations and two nitrogen treatments in solardomes. Individual plants were established in two litre pots filled with topsoil inoculated with soil from Keenly Fell, Northumberland (an upland calcareous grassland site containing both species). 24h mean ozone concentrations in the domes were 16, 34, 44, 51, 62, 73, 89 and 90ppb. The ambient ozone treatment of 34ppb was based on background ozone concentration in Snowdonia, North Wales, U.K. Nitrogen treatments of 0kg/ha/yr and 75kg/ha/yr in the form of NH_4NO_3 were applied weekly to each plant in tap water.

Above ground assessments of leaf count and senescence in *R.acris* were made over 12 weeks of treatment, A-C_i curves (net CO_2 assimilation rate, A, versus calculated sub-stomatal CO_2 concentration, C_i) were measured in weeks 8 and 13, and a full destructive harvest was completed in week 14. Increasing ozone treatment significantly increased senesced rosette leaf biomass ($p=0.019$), and significantly reduced root biomass ($p=0.001$). The effect of nitrogen treatment was not significant. There was no effect of ozone or nitrogen on the maximum rate of electron transport (J_{max}).

A-C_i curves were measured in week nine of the *D.glomerata* experiment, with a full destructive harvest in week 10. High N treatment significantly increased the biomass of both healthy and senesced above ground material compared to low N plants ($p\leq0.001$ and $p\leq0.01$ respectively), and therefore the total above ground biomass ($p\leq0.001$). A trend for reduced above ground healthy (green) biomass in high ozone and high nitrogen treated plants was apparent, but this interaction was not significant ($p=0.074$). Ozone reduced the biomass of healthy leaves and increased senesced leaf biomass ($p\leq0.01$ and $p\leq0.001$ respectively), but not the total above ground biomass. There was a significant interaction between nitrogen and ozone effects on root biomass ($p=0.017$). The high N treated plants had an enhanced negative response to increasing ozone concentration, although overall root biomass remained greater than the low N plants at the highest ozone treatment. There was no significant effect of nitrogen or ozone on J_{max} and no difference between the N treatments in maximum carboxylation efficiency.

This study has relevance for Defra policy as:

- It has highlighted the importance of studying combined effects of pollutants that commonly co-occur.
- It has shown that two common species of grasslands, *R.acris* and *D.glomerata* responded differently to the combined treatment of ozone and nitrogen, highlighting important potential effects on community composition in natural ecosystems.
- Increased N input has been shown to have synergistic effects on the response of *D.glomerata* to ozone stress and exacerbates ozone-induced reduction in carbon allocation below ground in this species.

* We wish to thank NERC and Defra for funding this PhD study

IS ACIDIFICATION OR EUTROPHICATION RESPONSIBLE FOR DECLINES IN SPECIES RICHNESS?

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An extensive field survey of acidic grasslands along a gradient of atmospheric nitrogen (N) deposition in the UK showed a dramatic decline in plant-species richness with increasing atmospheric nitrogen deposition. Reductions in plant species richness related to N deposition have been observed in a number of habitats including acid grasslands but the mechanisms of this decline have not been fully investigated. This talk presents results of a study testing the hypotheses that along a national gradient of N deposition there is a) an increase in species tolerant of low pH conditions as a result of soil acidification and b) an increase in competitive and nitrophilic species as a result of soil eutrophication.

Using plant characteristics and functional traits we examined changes in vegetation species composition along the gradient of N deposition in the UK. Mean C-S-R (competitor, stress tolerator, ruderal life history strategy) signatures were used to identify the competitive response of plant communities together with Ellenberg N (nitrogen) scores to identify increases in nitrophilic species. Ellenberg R (reaction, pH) scores were used to identify change in response to soil pH together with an index of soil acidity preference developed using regional survey data collected by Sheffield University.

Mean C-S-R signatures showed no significant correlation with N deposition, nor did mean Ellenberg N scores suggesting no change in the balance of competitive species. Ellenberg R scores and the index of soil acidity preference both showed significant relationships with N deposition indicating an increased dominance of acid tolerant species.

These results suggest that soil acidification as opposed to eutrophication and consequent competition between species is predominantly responsible for shifts in species composition and diversity linked to N deposition although the closer correlation between species richness and N deposition than species richness and soil pH suggests that eutrophication still plays a role in controlling vegetation composition. Soil acidification may be leading to reduced nutrient availability and metal mobilisation preventing the effects of N addition being apparent.

SULPHUR SIGNALS IN VEGETATION AND SOILS REFLECT CHANGING ANTHROPOGENIC SULPHUR POLLUTION SINCE 1850

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By measuring S isotopes in a unique archive of soil, herbage and wheat samples from the Rothamsted Park Grass Hay and Broadbalk Continuous Wheat Experiments, we estimated that in the control plots of the two long-term experiments anthropogenic S still accounts for about 25-30% of the S presently stored in the topsoil. The stable isotope signal ($\delta^{34}S$) in the samples reflect the dramatically changing sulphur dioxide pollution over the last 150 years, becoming more negative with increasing S emissions (Zhao et al, 1998, 2003). Measurements of $\delta^{34}S$ in samples in a national coal bank revealed that the negative signal is likely to derive from the coal burned in southern Britain at the time (Zhao et al, 2003). These results indicate that the vegetation samples are excellent records of the past anthropogenic SO_2 emissions at the experimental site where the $\delta^{34}S$ of original soil S was positive and different from that of anthropogenic sources.

Recent structural analyses using synchrotron-based X-ray Near-Edge Spectroscopy (XANES) on humic substance extracts of archived samples from the Rothamsted Park Grass Experiment reveal a significant (R^2=-0.58; P<0.05; N=7) shift in soil organic sulphur (S) forms, from reduced to more oxidized organic S between 1876 and 1981, even though soil total S contents remained relatively constant. Over the last 30 years, a decrease in emissions and consequent S deposition has again corresponded with a change of organic S structures of humic extracts – reverting in the direction of their early industrial composition, but with a lag time of 19 years. The ratio of oxidized-to-reduced organic S in humic substance extracts is now nearly double that of early industrial times at identical SO_2 emission loads (Lehmann et al, 2008). The significant and persistent structural changes in the nature of organic S in humic substances as a response to SO_2 emissions and deposition may have effects on recuperation of soils and surface waters from acidification.

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SPATIAL AND TEMPORAL TRENDS IN HEAVY METAL ACCUMULATION IN MOSSES IN THE UK AND EUROPE

Harry Harmens[1], David Norris[1], Eiko Nemitz[2] and participants of the European moss survey

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The first European moss survey was conducted in 1990/1 and has since then been repeated at five-yearly intervals. The most recent survey was conducted in 2005/6, with mosses collected from over 6,000 sites in 28 countries, including the UK. Samples were collected according to a standardised protocol and concentrations for 10 – 12 heavy metals were determined in the last three years' growth segments. European maps were produced based on the EMEP 50x50 km^2 grid, displaying the mean heavy metal concentration for each cell (Harmens *et al*., 2008).

In 2005/6, the lowest concentrations of heavy metals in mosses were generally found in (north) Scandinavia, the Baltic States and northern parts of the United Kingdom, and the highest concentrations were often found in Belgium and eastern European countries. Antimony concentrations were high in densely populated areas and in eastern European countries with high metal pollution levels.

The decline in emission and subsequent deposition of heavy metals across Europe has resulted in a decrease in the heavy metal concentration in mosses since 1990 for the majority of metals. Europe-wide the concentrations of arsenic, cadmium, iron, lead and vanadium have declined the most (by 45-72%), declines in the concentrations of copper, nickel and zinc were intermediate (20-30%), with no significant reductions being found for mercury (12% since 1995) and chromium (2%). Between 1995 and 2005, the decline in heavy metal concentration in mosses in the UK was generally higher than the decline observed European-wide.

Heavy metal deposition maps for the UK based on the metal concentration in mosses were produced for the years 2000 and 2005 (Ashmore *et al*., 2008) and compared with deposition maps based on the rural heavy metal deposition monitoring network (Fowler *et al*., 2006).

This study has relevance to Defra policy as:

- Identifying hotspots of heavy metal deposition in the UK;
- Monitoring the effectiveness of heavy metal emission abatement strategies.

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CONTINUOUS AND INTEGRATED MONITORING OF RURAL ATMOSPHERIC MERCURY LEVELS IN THE UK.

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This talk will present an insight into the monitoring of atmospheric mercury as part of the DEFRA funded heavy metals project at CEH. This has relevance to DEFRA policy as it is a required component of EMEP (European Monitoring and Evaluation Programme) monitoring, to show compliance with the air quality framework's 4th daughter directive, which obliges member states to assess levels of certain pollutants throughout their territories.

Included will be an overview of the some of the sources and cycling of the different species of mercury in the atmosphere, as well as the sampling and detection methods used for each of the three different mercury species. An outline of the Auchencorth Moss EMEP supersite mercury monitoring system, as well as CEH's rural integrated atmospheric mercury monitoring network will be given, allowing for a presentation through spatial mapping, of rural levels across the UK.

Emphasis will be given to trends in the accumulated data set and a discussion of these trends including; depletion and peak events, natural cycles and likely interaction of the atmospheric mercury with other atmospheric species such as Ozone and SO_2 present in the atmosphere.

MODELLING THE LONG TERM BEHAVIOUR OF HEAVY METALS IN UPLAND CATCHMENTS OF THE UK

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Simulation modelling with CHUM-AM was carried out to investigate the accumulation and release of atmospherically-deposited heavy metals (Ni, Cu, Zn, Cd and Pb) in twelve moorland catchments in the UK, covering ranges of climatic conditions, soil properties and metal inputs. CHUM-AM assumes two soil layers (L1, L2) and a third layer (L3) containing weathering mineral matter. The principal processes controlling heavy metals are competitive solid-solution partitioning of solutes (described with the WHAM speciation model on the basis of the weak-acid functional groups of soil organic matter), chemical interactions in solution (also described with WHAM), and chemical weathering. The model operates on a yearly time-step and is driven by an input file specifying annual amounts of deposition. Heavy metal deposition histories were generated by combining measured data for the last 30 years with information from lake sediment records. Anthropogenic loadings of Ni, Cu, Zn, Cd and Pb were high during the 19th and 20th Centuries, one or two orders of magnitude greater than estimated inputs from background deposition and mineral weathering. The model was calibrated using major solute data (acidification status), then used to predict heavy metal behaviour. Reasonable agreement between predictions and contemporary measurements of soil and water concentrations was obtained for Ni, Cu, Zn and Cd, but minor "tweaking" was required for Pb. The results indicate that weakly-sorbing metals (Ni, Zn, Cd) respond on timescales of decades to centuries to changes in metal inputs or acidification status. More strongly-sorbing metals (Cu, Pb) require centuries to millennia.

This study has relevance to Defra (the main funding source) because it demonstrates that the long-term dynamics of heavy metals can be predicted with reasonable confidence, thereby permitting timescales of response to emission control policy to be assessed.

OMBROTROPHIC PEAT BOGS AS ARCHIVES OF ATMOSPHERIC METAL DEPOSITION: EXAMPLES FROM SCOTLAND

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Human activity has affected metal emissions to the atmosphere on a global scale for several thousand years, resulting in widespread contamination of the environment with toxic metals such as Pb, and on a scale exceeding natural levels by several orders of magnitude, thereby posing a potential threat to both human and environmental health. Ombrotrophic peat bogs offer an opportunity to study the atmospheric deposition and anthropogenic geochemical cycles of many trace metals, as they receive all their water and nutrients solely from the atmosphere by dry and wet deposition. Dated cores from such bogs have proved especially useful as archives of atmospheric Pb deposition, as Pb is essentially immobile in ombrotrophic peat and, more recently, elements such as As and Sb have also received attention. Using the historical trends of atmospheric Pb, As and Sb deposition recorded in four Scottish ombrotrophic bogs over the past 2,500 years, the principles and applications of using peat bogs as archives of past atmospheric metal deposition will be illustrated. The relevance of site-specific conditions and element- and plant-specific differences in initial trapping and retention, as well as the possible limitations that exist for some metals (e.g. Mn, Fe, Zn) due to nutrient cycling and redox remobilisation processes, will be considered. The relationship between relative trends in recent metal deposition records derived for the four Scottish bog sites with moss archive records and direct measurements of deposition and UK emissions will also be discussed.

PROFESSIONAL ISSUES IN ECOLOGY.

Jim Thompson

Executive Director, IEEM

If ecology is to engage with society at large it has to ensure that in common with other professionals such as planners and engineers, it has a proper professional basis to do so. There is an increasing raft of European Union legislation including the Environmental Impact Directive, the Habitats Directive, the Water Framework Directive and the Environmental Liabilities Directive. Such directives and others demand as never before, the skills of professional ecologists to deal with these significant practical conservation issues of the day. There is also increasing interest in ecosystem services and the economic significance of the conservation of biodiversity as evidenced in the recent TEEB report and there may be opportunities as part of the stronger voice for green economics emerging in the aftermath of the current economic crisis. The Institute of Ecology and Environmental Management (IEEM) with about 4000 members has a well established track record in the UK and western Europe in developing training, running seminars, conferences, informing members, providing guidance and, if necessary, disciplining its members if they do not comply with the Code of Professional Conduct. The paper will use the example of IEEM and how it deals with issues such as:

- Professional Status
- Membership Qualifications
- A Code of Professional Conduct;
- Continuing Professional Development;
- Making ecology heard in the wider society;
- Skills – is there a shortage?
- Salaries and conditions for Ecologists;
- Being part of organizations such as the Society for the Environment (SocEnv) in the UK and the European Federation of Associations of Environmental Professionals (EFAEP) on a wider European scale.

POSTERS

SUMMER 2008 ACTIVITIES AT THE OPAL AIR CENTRE

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Air pollution is an issue of global importance and understanding its impacts on the natural environment is one of the biggest challenges facing biologists at the current time. The new OPAL Air Centre at Imperial's Silwood Park campus houses an experimental open top chamber facility for the controlled exposure of plants to air pollutants, particularly ozone. Research activities over the next few years will focus on understanding the impacts of pollution on individual plants, plant communities and important ecological functions.

A seven week long experiment began in July 2008, exposing plants to four different ozone concentrations (filtered air, 40, 70 and 100 ppb) and two levels of nitrogen (N) (0, 50 kg ha^{-1}). The investigation involved phenological, physiological, growth and microbial assessments upon model calcifugous grassland communities. In September 2008, all plant material was destructively harvested and weighed.

Results from the study showed an overall significant reduction of biomass in the mixed community pots, both above and below ground, in response to elevated ozone concentrations. However, the communities' response to greater N availability was less clear; only above ground biomass was significantly increased and there was an indication of greater sensitivity to ozone in some species, but a reduction in others where N was applied. This is likely to have longer-term consequences for plant community composition under future patterns of ozone and nitrogen deposition.

Along with the research activities, a science fun day and Summer School was held in October. Over 300 young people and their families took part in activities with a focus on air pollution and the environment. Attendees who took part in six or more activities were presented with a 'Young Scientist' award. Tours were also conducted around the OPAL air centre and the Centre for Population Biology's Ecotron controlled environment facility.

Policy implications:
This and future studies at the OPAL Air Centre will provide a comprehensive evaluation of the impact of elevated ozone concentrations, in combination with increased nitrogen availability, on calcifugous grassland habitats. These data can then provide information on BAP species and habitats at risk from future pollution scenarios and thus contribute to the evidence underpinning emission reduction policies.

CLIMATE CHANGE IMPACTS ON ECOSYSTEM FUNCTION

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Climate model outputs described in the IPCC 4th Assessment for 2080-2100 predict that rainfall events in South East England will be ~30% lower in summer, ~15% higher in winter, and that summer rainfall events will become less frequent and more intense. Climate change is likely to affect plants and the ecosystem services they provide by inducing water stress. Therefore, my experiment focuses on the direct effects of changing rainfall patterns on plant community interactions and ecosystem functioning, and the consequences of indirect effects of climate-driven changes to plant biodiversity. Ecosystems function more effectively when their species support a diversity of ecological functions, as their varied effects on their environment can complement one another. This can manifest as resilience against perturbations. This experiment involves field manipulation of climate and plant trait diversity to investigate whether diverse plant communities will buffer ecosystem functioning against climate change, and to allow identification of the most vulnerable plant groups and characteristics.

To establish a plant functional diversity gradient, Silwood Park grassland species were grown individually *ex situ* and functional traits, including foliar N content, specific leaf area and biomass were measured. A cluster analysis was then applied to these data to generate three functional groups. The data are grouped into large perennial species, caespitose grasses and annuals, including most legumes.

These functional groups were then selectively weeded from grassland plots to generate all possible combinations of one, two or three groups. This diversity gradient was combined with a climate treatment based on the IPCC rainfall predictions. This treatment was applied using specially designed rain shelters which were either permeable (control) or collected water, allowing for re-application in line with future scenarios. To examine how this diversity modifies ecosystem resilience to climate stress, measures of biogeochemical cycling and vegetation surveys will be carried out in a time series over the next three years.

- This study will demonstrate the role of plant biodiversity in determining ecosystem response to climate change.
- Increased understanding of the relationship between plant functional traits and biogeochemistry will improve the ability of scientists and policy makers to predict and manage the impacts of future climate change on ecosystem functions and services.

AMMONIUM: A MOBILE CATION IN N-IMPACTED SOILS?

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Introduction

Over past decades, emphasis in N deposition impacts research has concentrated on the mobility of nitrate within soils and through soils to surface waters. It is still regarded by most as the key indicator of N saturation in minimally managed soils. In 2004, Research by the Environment Dept. at York showed ammonium to be mobile (up to 0.21 mg of N /l) in upland sub-catchments of the R. Etherow under high discharge conditions. This prompted us to test the hypothesis that ammonium is more mobile in N-impacted soils than many believe.

Approach

We have used 6 main approaches:

- Conventional absorption isotherms.
- Measurement of water soluble ammonium concentrations.
- Intact microcosm leaching.
- Reconstructed microcosms.
- Comparison of atmospheric deposition and soil-generated ammonium and nitrate fluxes.
- Assessment of ammonium mobility in the Yorkshire R. Derwent.

We have used 3 sites: Hob Moor, a Nature Reserve just outside York with soils ranging from freely draining sandy loams to poorly draining silty clay loams; grass verges beside playing fields near York; and the River Derwent catchment from Fylingdales Moor down to Loftsome Bridge near the Humber Estuary.

Results

The absorption isotherms data for diverse soil types at 2 depths from Hob Moor showed ammonium to be significantly soluble at both high and low concentration inputs. We also found quite high concentrations of water-soluble ammonium in other unfertilized grassland soils around York. Intact core (including vegetation) leaching experiments with simulated rain containing an appropriate concentration of sea salts for 5 soils from Hob Moor also showed ammonium to be clearly mobile at significant concentrations and moving down through the soil profiles for soils covering a range of pH values and textures from fine sandy loam to silty clay loam.

For acid grassland soils from Hob Moor, we have been testing the hypothesis that ammonium is produced primarily in the litter horizon, then leached down the profile to be partially nitrified at depth. Preliminary results using reconstituted cores with no litter, surface litter, or litter mixed to 15 cm have confirmed the hypothesis. In previous studies the importance of this process has largely not been realised. We have also shown that when KCl-extractable ammonium and nitrate are measured in winter in N-impacted soils, most of the N found is residual accumulated pollution rather than soil-generated mineral N.

We have used Environment Agency data for 9 sites along the River Derwent in Yorkshire over 20 years to demonstrate the mobility of ammonium in both minimally managed and intensive agricultural catchments. Reduced-N concentrations have been improving steadily over recent years in agriculture-impacted parts of the catchment, probably following the Foot and Mouth outbreak in 2001, even before the catchment became an NVZ. However severe drought such as that in N. Yorkshire in 2006 may increase ammonium-N concentrations in river water.

Relevance to Defra Policy

Correct understanding of how the N-cycle functions in soils is crucial for setting N critical loads for soils and natural ecosystems, and for design of pollution abatement strategies for management of N pollution of surface waters and ground waters. The novel concept of atmospheric pollution-derived N dominating over mineral N derived from mineralization of soil organic matter in winter could have far reaching policy consequences.

VEGETATION DIVERSITY IN URBAN MEADOWS IN THE HELSINKI METROPOLITAN AREA

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Sprawling urban regions often contain remnants of semi-natural habitats that, with appropriate management, provide suitable environments for threatened forb species as well as interdependent insects such as pollinators. Furthermore, municipalities are committed to policies for the maintenance of biodiversity. However, little is known about the influences of urbanization factors (e.g. nutrient deposition, landscape composition) on meadow assemblages. As part of the Helsinki Meadows project, we investigated plant communities in 18 meadow habitats in Helsinki in the summer of 2007. Our results show that the number of meadow species is lower in urban than in rural meadows. Altogether, 253 species were found, of which 3 (*Achillea millefolium, Anthcriscus sylvestris, Stellaria graminea*) appeared in each meadow and 70 were only found in one of them. One vulnerable species, *Galium verum,* and one near threatened species, *Dianthus deltoides*, were found in the studied meadows. These species are known to be among the best representatives of semi-natural grassland habitats in the area. The more mesic the meadow was, the higher was the abundance of grasses and, consequently, the lower was the forbs/grasses ratio. The average number of species per 1 m^2 was higher and the soil N content was lower, especially that of NO_3-N, in regularly managed meadows than in unmanaged ones. The soil NO_3-N concentration was positively correlated with the length of roads within a buffer zone of 1 km radius around the meadows. These data show that management of urban meadows successfully mitigates eutrophication caused by increased N deposition and thus promotes the occurrence of plant species that are typical of open, N poor meadows in particular. In contrast, the area of meadows, parks and other built green areas as well as forests within the buffer zone did not affect the diversity of plant species in the studied meadows.

THE EFFECTS OF ROADS ON SPECIES COMPOSITION AND ECOSYSTEM FUNCTION

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Anthropogenic activities are having large impacts on natural nutrient cycles. Vehicles contribute significantly to changes in these cycles by emitting a suite of pollutants including carbon dioxide, oxides of nitrogen, methane, particulates and volatile organic chemicals. However, the effect that these emissions are having on the diversity and functioning of ecosystems is poorly understood. The data that currently exist suggest that emissions are causing changes to vegetation composition, favouring species adapted to high nutrient conditions and having negative effects on plant health.

The aim of this research is to consider the impacts that vehicle emissions and roads are having on the species composition of different ecosystems, particularly focussing on rare and endangered species in ecosystems of high nature conservation importance, such as lowland grasslands. Surveys of the abundance of higher and lower plant species, measurement of pollutant concentrations and an analysis of local abiotic conditions will be used to relate vegetation patterns to drivers of change.

Changes to nutrient cycles can also lead to changes in ecological processes including soil carbon storage capacity, plant biomass accumulation and nutrient leaching. Roads cover 395,000 km in the UK, and their impacts on adjacent vegetation have been shown to stretch up to 200m either side of the road. Associated effects on the functioning of roadside ecosystems may therefore be important at both the local and regional scale. This study has policy relevance through its quantification of effects of vehicle emissions on roadside plant communities and ecological processes, and will contribute to an improved understanding of the influence of roads on the natural environment.

CLIMATE CHANGE AND THE UPLANDS: INTEGRATING CURRENT SCIENTIFIC KNOWLEDGE TO INFORM POLICY

Joanna Clark, Angela Gallego-Sala, Harriet Orr, Sarah Cornell, Chris Freeman, Jo House, Colin Prentice, Pete Smith

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The UK uplands cover around 40% of the land, contain most of the national soil carbon stocks, supply around 70% of the drinking water, are used to supply food and timber, support tourism and many recreational activities. They are an important national asset that may be put under additional pressure from a changing climate. Recent observations of a decline in UK soil carbon stocks and increased carbon in UK freshwaters have highlighted the need for improved understanding of upland ecosystem functioning and 'service' provision (e.g. carbon storage, water quality, biodiversity etc.) to inform effective management now and in future. This project intends to bring together existing knowledge and data through a partnership network to identify what is known and what needs to be understood to deliver sustainable management of upland resources. Work is currently underway and we welcome feedback/input for anyone interested in these issues.

Policy relevance:
This project will develop a series of national-scale maps to inform policy on:

(i) the current condition/pressures on upland organic soils
(ii) vulnerability of upland peat formation to climate change

QUANTIFYING ATMOSPHERIC NITROGEN DEPOSITION ON LOWLAND HEATHLAND: A SYNTHESIS OF LONG TERM DATA FROM THURSLEY COMMON

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Elevated rates of nitrogen deposition can lead to the eutrophication of sensitive terrestrial ecosystems and the associated change in plant community characteristics and ecosystem function. Since 1989, a series of nitrogen manipulation experiments have been carried out at Thursley Common NNR, a lowland heathland in Surrey. Current experiments include an ongoing N addition study and a recovery experiment. The ongoing experiment, started in 1998, shows large and significant effects of N addition (0 or 30 kg ha-1 yr-1) on *Calluna* growth, flowering and canopy development, detrimental effects on understory lichen and bryophyte abundance, as well as strong effects on soil chemistry, nutrient cycling and the soil microbial community. Following a severe summer fire in 2006, vegetation re-growth was strongly stimulated in plots receiving additional N. Analysis showed that, despite the intensity of the fire, treatment-related differences in soil nutrient stores and availability persisted, driving observed patterns in vegetation regeneration.
The recovery experiment, now in its 13th year, has monitored vegetation growth and soil chemistry since N additions ceased in 1996 (0, 7.7 or 15.4 kg ha-1 yr-1, 1989-1996). During this time, persistent effects of former N treatments have remained, with treatment-related differences still seen in terms of *Calluna* growth, lichen abundance and soil chemistry. Interestingly, the severe fire of 2006 has increased the size of the persistent N signal, with larger effects of former N treatments apparent in 2008 than in recent years. This poster will summarise the main patterns and trends seen at Thursley over the past 10 years.

Defra policy relevance:

- Significant effects of nitrogen deposition, both above- and below-ground are evident at relatively low levels of nitrogen input.

- Nitrogen inputs accumulate in the system, with negligible leaching even after prolonged inputs. Accumulated stores continue to exert a significant influence on vegetation and soil processes many years after nitrogen inputs cease, suggesting that recovery from even relatively modest eutrophication will be a slow process.

MACROLICHENS ON TWIGS AND TRUNKS AS INDICATORS OF AMMONIA CONCENTRATIONS ACROSS THE UK – A PRACTICAL METHOD.

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Lichen community composition on acid-barked trees has been shown to respond to increasing atmospheric NH_3 concentrations by loss of acidophyte species and an increase in nitrophyte species. A simple method of sampling selected acidophyte and nitrophyte lichens on trunks and twigs of trees in the vicinity of ammonia monitoring sites across the UK allowed us to test the correlation of lichen communities with ammonia concentrations across the climatic and vegetation zones of the UK.

Sites were selected and participants introduced to standard lichen sampling and identification techniques at a workshop co-organised by NHM and CEH Edinburgh. L_{AN} (Lichen Acidophyte Nitrophyte) values were calculated for all sites, based on the frequency of acidophyte and nitrophyte macrolichens on trunks and twigs. Bark samples from trunk and twig were collected, and surface bark pH measured in the lab, to test the correlation of acidophyte and nitrophyte communities with bark pH.

L_{AN} values on tree trunks and twigs are correlated with NH_3 concentrations across the UK. However, acid-barked trees, e.g. *Quercus*, provide a better correlation with NH_3 than basic-barked species. Lichens on twigs respond to increasing ammonia at lower concentrations than lichens on trunks, and considerably lower than the critical level, confirming that the twig L_{AN} can act as a sensitive early warning system of changes in atmospheric NH_3.

P.A.Wolseley, I.D. Leith, N. van Dijk, and M.A. Sutton· (2008) Macrolichens on twigs and trunks as indicators of ammonia concentrations across the UK – a practical method. In: Sutton, M.A., Reis, S. and Baker, S.M.H. (eds.) *Atmospheric Ammonia*. Springer Science. 101-108.

HOW DO CHANGES IN HEATHLAND COMMUNITY COMPOSITION AFFECT ECOSYSTEM FUNCTION?

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Pollution and climate change can affect ecosystem function through direct and indirect pathways, and there are also likely to be interactions between these two. Examples of 'direct' effects include changes in plant physiology and soil biogeochemistry, whereas 'indirect' effects result from changes in plant species composition and the potential for associated shifts in key ecosystem processes. This study is investigating the indirect effects of pollution- or climate-driven changes in plant community composition on the function of heathland ecosystems using both field surveys and mesocosm approaches. The aim of this study is to test whether there are critical thresholds of heathland plant community composition at which point ecosystem properties switch to resemble conditions associated with monocultures of particular plant species.

Between 2007 and 2008, soil cores were collected from the field at three Lowland Heathland sites (Thursley, Yateley and Frensham). Samples were collected from under three dominant heathland plant species (*Calluna vulgaris, Deschampsia flexuosa and Ulex minor*) growing either in monoculture or in varying proportions. Samples were then analysed in terms of their physico-chemical characteristics, microbial activities (CO_2 flux, PME and phenol oxidase enzyme assays), and nutrient availabilities. In parallel, intact turfs were collected in March 2007 from Thursley Common NNR, to establish a mesocosm experiment with differing proportions of the three heathland species listed above.

The field results show that site and management history significantly affect heathland properties such as soil pH, moisture content, total plant and soil N and P contents, plant available soil N concentrations, N mineralisation rate, phenol oxidase activity and soil respiration rate. In addition, two batches of soil samples taken from Thursley in autumn 2007 and spring 2008 show that moisture content, total N and P contents, N mineralisation rate and phosphatase activity differ significantly between seasons. Analysis to date shows that plant community composition generally has only a small effect on soil properties and processes, relative to the magnitude of differences seen between sites. The mesocosm study will be destructively analysed in 2009, to determine whether plant community composition affects key ecosystem processes when differences in topography and microclimate are controlled for.

Defra policy relevance:

- No information currently exists on the link between community composition and ecosystem function for heathland systems. This study should provide novel insight into this link, permitting extrapolation of the consequences of shifts in above-ground plant communities, through whatever means, for the functioning of these conservationally important ecosystems, and the implications for ecosystem service provision.

INVERTEBRATES IN TESTING ENVIRONMENTAL POLLUTANTS AND ECOSYSTEM STABILITY

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Pollution can cause physical, chemical and biological changes in water quality, reflected in changes in the flora and fauna of rivers and streams.. These changes in different groups of stream-bed macro-invertebrates occur due to sensitivity of these organisms to a pollutant which varies between taxonomic types. As pollution increases, sensitive species are replaced by tolerant species and community diversity declines.

Higher-level community metrics associated with resilience theory, such as the number of modes in biomass size distributions, are also though to change with respect to level of disturbance and pollution. To test this concept, surveys were carried out on rivers in Yorkshire at sites known to experience different degrees of pollution. Invertebrate body masses were recorded and the number of modes determined as the number of gaps between different size rankings, and related to the water quality status of the sites as determined by standard biological indices. The results indicate that water quality is reflected in the number of gaps which may reflect the resilience of the system. The results are discussed in the context of Holling's Textural Discontinuity Hypothesis.

AIR POLLUTION IMPACTS TO AGRICULTURE IN PESHAWAR

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- Peshawar is the capital of North West Frontier Province (NWFP) of Pakistan. Rapid urbanization and an exponential increase in the number of all types of vehicles have given rise to the deterioration of air quality, especially in the big urban areas of Peshawar. Dense smoke emissions have also been reported from foundries, brick kilns and rolling mills in Peshawar. There are about 400-450 brick kilns around the city.
- The aim of the study was to assess the visible injuries to crops of the area.
- The study on air pollution effects on various crops was assessed in two surveys in 2008 from February to June and October to January at Agricultural University (AUP), Agricultural Research Institute Tarnab (ARI), near Brick kiln fields (BKF) and Charsadda (Control).
- Suspected ozone foliar injuries were observed on potato and onion at ARI site. Monthly mean ozone concentrations measured using passive samplers in May/June were 102µg m^{-3} and 82µg m^{-3} for AUP and ARI, respectively, indicating that the presence of elevated ozone levels.
- Visible injuries were also observed in the brick works area to mango, plum and apricot leaves. The HF level in the air was higher in BKF (0.3µg/m^3) than in ARI. The fluoride content of apricot, plum and mango leaves was significantly higher at BKF compared to control sites. It was concluded that substantial visible injuries to crop fruits leaves in BKF site were due to hydrogen fluoride emitted from brick kiln factories in the surrounding areas.
- This is the first study carried out on the effects of air pollution on crops in Peshawar and suggests that air pollution may be having significant effects on the growth and yield of sensitive crops.

THE IMPACT OF ELEVATED ATMOSPHERIC CO_2 ON N FIXATION BY *ALNUS GLUTINOSA*, MEASURED *IN-SITU* IN A FREE AIR CO_2 ENRICHMENT EXPERIMENT (BANGORFACE).

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Elevated atmospheric CO_2 is predicted to have a 'fertilisation' effect on forest growth – at least in the short to medium term. However, this increased growth will have to be supported by an increase in nitrogen uptake or in the efficiency of N use. As a result it is predicted that forest will become progressively more N limited, eventually restricting their response to increasing atmospheric CO_2. One possible exception is trees that are able to directly access N that is fixed from the atmosphere (e.g. *Alnus* spp.). In this study we measured the amount of N fixed by *Alnus glutinosa* trees growing in monoculture or in mixture with *Betula pendula* and *Fagus sylvatica* by comparing their N stable isotope composition.
This study has relevance to DEFRA policy as:

- *Alnus glutinosa* trees growing in mixture supported increased growth with increased N fixation, suggesting enhanced mitigation of elevated atmospheric CO_2, but…
- The transfer of fixed N to co-occurring non N-fixing tree species was reduced when atmospheric CO_2 was elevated suggesting that N fixing tree species will become less valuable for supporting the growth of mixed species forests in a CO_2 enriched world.

LINKING BIOGEOCHEMICAL CYCLING TO MICROBIAL FUNCTION IN A N PERTURBED SEMI-NATURAL ECOSYSTEM

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This study has relevance to Defra policy as:

- It is investigating the effects of enhanced nitrogen deposition in peat bogs on the carbon cycle to determine whether there is, or there is the potential, for a shift from being a carbon sink to a carbon source

Whim Moss is a semi-natural peat bog in the Scottish Borders where a novel N manipulation program has been running since 2002. Investigations are being carried out in to the effects of different forms and concentrations of N at all levels of the ecosystem.

This PhD aims to look more closely at microbial functions within the system and how they are linked to altered biogeochemical cycles using a combination of field and laboratory studies. Monthly fieldwork involves measuring N_2O, CH_4 and CO_2 fluxes using closed static chambers and the collection of soil water from rhizon samplers. Climatic data is continuously collected automatically and water table levels, soil temperature and soil cores are also collected whenever other measurements are made.

There is a need for a greater understanding of microbial processes within soils; especially regarding processes resulting in net emission of the greenhouse gases N_2O and CH_4. Stable isotope enrichment and natural abundance approaches will be applied either in the field or laboratory, to source partition N_2O and to quantify CH_4 oxidation rates under a range of N concentrations, water table depths, temperature and pH, and related to the underpinning microbial diversity.