TALKS

INCORPORATION OF OZONE DETOXIFICATION INTO FLUX MODELS

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The need to quantify impacts of ground-level O_3 on vegetation under environmentally- relevant conditions, has led to a move from a critical level approach toward a cumulative flux/stomatal uptake (critical load) approach. Flux-based approaches endeavour to estimate O_3 uptake *via* stomata, but there is currently no means to incorporate the manner in which environmental variables influence ozone detoxification capacity. Experimental findings that will facilitate the modelling of environmentally-induced shifts in ozone detoxification capacity (i.e. critical flux threshold) in wheat will be reported. Endeavours to parameterize stomatal flux models with recently-collected data for flag leaves of spring and winter wheat over a range of conditions will also be highlighted.

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APOPLAST REDOX STATUS: A NEW PERSPECTIVE ON PLANT DEFENCE RESPONSES

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Transformed tobacco (*Nicotiana tabacum* L.) plants, over- and under- expressing ascorbate oxidase (AO), have been used as a model to dissect the direct and indirect importance of apoplast redox status in mediating ozone tolerance. Initial studies focussed on the direct role played by apoplast redox status in the capture and detoxification of ozone (and its reactive dissolution products) in leaf cell walls. More recently, our goal has been to identify whether cell wall redox status plays a significant indirect role in mediating ozone tolerance via the up-regulation of intracellular defences. On the one hand, targeted studies have analyzed changes in the expression of nuclear genes known to be involved in mediating oxidative-stress tolerance. On the other, subtractive libraries are being prepared that promise a non-targeted means of probing shifts in gene expression profiles driven by apoplast redox status. The ultimate goal is to utilise the identified gene profiles to construct custom defence-related cDNA microarrays to evaluate similarities between responses induced by ozone and other environmental stresses.

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QTLS GOVERNING OZONE IMPACTS ON WHEAT YIELD

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Little attention has focused on the identification of genetic traits governing plant responses to ozone and/or impacts on yield components. This presentation will report provisional findings from an extensive study employing a population of 96 recombinant inbred wheat lines, for which there is a comprehensive genetic map, in a bid to identify QTLs (quantitative trait loci) governing ozone 'tolerance'. Plants were exposed in 16 open top chambers (OTCs) to four levels of ozone during the 2003 growing season. Exposure-response relationships were examined for yield components, and extensive sampling performed to map key physiological and yield-related traits (e.g. stomatal conductance, leaf & stem sol. carbohydrates, ascorbate content, specific leaf area etc etc.). Data analysed so far will be presented.

IS OXIDATIVE STRESS A KEY SIGNAL UNDERPINNING ACCLIMATION TO SALINITY IN THE ICE PLANT ?

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In the halophyte *Mesembryanthemum crystallinum*, exposure to salinity results in the *de novo* induction of two important metabolic pathways, namely pinitol synthesis and Crassulacean acid metabolism (CAM). The accumulation of pinitol and other cyclitols are thought to act as osmoprotectants whilst CAM conserves plant water status in a saline environment by permitting the uptake of CO_2 at night. Using gaseous ozone to elicit oxidative stress, we have tested the hypothesis that oxidative stress is a key signal for up-regulating the major genes and proteins required for the operation of the pinitol biosynthetic pathway and CAM in this model halophyte.

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ESTABLISHING THE FUNCTIONAL SIGNIFICANCE OF HAP5C IN OXIDATIVE DEFENCE AND REPAIR PROCESSES

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In *Saccharomyces cerevisiae*, the CCAAT-binding factor has been shown to comprise a heteromeric complex containing HAP (Heme–Activated Protein) 2, 3, 4 and 5. All 4 subunits are required for DNA-binding activity to occur. Heme-activated genes appear to control oxidative repair functions (e.g. MnSOD and catalase) and mitochondrial functional components, such as cytochrome c. This study highlights the identification and manipulation of a new HAP, with the aim of (i) fathoming the function of the HAP complex in higher plants and (ii) exploring the importance of respiration in fuelling oxidative defence and repair processes.

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BIOMASS REDUCTION OF JUVENILE BIRCH IS MORE STRONGLY RELATED TO STOMATAL UPTAKE OF OZONE THAN TO INDICES BASED ON EXTERNAL EXPOSURE

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In order to test the hypothesis that ozone-induced limitation of biomass production in juvenile silver birch (*Betula pendula* Roth) is driven by stomatal uptake of ozone (O_3) rather than external expose, biomass reduction was related to the cumulative uptake of O_3 through stomata (CUO), to the accumulated exposure to O_3 over a threshold of 40 nmol mol^{-1} during daylight hours (AOT40), and to the sum of daytime concentrations exceeding 60 nmol mol^{-1} (SUM06). The analysis included data from nine experiments conducted at three different sites – Kuopio (Finland), Östad (Sweden) and Birmensdorf (Switzerland). Stomatal uptake of O_3 was estimated using a stomatal conductance (g_s) model which was parameterised for juvenile birch in southern Sweden, including g_s response functions for photosynthetic photon flux density, water vapour pressure deficit of the air and air temperature. Experiment-specific maximum g_s (g_{max}) as well as g_s in darkness were assessed through local measurements.

Biomass reduction was more strongly related to the CUO above a moderate uptake threshold (CUO>x) than to AOT40 and SUM06, corroborating our working hypothesis. A main reason for the superior performance of CUO>x was the significant positive relationship between experiment-specific g_{max} and biomass reduction. In addition, AOT40 and SUM06 did not account for the growth limiting impact of nocturnal O_3 uptake in Birmensdorf. A sensitivity analysis was performed in order to evaluate the impact of non-stomatal leaf surface deposition of O_3 on modelled CUO>x values. CUO>x was largely insensitive to the estimate of non-stomatal leaf conductance for O_3 as a result of turbulent conditions at the experimental plots. In summary, we conclude that CUO>x was more successful in explaining the variation in biomass reduction in juvenile birch, as compared to O_3 indices based on external exposure.

RESPONSES OF LOCALLY GROWN MALAYSIAN RICE CULTIVARS (*ORYZA SATIVA*, L.) TO AMBIENT AND INCREMENTED O_3 LEVELS IN OPEN TOP CHAMBERS AND GREENHOUSE CHAMBERS

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The sensitivity of Malaysian locally grown rice cultivars (*Oryza sativa* L.) to various O_3 levels is investigated. In first experiment, two widely adopted local cultivars, MR84 and MR185, were grown in open top chambers and subjected to the filtration treatment on the campus of University Putra Malaysia during the main rice growing season in peninsular Malaysia. The result indicated that adverse impacts on growth and yield were observed and were attributed to phytotoxic levels of ambient O_3. There was a clear difference in the sensitivity of the two selected cultivars. A yield reduction of 6.3% was observed for MR185 ($p < 0.01$) which was largely due to an increase in grain sterility, whilst the yield reduction for MR84 was not statistically significant.

In second experiment, the same rice cultivars were grown in greenhouse chambers and exposed to four different levels of O_3. The four levels were selected in close relation to the Malaysian peri-urban ambient level (approximately 30 ppb, 8-hour mean), the Malaysian guideline level (approximately 60 ppb) and possible future higher O_3 levels (approximately 90 ppb) with control level (approximately 10 ppb). Both morphological and physiological measurements demonstrated distinctive impacts of O_3 treatments. The plants treated with the highest O_3 concentration showed different morphological development, probably induced by severe foliar injury and physiological adaptation of the plants to the O_3 stress. The physiological measurements revealed a high sensitivity at the early and late vegetative stages.

The study highlighted the responses of Malaysian local rice cultivars to realistic O_3 levels. It was extrapolated that MR84, which was found to be physiologically sensitive, responded to O_3 relatively quickly and altered its morphology to compensate for effects on growth and yield, while MR185, found to be physiologically insensitive, responded to O_3 stress slowly which resulted in more severe impacts on growth and yield parameters. The present studies also proved that yield could be reduced substantially in the field ambient levels especially when other parameters associated with grain yield were affected, which was accompanied by increasing yellowing of leaves and premature senescence.

OZONE SENSITIVITY IN UPLAND VEGETATION

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This study aims to investigate the sensitivity to ozone of representative species of selected upland communities in the UK, grown as individual species and in small model communities. In the first year of study plants were collected from Snowdonia, UK or grown from seed of known local origin. In August and September 2003, thirty-three species were exposed to ozone for 10 weeks in the solardomes at CEH-Bangor. Two domes were controls, with ozone added to charcoal filtered air to give a total ozone concentration of 20 ppb. An episodic ozone regime was applied during daylight hours to two other domes, with concentrations rising to 80 ppb on day 1, 100 ppb on days 2 and 3, and 80 ppb on day 4. Ozone concentrations remained at 20 ppb at all other times.

Ozone specific leaf injury was observed on several species including *Potentilla erecta, Carex echinata, Dryas octopetala*, *Oxalis acetosella, Nardus stricta, Eriophorum angustifolium*, *Carex panicea* and *Carex demissa*. Slight injury was observed on *Scirpus cespitosa*. Increased/premature senescence was observed on *Scirpus cespitosus, Viola lutea, Agrostis capillaris, Agrostis vineale* and *Anthoxanthum odoratum.* There was an increased dry weight of flowers in *Carex echinata* for plants treated with ozone. Significant decreases in biomass in response to ozone were found for some species.

A few additional species of high conservation value will be screened for ozone sensitivity in 2004. Plants will be exposed in small representative communities and the influence of neighbouring species will be investigated. Detailed physiological measurements will be carried out on the component species.

LONG-TERM SIMULATION OF IMPACTS OF NITROGEN DEPOSITION ON HEATHLANDS AND MOORLANDS IN THE UK

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The increased deposition of nitrogen (N) from the atmosphere over the last century has been associated in Europe with changes in species composition, including replacement of characteristic ericaceous shrubs (such as *Calluna vulgaris*) by grasses in heathlands and moorlands. However, these changes may also be associated with changes in management practices and environmental stresses, which may interact with changes in nitrogen deposition. Policies have now been implemented to reduce N deposition, but whether, and over what timescale, changes in vegetation composition will be reversed is very uncertain.

A model was developed to simulate competitive growth between *Calluna vulgaris* and the grass species *Deschampsia flexuosa* and *Molinia caerulea*, driven by light and nitrogen availability. The model was parameterised for application to UK heath and moorland systems, and tested using a synthesis of data over 10 years from three field manipulation experiments in the UK (HEATHSOL-UK). New routines to simulate management (burning, mowing, sheep grazing) were incorporated, and the model included a stochastic treatment of heather beetle responses.

The model outputs were compared with results from three long-term field manipulation studies of the impacts of increased nitrogen deposition (0-120 kg N ha^{-1} yr^{-1}) on lowland and upland heathlands in the UK, to test if common responses are observed (Power *et al*., 2004). Five versions of the model were developed, each reflecting different assumptions about the fate and turnover of soil N. Model outputs supported the deduction from mass balance calculations at two of the field sites that N additions have resulted in an increase in immobilisation. Immobilisation was needed to prevent the model over-estimating measured N leaching although this version of the model significantly underestimated *Calluna* biomass. Model versions which included uptake of organic N by *Calluna* and re-mobilisation of N from the soil organic store provided some improvement in the fit between modelled and field biomass data, but re-mobilisation also led to an over-estimation of N leaching.

The effects of increases and decreases in N deposition over a period of 250 years were simulated under different management regimes. Model runs demonstrated that changes in species composition in response to step changes in N deposition may occur over several decades and management cycles. The simulations show a strong effect of management intensity, and in particular litter removal, in modifying the long-term impact of nitrogen deposition.

THE IMPACTS OF ELEVATED NITROGEN DEPOSITION AND ENVIRONMENTAL STRESS ON THE FLORA AND NITROGEN CYCLING OF A LOWLAND HEATH

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This study was part of an ongoing investigation into the long-term effects of nitrogen enrichment and environmental stress on lowland heath ecology and nutrient cycling. The original experimental site, 4 replicate blocks of 2m x 1m plots, was established on pioneer-phase *Calluna vulgaris – Deschampsia flexuosa* heathland in 1996 (Cawley, 2000). Nitrogen treatments (0, 20, 60 & 120 kg N ha^{-1} yr^{-1}) have been applied on a fortnightly basis, against a background deposition of ~20 kg N ha^{-1} yr^{-1} (NO_x & NH_y). During 1997 the plots were split and a six-month drought versus non-drought treatment introduced. The period of environmental stress experienced by the dominant *C. vulgaris* canopy was extended over the following two years (1998 & 1999) by a natural outbreak of *Lochmaea suturalis*. Zero-tension lysimeters were installed under the non-droughted half of these plots (2001), facilitating study of increased nitrogen deposition effects upon nitrogen losses through leaching. A second set of experimental plots were started in 2000 to enable study of germination and establishment of *D. flexuosa* under conditions of increased nitrogen deposition and canopy gap creation in an otherwise closed *C. vulgaris* canopy.

This study has shown that elevated, long-term deposition of atmospheric nitrogen in combination with periods of environmental stress can contribute to significant changes in the ecology and nutrient cycling of a lowland heath. Elevated nitrogen deposition was found to induce significant increases in: tissue nitrogen content of *Calluna* and *Hypnum* sp.; litter nitrogen content; the loss of nitrogen from the system through leaching. Additionally, there were significant reductions in the C/N ratio of both vegetation and soil. By 2001, few effects of the 1997 drought continued to be apparent in the heathland vegetation. However differences were recorded in the nitrogen content and C/N ratio of the soil components of the droughted and non-droughted plots.

Some responses were not as expected, such as a transitory increase in the *Deschampsia* population. The predicted outcome, based on studies of other European lowland heaths, would have been for a marked transition to a *Deschampsia*-dominated canopy, especially in those high nitrogen (80N & 140N) treatment plots which had been droughted in 1997. An equally unexpected outcome of this study was the significant recovery of the moss layer after the cessation of drought conditions in 1997, which may have implications on the vegetation interactions recorded at this site.

THE EFFECT OF NITROGEN DEPOSITION ON HEATHLAND SYSTEMS

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Nitrogen cycling is a fundamental ecological process and is the focus of much scientific attention due to concerns about the impact of excess N on ecosystems. The movement of N through the environment is cyclic and any atom of N can move between the gaseous, liquid and solid phase. The fate of added N can be determined using stable isotope tracers, such as ^{15}N. Previous studies employing these tracers have provided detailed measurements of short term nitrogen flux through environmental systems; this is readily achievable through simple quantification of the tracer as it passes into distinct partitions of the ecosystem.

In recent years, strong evidence has emerged showing that enhanced rates of nitrogen deposition throughout Europe have resulted in nutrient poor, semi-natural ecosystems, such as lowland heath, becoming less limited by nitrogen. Observations have shown that heathland is one of the fastest declining habitats in the UK and Europe, and an involvement of nitrogen deposition is suspected. The current research aims to determine the fate of added N in a lowland heath ecosystem.

The main objective of this investigation is to quantify how much added N is immobilised in the microbial pool, how much is taken up by plants and is either leached or denitrified. This is being investigated by applying ^{15}N-labelled ammonium sulphate to a long term nitrogen manipulation study at Thursley Common, in Surrey. Earlier investigations carried out at Thursley have suggested that the bulk of experimental N additions accumulate within the soil as the amount of N accumulated in the plant and litter compartments, combined with small losses from the system, do not account for the total N input. It is anticipated that results from this study will improve our understanding of the fate of nitrogen deposition in managed ecosystems and thus contribute to the refinement of nitrogen critical loads for heathlands.

THE EFFECTS OF ATMOSPHERIC NITROGEN DEPOSITION ON THE SOIL CHEMISTRY AND SPECIES COMPOSITION OF SEMI-NATURAL ACIDIC AND CALCAREOUS GRASSLANDS

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Long term (11 and 8 year) additions of atmospheric nitrogen deposition were made to semi-natural acidic and calcareous grasslands in the Derbyshire Dales NNR. Changes in soil chemistry and species composition were investigated. Soil pH decreased on the calcareous grassland but not on the acidic. Extractable nitrate and ammonium were greatly enhanced on both grasslands, whilst many extractable base cations decreased. Despite the length of the additions, both grasslands showed only modest responses in species composition. Mosses and forbs were shown to decline, but no single species was completely eliminated. Grasses were shown to be resilient, but did not increase in abundance. Sedge abundance increased on the calcareous grassland.

ATMOSPHERIC NITROGEN INPUTS TO A SAND DUNE SYSTEM IN SOUTH WALES, IN CONTEXT OF THE WIDER NITROGEN BUDGET FOR THE SITE.

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Merthyr Mawr is a varied and complex dune system in South Wales, with a range of dune forms and habitats along a coastal plain and extending up a limestone escarpment. The site experiences N inputs from a range of sources. These include significant 'natural' inputs such as biological fixation by *Hippophae rhamnoides*, in addition to nitrate rich groundwater, atmospheric emissions from surrounding agricultural land and a sewage treatment works on the eastern margin. The aim of the study is to put external N inputs at the site into context and assess any effects on N accumulation in the dominant dune habitats.

This study will create a N budget for the four major dune habitats at the site: Mobile dunes, grazed fixed grassland (maintained by rabbit grazing), ungrazed rank grassland, and dune slacks. We are quantifying atmospheric inputs of N, both wet and dry, and will present results of the spatial distribution of ammonia across the site.

An additional source of N at this site is groundwater. Springs emerge at the base of the limestone scarp and these contain high levels of nitrate. In summer, these springs are usually dry. However, in winter the outflow from the springs frequently floods dune slacks to depths of up to 2m. Upwelling groundwater reaches the surface at other parts of the site in winter. Dipwells to sample groundwater and rhizons to sample soil water were installed to determine the zone of influence of nitrate rich groundwater at the site.

N pools in soil and vegetation are being assessed and a crude measure of annual N uptake by plants will be achieved by comparing summer and winter N pools.

Preliminary results from this study will be presented.

COMPARISON OF THE IMPACTS OF TWO ATMOSPHERIC NITROGEN SPECIES ON *CALLUNA VULGARIS* (L.) ECO-PHYSIOLOGY

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This experiment investigated and compared the effects of two different N forms, ammonia and ammonium, on the eco-physiology of *Calluna vulgaris* grown both in open top chambers treated over a five year period, and in a large-scale field N-manipulation that had seen one years treatment. Shoot extension, pigment content and chlorophyll fluorescence were measured during the fifth growing season of plants treated in the open top chambers, and during the second growing season of the large-scale field experiment.

Results suggest that NH_3 is more beneficial to *Calluna* phyto-chemistry and growth than NH_4^+, but that photosystem II efficiency and □-carotene concentration are more negatively affected by NH_3 than NH_4^+. The comparison of pigment concentrations and shoot extension data collected from the two separate experiments suggests that treatment history or previous N exposure does affect plant response to enhanced nitrogen exposure.

Keywords: anthocyanins, □-carotene, chlorophyll, *Calluna vulgaris*, field nitrogen simulation, open top chambers, shoot growth, treatment history.

RELEVANCE OF NITROGEN EXPERIMENTS ON HEATHER MOORLAND FOR THE BRITISH UPLANDS

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More than any other rural region of Britain, the southern Pennines has seen a massive pollution load ever since the Industrial revolution. Nowadays, much of the heather on the moors is regularly injured by climatic or other stresses, while below the purple canopy there is a poverty of lichens and mosses. The causes have never been clear but, on the evidence of our experiments in Wales, nitrogen pollution remains a prime suspect.

Since 1989 we have investigated the impact of experimental additions of nitrogen on a heather moorland in a cleaner area in north Wales. Heather moorland is a community where the plant, animal and microbial life are adapted to a meagre supply of nitrogen. The dominant plant, heather, and the rich variety of mosses and lichens growing with it are highly efficient at using and re-cycling the nutrient and as a result flourish in the poor soil conditions. But in our long-term experiments we found the character of the heathlands changed for the worse when nitrogen was added. The most nitrogen sensitive plants were the lichens, which quickly declined after the start of nitrogen additions. Next affected the delicate mosses were replaced by the more nitrogen-loving ones. Lastly heather, one of the most valued plants in the British flora, showed signs of damage from over-consumption of nitrogen. The added nitrogen caused the plant to age and weaken, repeatedly suffering increased injury caused by the cold, drying conditions in successive winters.

But do these experiments, with their stark outcomes, help us to predict the impact of nitrogen pollution from the air on heathlands in the regions such as the southern Pennines? Diagnostic approaches to identifying impacts of nitrogen pollution in heather moorlands will be addressed.

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A STUDY OF THE LICHENS IN LONDON UNDER CONTEMPORARY ATMOSPHERIC CONDITIONS (2002-2003)

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This study investigates changes in diversity and distribution of corticolous lichens in London since the last major survey in 1970 when sulphur dioxide was at a peak and only nine epiphytes were recorded.

For the first time in the UK a quantitative epiphytic survey has been completed, recording from a single phorophyte, *Fraxinus excelsior*, at a background location in every London borough. The position of each relevée was recorded using a geographical positioning device and the associated flora, pH and girth data mapped using a geographical information system (Arc GIS). Distribution maps for each lichen species and associated measurements were then overlaid with computer generated, fine-scale pollution and climatic maps of London. Relevée data was analysed using canonical correspondence analysis.

The study reveals that London's epiphytic flora has made a spectacular recovery. Seventy-four corticolous species were recorded from 334 trees. Thirteen species are new to the Capital and forty percent are associated with eutrophication. The main environmental variables affecting distribution were bark pH, precipitation, girth, nitrogen deposition and transport pollutants. The most widely distributed and abundant species belong predominantly to the families Physciaceae and Teloschistaceae. Their frequency was highly correlated with NOx concentrations. *Xanthoria parietina* was recorded with severely reduced pigmentation at the sites of highest NOx suggesting possible toxic effects. Diversity increased dramatically at sites where annual average concentrations of NOx fell below 150 μg m^{-3} and most new and rare species were recorded below 100 μg m^{-3}. Interestingly, the most common species are those also recorded when SO_2 was at a peak, although then most were confined to stone.

Foliose species returning early under ameliorating conditions (*Flavoparmelia caperata, Punctelia subrudecta* and *Physcia aipolia*) have established well. Newly colonising crustose species belonging to the family Lecanoraceae (*L. confusa, L. symmicta, L. carpinea*), generally confined to twigs, were widely recorded on tree boles. No clear gradient of increasing flora with distance from the city is now apparent. The Epping Forest flora furthest from London and historically the richest, is now the poorest. Bark pH averaged 5.3; this is far less acidic than the unnaturally low acidity recorded on *Fraxinus excelsior* in the 1960s and this increase in bark pH is partly responsible for the low records of acidophytes. The once ubiquitous *Lecanora conizaeoides* was recorded, but is much diminished, as were other acidophyte species including *Hypogymnia physodes* and *Cladonia* species.

London remains the most polluted area of the UK, with elevated nitrogen, in its many forms, the main pollutant. Indications are that a rich urban flora is developing at many background sites. Low sulphur dioxide and artificially high nutrient availability may be encouraging the present rapid re-colonisation, but it remains to be seen how far these newly colonising species can compete with the already widely

established, fast growing, but unremarkable flora dominated by the Teloschistaceae and Physciaceae.

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MONITORING THE EFFECTS OF AIR POLLUTION IN BRITISH FORESTS

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Forest condition monitoring was established in the 1980s, largely as a result of concerns over the impacts of air pollution. Crown density is used as the primary indicator and is measured annually for five species at over 300 plots. The most worrying aspect is an apparent detrioration in the condition of oak, with large interrannual variation in other species, generally linked to climate or insect pest outbreaks. More intensive measurements are made at twenty plots, including deposition, pollutant concentrations, ground vegetation assessments, meteorology, soil solution, ozone injury and growth. After ten years of monitoring trends are becoming apparant, particularly in soil solution chemistry. However, although criticals loads maps show widespread exceedance for both acidity and nitrogen there is no widespread evidence of damage to trees.

CARBON FLUX FROM ATMOSPHERE TO SOILS UNDER ELEVATED CO_2 CONCENTRATIONS

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Under the Kyoto Protocol, many countries will be allowed to substantially offset carbon emissions with terrestrial "carbon sinks". However, the nature of these sinks is poorly understood and quantified, particularly in the context of rapidly increasing atmospheric CO_2 concentrations. Forest soils – one of the largest terrestrial carbon stores – may have the greatest potential to act as long-term carbon sinks; but directly measuring changes in their carbon content (e.g. in FACE experiments) is difficult due to the problems of detecting small changes in a very large carbon pool, and spatial variability. Six native European tree species, selected for their contrasting ecophysiological traits, were grown at four CO_2 concentrations, ranging from ambient to ambient + 300 μmol mol^{-1}, with two levels of nutrient supply. The trees were grown in mesocosms containing soil from a C_4-dominated grassland, which had a carbon isotope ratio ($\delta^{13}C$) of –14.7‰; the $\delta^{13}C$ of the tree fine roots (taken as a measure of $\delta^{13}C$ of "new" carbon added to the soil) ranged from -27‰ (ambient) to -40‰ (ambient + 300 μmol mol^{-1} CO_2). The contrasting $\delta^{13}C$ of "old" and "new" carbon enables the accurate quantification of carbon fluxes to the soil, even at ambient CO_2. At ambient CO_2, mean fluxes of "new" carbon to the soil were 1.97g l^{-1} (low nutrients) and 2.14 g l^{-1} (high nutrients); however, at ambient + 300 μmol mol^{-1} CO_2, carbon fluxes were reduced to 1.13 g l^{-1} and 1.54 g l^{-1} (low and high nutrients respectively) ($P < 0.0005$).

THE ECOLOGICAL IMPACTS OF AIR POLLUTION FROM ROAD TRANSPORT ON LOCAL VEGETATION

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Motor vehicles emit a cocktail of pollutants and are a major contributor to air pollution in many areas of the UK, both rural and urban. The pollutants that may be ecologically important include nitrogen oxides (NO_x), volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), metals and particulates. Ammonia (NH_3) and nitrous acid (HONO) are potentially important, particularly at the roadside, but these pollutants have been ignored in the literature.

Previous studies have focused on the individual components of vehicle emissions; however, there is a lack of data on the effects of pollutant mixtures on vegetation, particularly in the field. Thus little is known regarding the ecological impacts of air pollution from roads on associated vegetation.
Data are presented on the vegetation of two sites adjacent to the M62 motorway in West Yorkshire: one woodland and one blanket bog site. Surveys of oak tree health (at the woodland site) and species composition (at the blanket bog site) were undertaken on transects away from the motorway. In addition, material of seven bryophyte and three lichen species was transplanted from relatively 'clean-air' sites to different distances from the motorway at both sites.

The oak tree health survey found increased defoliation and insect damage near to the motorway. No clear relationship was found between distance from the road and vegetation species diversity at the moorland site. However, the moss *Polytrichum commune*, shows a significant decline in frequency with distance from the motorway.
In a number of the transplanted bryophyte species, chlorophyll concentrations, membrane leakage and growth significantly increased with proximity to the motorway. Nitrogen concentration was determined for one species from each site and found to be significantly higher near the road in the woodland transplant. No significant responses were seen in the lichen species tested, with the exception of changes in visible damage.

The 'edge effect' of the road was estimated to extend to approximately 100 m at these two sites, according to the measured parameters. This distance was consistent with the measured profile of NO_2, which declined exponentially, dropping to background levels at about 100 m. Other motor vehicle pollutants, however, were not measured.

LICHEN AND BRYOPHYTE BIODIVERSITY IN LONDON BIOMONITORING AND RE-INVASION

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Lichen and bryophytes are often used as biomonitors of air quality for two reasons.

1. Lichens and bryophytes do not have a filter, but absorb any component from the ambient air.
2. Most lichens and bryophytes are very selective in their habitat requirements. Some live in clean air, others with e.g. nitrogen excess. The habitat specialisation is caused by low competition skills.

The combination of passive nutrient intake and specialised habitat requirement is the reason why they can inform us of the habitat and atmospheric condition including peaks and averages over the period of their life, just by the presence of particular species. That is: if we understand the requirements correct. Shade, stemflow, local point sources such as roads etc. can easily disturb the standardisation of monitoring trees.

A new European standardised method was applied to 150 common oaks distributed in Greater London in order to find out -

- the patterns of Lichen Diversity Index (LDI), Nitrophile (NIW) and acidophile (AIW) species across London.
- if species distribution, LDI and NIW-AIW correlates with local air pollution level, geology, bark pH etc.
- why the lichen flora of Regent Park, Hyde Park and Primrose Hill so diverse and home of "clean air" "acidophytes" such as *"Usnea"* when it is in the centre of London?
- which species are new to London and UK and why they invade.

And most important:

- How to get a reasonable estimate of air quality with minimum workload.

Methods and results will be run through.

INVESTIGATING BIOGEOCHEMICAL SIGNATURES IN THE LICHEN *PARMELIA SULCATA* IN BURNHAM BEECHES, W. LONDON

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Biogeochemical signatures of different stages of the life cycle of *Parmelia sulcata*, one of the commonest lichens in the UK and historical samples were compared by multi-element and isotopic analysis with the bark substrate. Eighteen elements (N, S, P, Fe, Al, Zn, Ti, Cu, As, Sb, Cd, Co, Se, Li, Th, Tl, Cs and Be) reached maximum concentrations in senescent lichens but (apart from Mn) at lower concentrations than reported from other industrial regions. High N lichen concentrations in senescent material suggest exceedances of critical levels established for deciduous woodlands further supported by observations of alien algae and 'nitrophytic' lichens colonising lichen surfaces. Higher negative d 15N recorded in lichen samples compared with bark suggest ammonia over NOx today dominates the lichen's N assimilatory budget, which may partly arise from motor vehicles. Several elements reach maximum concentrations in samples alongside roads which when standardised against aluminium are highly correlated with N, S and their isotopes further suggesting an influence from traffic emissions. Maximum recorded concentrations of Ca and Sr in bark not correlating with roads suggest a local geological origin. High Ga, Ba, Pb and Ni bark contents testify to a legacy from high SO_2 concentrations including pollution from petrol which formerly carried higher lead concentrations than today. High bark and lichen Mn concentrations require further evaluation especially as Mn is known to limit lichen growth and was introduced in 1995 in the UK as an organic derivative, methylcyclopentadienyl manganese tricarbonyl (MMT) as an anti-knock agent to substitute for Pb in unleaded petrol.

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EARLY IMPACTS OF DIFFERENT N FORMS ON SEMI NATURAL VEGETATION GROWING ON AN ACID ORGANIC SOIL

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This paper describes the effects of different N forms. NH_3 (dry deposition), NH_4^+ or NO_3^- (wet deposition) on *Cladonia portentosa* and the frost hardiness of *Calluna vulgaris.* The vegetation has a history of low N inputs <10kg N ha^- 'yr^-' has been unmanaged other than by rabbits for at least 60 years and is dominated by degenerate Calluna. Treatments are supplied as and when meteorological conditions allow which means the wet deposition may be applied very spasmodically and likewise the NH_3.

Negative effects were observed in *Cladonia portentosa* initially under conditions of high NH_3 but as the accumulated dose increased, damage was observed at lower concentrations i.e. further along the NH_3 transect and also in the high N wet deposition plots. In the frost hardiness studies the importance of sufficient replicates was recognised and implications of this will be discussed for the mixed age Calluna community. Effects on frost hardiness were mixed – depending on the N form and time of year. The extent of the relative toxicities of the different N forms will be discussed.

POSTERS

IMPACT OF OZONE ON OILSEED RAPE (*BRASSICA NAPUS* L.) REPRODUCTIVE STRUCTURES

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Little is known about the impacts of ozone on plant reproductive biology. It is possible that impacts of air pollutants, such as ozone, may influence grain yield/seed production directly. Indeed flowering in many crops and wild plants often coincides with the pollution episodes. This poster reports on investigations directed toward an assessment of the impacts of ozone on reproductive biology of rapid-cycling *Brassica napus* L. (Wisconsin Fast Plants). Pollen germination and pollen germ-tube development were both found to be negatively affected by ozone – consistent with the findings of Bosac *et al*. (1993) and Stewart *et al*. (1996). Ongoing studies are profiling ozone-induced shifts in the amount and composition of nectar and it is intended downstream, to link these studies to insect feeding behaviour and embryogenesis. Provisional data indicate that direct effects of ozone on reproductive development could be an important, but as yet largely overlooked, contributor to ozone-induced shifts in the yield of crop plants and the composition of wild plant communities.

MECHANISTIC STUDIES OF ANTIOXIDANTS AND THEIR LINKAGE WITH OZONE SENSITIVITY

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This poster illustrates night-time stomatal conductance for a number of wild plants as part of a project studying effects and detoxification of ozone in upland vegetation. Studies investigating the impacts of equivalent daytime and night-time uptake of ozone and linkages with cell wall localized ascorbate will be introduced, along with ongoing studies (i) profiling the protein and metabolite composition of leaf cell walls in a bid to increase understanding of potential reaction targets for ozone, and it's reactive dissolution products, in the leaf apoplast, and (ii) examining the impacts of simulated 2050 upland ozone climate on the composition of long-established mesocosms simulating "improved" upland grasslands subject to contrasting nutrient histories and diversification measures (i.e. presence/absence of the hemi-parasite *Rhinanthus minor* L.).

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SITE CONDITION MONITORING WITH TWIG EPIPHYTES

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Twigs of forest trees offer the most recent bark substrate for lichen colonisation, which together with a relatively homogeneous microclimate and absence of competitors, provides an ideal substrate on which to study ongoing lichen colonisation, and response to changes in atmospheric conditions with time. The resulting twig flora is dominated by pioneer lichens whose establishment is dependant on the prevailing air quality.
To study changes occurring over 8 years, the epiphytic twig flora of *Quercus petraea* in four sites in Tycanol NNR, Wales was revisited in 2003. This data is compared with a former data and a study of epiphytic twig floras in Kås Forest in Denmark, in order to detect large scale shifts in environmental conditions. Bark pH of twigs and trunk was assessed and total Nitrogen (% N) in *Hypogymnia* species in all sites.

Increased bark pH of twigs and trunks as well as increased %N in *Hypogynmia* corresponds with a reduction in frequency of `acidophytes´ such as species of *Hypogymnia* and *Usnea* and an increase in `nitrophytes´ such as *Lecidella elaeochroma,* and species of *Physcia* and *Xanthoria*. These are most abundant in the Danish sites which are distinguished in the cluster analysis by the high frequency of `nitrophytes´ and near absence of "acidophytes". These sites have highest % N content in *Hypogymnia*, highest bark pH of twigs and high bark pH of trunks. Bark pH of twigs correlates significantly better to % N in *Hypogymnia* than bark pH of trunks.
The results suggest that lichen floras of epiphytic twigs and bark pH of twigs could provide a useful early warning system to predict local changes in atmospheric condition.

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