Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

SCOTTISH EXECUTIVE

defra
Department for Environment Food and Rural Affairs

CAPER 2007

32nd Annual Meeting

SHEFFIELD UNIVERSITY

2nd - 4th April 2007

Programme and Abstracts

CAPER Secretariat sponsored by **defra**

CAPER 2007

COMMITTEE ON AIR POLLUTION EFFECTS RESEARCH
Department of Animal and Plant Sciences, University of Sheffield

2nd – 4th April 2007

Programme

Monday 2nd April

Room B52, Department of Animal and Plant Sciences, Alfred Denny Building

12.00 Registration

13.00 Buffet lunch plus tea, coffee

14.00 Invited talk: Dr Ben Surridge (Catchment Science Centre)
Reducing the concentration of phosphorous in UK rivers: wetlands not always to the rescue

14.40 Invited talk: Dr Rob Bryant (Department of Geography)
Remote sensing of aerosols

15.20 Tour of CONVIRON climate control facilities (Department of Animal and Plant Sciences)

16.00 Tour of experiments at Tapton experimental gardens with going to the halls to check in to your accommodation)

17.30 Poster session, drinks reception and evening meal. Fulwood and Abbeydale rooms, University House, Food served at 18.30 (drinks available from 17.30)

Help will be available for those needing assistance to get themselves and their bags from Animal and Plant Sciences to the accommodation, but depending on numbers, some patience may be required.

Tuesday 3rd April

Department of Biomedical Sciences Conference Room,
Alfred Denny Building

	Breakfast from 7.30am	Tapton Halls of Residence
	Session Chair: David Fowler	
09.00	Dr. Hope Brett (Environmental Agency)	UK Air Pollutants: Key facts and monitoring data
09.20	James Faulconbridge (SEI)	Nitrogen deposition and global biodiversity
09.40	Lui Xuejun (China Agricultural University)	Quantification of atmospheric deposition of nitrogen in the North China Plain
10.00	Sophie Green (University of York)	Disruption of biogeochemical cycles in soils by road salting alters the fate of N disposition
10.20	Sanna K. Kivimäki (CEH Edinburgh)	Sensitive Sphagnum – does enhanced N Deposition represent a threat to Sphagnum and thus the sustainability of the Scottish peatlands
10.30	***COFFEE***	
	Session Chair: Sally Power	
10.50	Chris Field (MMU & CEH)	Carbon and nitrogen cycling in ericaceous peatlands
11.10	María Arróniz-Crespo (University of Sheffield)	Physiological responses of bryophytes to long term nitrogen deposition and rates of recovery in grassland ecosystems
11.30	Niki Papanikolaou (MLURI & University of Aberdeen)	Simulated nitrogen deposition and temperature manipulations in a montane heathland: Microbial Responses
11.50	Alan Jones (Imperial College London)	The role of phosphorus in heathland response to nitrogen deposition

12.10	Pauline Currey	Interactions between atmospheric nitrogen deposition and carbon dynamics in peatlands
12.30	***LUNCH***	Alfred Denny Building
	Session Chair: David Fowler	
13.30	Phil Grime (Guest Speaker)	The British Flora in a changing world
14.30	Philippine Vergeer (University of Leeds)	How do plants respond to nitrogen?
14.50	William Purvis (Natural History Museum)	Lichen biomonitoring at Burnham beeches special area of conservation (SAC), Buckinghamshire, UK
15.10	Erika Hogan (Nottingham University)	Nitrogen enrichment promotes phosphatase activity in Cladonia portentosa
15.30	***TEA***	
	Session Chair: Malcolm Cresser	
16.00	Elizabeth Jones (Imperial College London)	The effects of road traffic on the quality of urban green spaces
16.10	Tania G. Sanders (Nottingham University)	Assessing constraints on tree line advance due to nutrient availability
16.20	Laurence Jones (CEH Bangor)	Nitrogen and grazing impacts in sand dune grassland – A manipulation experiment
16.40	Odhran O'Sullivan (Sheffield University)	Impacts of long term nitrogen pollution on grassland vegetation
17.00	Gareth Phoenix (Sheffield University)	Nitrogen impacts on phosphorus limitation in calcareous grasslands: A key driver of floristic change
17.20	Neil Cape (CEH Edinburgh)	Reassessment of critical levels for atmospheric ammonia
	DINNER	Tapton Halls of Residence

Wednesday 4th April

Department of Biomedical Sciences Conference Room, Alfred Denny Building

	Breakfast from 7.30am	Tapton Halls of Residence
	Session Chair: Mike Ashmore	
09.00	Sirkku Manninen	Elevated O_3 affected the mibrobial community in a meadow soil
09.20	Sylvia Toet (University of York)	Plant and soil responses to ozone in a lowland raised mire
09.40	Gina Mills (CEH Bangor)	Is our upland vegetation at risk from rising background ozone pollution?
10.00	Jeremy Barnes (University of Newcastle)	Derivation of detoxification algorithm for improved ozone risk assessment
10.20	Kirsten Wedlich	Ozone effects on an upland grassland community
10.30	***COFFEE***	
	Session Chair: Neil Cape	
11.00	Felicity Hayes (CEH Bangor)	Evidence of impacts of ambient ozone on vegetation across Europe
11.20	Agnieszka Kaminska (University of Newcastle)	A QTL for grain yield on 7AL of wheat is activated by ABA and low nutrient treatments during flag leaf ontogeny
11.40	Simon Peacock	Impacts of ozone on semi-natural vegetation
12. .00	Tim Morrissey	Development of ozone flux modelling for semi-natural grasslands
12.20	Simon Caporn	Turning the clock back - research into restoring the Southern Pennines after 200 years of air pollution
12.40	***LUNCH***	Alfred Denny Building
	CLOSE	

Contacts

Dr Simon Bareham
Senior Pollution Impacts Adviser
Countryside Council for Wales HQ
Plas Penrhos
Ffordd Penrhos, Bangor
Gwynedd LL57 2LQ

Tel: 385500/385664

email: s.bareham@ccw.gov.uk

Ms Yang Zhang
AEN Division
Rothamsted Research
Harpenden
Herts AL5 2JQ

Tel: 01582 763 133

email: Liu.xuejun@bbsrc.ac.uk

Dr Tim Morrissey
Stockholm Environment Institute – York
University of York
Heslington
York YO10 5DD

Tel: 01904 432 890

email: tm136@york.ac.uk

Dr Sarah Honour
Defra, AEQ
7/F15 Ashdown House
123 Victoria Street
London SW1E 6DE

Tel: 0207 082 8373

email: sarah.honour@defra.gsi.gov.uk

Dr John Pearson
Department of Biology
UCL
Gower Street
London WC1E 6BT

Tel: 0207 679 3562

email: John.pearson@ucl.ac.uk

Dr Deidre Wilson
Scottish Agricultural College
King's Buildings
West Mains Road
Edinburgh EH9 3JG

Tel: 0131 535 4181

email: Deidre.wilson@sac.ac.uk

Mr Chris Field
6 Mickey Lane
Sheffield S17 4HB

Tel: 07810 326744

email: fieldchris@yahoo.co.uk

Dr Simon Caporn
Department of Environment & Geographical Sciences
Manchester Metropolitan University
Oxford Road
Manchester M1 5GD

Tel: 0161 247 3661

email: s.j.m.caporn@mmu.ac.uk

Rebekka Artz
The Macaulay Institute
Craigiebuckler
Aberdeen AB15 8QH

Tel: 01224 498 200

email: r.artz@macaulay.ac.uk

Professor Nancy Dise
Department of Environment & Geographical Sciences
Manchester Metropolitan University
John Dalton East Building
Chester Street
Manchester M1 5GD

Tel: 0161 247 1593

email: n.dise@mmu.ac.uk

Dr Sally Power
Imperial College London
Silwood Park Campus
Ascot
Berkshire SL5 7PY

Tel: 0207 594 2318

email: s.power@imperial.ac.uk

Dr María Arróniz-Crespo
Department of Animal and Plant Sciences
University of Sheffield
Sheffield S10 2TN

Tel: 0114 222 0073

email: m.arroniz-crespo@sheffield.ac.uk

Ms Pi-hui Chang
Imperial College
Silwood Park
Buckhurst Road
Ascot
Berkshire SL5 7PY

Tel: 07933 556 840

email: p.chang06@imperial.ac.uk

Mr Alan Jones
Room 105
Imperial College
Silwood Park
Ascot
Berkshire SL5 7PY

Tel: 07866 367761

email: alan.jones@imperial.ac.uk

Mrs Tanja Sanders
The School of Biology
University of Nottingham
University Park
Nottingham NG7 2RD

Tel: 07783 365 819

email: plxtw1@nottingham.ac.uk

Dr Philippine Vergeer
School of Biological Sciences
University of Leeds
Miall Building
Leeds LS2 9JT

Tel: 07981 919 614

email: p.vergeer@leeds.ac.uk

Dr Leon Van de Berg
Environment Department
University of York
Heslington
York YO10 5DD

Tel: 07981 918 537

email: Ljvdb500@york.ac.uk

Mr Odhran O'Sullivan
Animal and Plant Sciences
Alfred Denny Building
University of Sheffield
Western Bank
Sheffield S10 2TN

Tel: 0114 222 4771

email: odhran.osullivan@sheffield.ac.uk

Mr James Faulconbridge
5 Burton Lane
Whatton
Nottinghamshire NG13 9EQ

Tel: 07758 837408

email: Jf155@york.ac.uk

Mr Steve Bonnage
ADC Bioscientific Ltd
1st Floor, Charles House
Furlong Way
Great Amwell
Herts SG12 9TA

Tel: 01920 487 901

email: sales@adc.co.uk

Niki Papanikolaou
Catchment Management Group
Macaulay Institute
Craigiebuckler
Aberdeen AB15 8HQ

Tel: 01224 498 200

Email: n.papanikolaou@macaulay.ac.ulk

Ms Rosy Eaton
14 Belle Vue Terrace
York YO10 5AZ

Tel: 01904 639 566

Email: re510@york.ac.uk

Miss Felicity Hayes
Centre for Ecology and Hydrology (Bangor)
Deiniol Road
Bangor
Gwynedd LL57 2UP

Tel: 01248 370 045

Email: fhay@ceh.ac.uk

Dr Sylvia Toet
Environment Department
University of York
Heslington
York YO10 5DD

Tel: 01904 432 727

email: st501@york.ac.uk

Professor Mike Ashmore
Environment Department
University of York
Heslington
York YO10 5DD

Tel: 01904 434 070

email: ma512@york.ac.uk

Dr Mike Pilkington
Department of Animal and Plant Sciences
Alfred Denny Building
University of Sheffield
Western Bank
Sheffield S10 2TN

Tel: 0144 222 0062

email: m.g.pilkington@sheffield.ac.uk

Dr Laurence Jones
Centre for Ecology and Hydrology (Bangor)
Deiniol Road
Bangor
Gwynedd LL57 2UP

Tel: 01248 370 048

Email: LJ@ceh.ac.uk

Professor Malcolm Cresser
Environment Department
University of York
Heslington
York YO10 5DD

Tel: 01904 434 065

email: Msc5@york.ac.uk

Miss Sophie Green
Environment Department
University of York
Heslington
York YO10 5DD

Tel: 07834 593 965

email: Sg507@york.ac.uk

Dr Gareth Phoenix
Department of Animal and Plant Sciences
University of Sheffield
Western Bank
Sheffield S10 2TN

Tel: 0114 222 0082

email: G.phoenix@sheffield.ac.uk

Professor J Neil Cape
Centre for Ecology and Hydrology (Edinburgh)
Bush Estate
Penicuik
EH26 0BQ

Tel: 0131 445 8533

email: jnc@ceh.ac.uk

Dr Hope Brett
Environment Agency
Lower Bristol Road
Booth
Banes BA2 9ES

Tel: 01225 487 648

email: hope.brett@environment-agency.gov.uk

Ole William Purvis
Department of Botany
Natural History Museum
Cromwell Road
London SW7 5BD

Tel: 0207 9425416

email: w.purvis@nhm.ac.uk

Professor Xuejun Liu
AEN Division
Rothamsted Research
Harpenden
Herts AL5 2JQ

Tel: 01582 763 133

email: Liu.xuejun@bbsrc.ac.uk

Dr David Johnson
School of Biological Sciences
University of Aberdeen
Cruickshank Building
St Machar Drive
Aberdeen AB24 3UU

Tel: 01224 273 857

email: D.Johnson@abdn.ac.uk

Professor David Fowler
Centre for Ecology and Hydrology (Edinburgh)
Bush Estate
Penicuik EH26 0BQ

Tel: 0131 445 4343

email: dfo@ceh.ac.uk

Dr Lucy J Sheppard
Centre for Ecology and Hydrology (Edinburgh)
Bush Estate
Penicuik EH26 0BQ

Tel: 0131 445 4343

email: ljs@ceh.ac.uk

Ms Kerstin Wedlich
27 St Paul's Terrace
York YO24 4BL

Tel: 01904 643 797

email: Kw514@york.ac.uk

Miss Erika Hogan
School of Biology
University of Nottingham
University Park
Nottingham NG7 2RD

Tel: 07732 086 993

email: plxejh@nottingham.ac.uk

Miss Elizabeth Jones
Imperial College London
Silwood Park Campus
Buckhurst Road
Ascot SL5 7PY

Tel: 07855 677 313

email: Elizabeth.jones05@imperial.ac.uk

Dr Gina Mills
Centre for Ecology and Hydrology (Bangor)
Deiniol road
Bangor
Gwynedd LL57 2UP

Tel: 01248 370 045

email: gmi@ceh.ac.uk

Miss Kerry Dinsmore
Centre for Ecology and Hydrology (Edinburgh)
Bush Estate
Penicuik EH26 0BQ

Tel: 0131 445 8583

email: kjdi@ceh.ac.uk

Mrs Pauline Currey
Macaulay Institute
Craigiebuckler
Aberdeen AB15 8HQ

Tel: 01224 498 200

email: P.Currey@macaulay.ac.uk

Sanna Kivimäki
Centre for Ecology and Hydrology (Edinburgh)
Bush Estate
Penicuik EH26 0BQ

Tel: 0131 445 4343

email: s.kivimaki@sms.ed.ac.uk

Dr Sirkku Manninen
Department of Biological and Environmental Sciences
P.O. Box 56
FI-00014 University of Helsinki
Finland

Tel: +358 9 191 59101

Email: sirkku.manninen@helsinki.fi

UK Air Pollutants: Key facts and monitoring data

Dr. Hope Brett

Environment Agency, Lower Bristol Road, Bath BA2 9ES

The Environment Agency's new UK Air Pollutants (UKAP) digest is a convenient desk-top companion of key data for air-quality professionals.

UKAP is the first publication to collate such a wide variety of UK air pollutant information, and presents this in a clear and user-friendly format. It is an essential reference for all those involved in planning, regulating and managing local air quality.

UKAP summarises ambient air-pollution data for 143 pollutants, including nitrogen oxides, ozone-depleting substances and persistent organic pollutants.

Each pollutant entry presents UK-wide monitoring data for 2000-2003 and details of chemical formula and structure.

Entries for the 51 most important pollutants include summaries of emission trends, emission inventories, environmental standards, monitoring sites and concentration statistics.

UKAP also links to other sources of air-quality data, including online monitoring data and information on health effects.

UKAP was developed by Jaume Targa, Xingyu Xiao, Justin Goodwin and Jon Bower at AEA Technology and Richard Derwent at Rdscientific.

Nitrogen deposition and global biodiversity

James Faulconbridge, Rosy Eaton, Yu-Jue Wang, Kevin Hicks and Mike Ashmore

Stockholm Environment Institute, University of York

Although the impacts of nitrogen deposition on sensitive ecosystems of northern Europe and North America are well-established, its current and future impacts on global biodiversity are uncertain. A recent analysis has identified global hotspots of plant biodiversity which may be at risk from adverse impacts of nitrogen deposition based on current critical loads (Phoenix et al., 2006 Global Change Biology, 12, 470-476). In this paper, we extend this analysis to WWF's global 200 (G200) terrestrial ecoregions, which have been identified as priority global conservation areas to protect a broad diversity of the planet's ecosystems.

A global GIS analysis indicated that mean modelled N deposition rate (Dentener et al. 2006 Global Biogeochemical Cycles, 20, GB4003) in the G200 area was 40% higher than the global terrestrial average. Under a 'business as usual' scenario, about 25% of the G200 area is predicted to have a mean deposition rate above 10 kg ha^{-1} yr^{-1} by 2030. The ten eco-regions with a predicted mean N deposition above 20 kg ha^{-1} yr^{-1} were all in south and east Asia. The biome with the highest predicted mean N deposition was temperate broadleaved forest, followed by tropical forests, tropical savannahs and mangroves.

A more detailed risk assessment was undertaken for three individual ecoregions, which identified important local features that are likely to influence the impacts of N deposition. In the Drakensberg Mountains of southern Africa, the soils are sensitive to acidification, and many of the characteristic grassland communities are sensitive to N fertilisation. In the Brazilian cerrado, there is a major threat from invasive African grass species which may be exacerbated by N deposition through modifying the outcome of competition with native species, and increasing biomass and thus fire temperatures. In the temperate forests of south-west China, modelled N deposition already exceeds 25 kg ha^{-1} yr^{-1}, but studies have focussed on the impacts on acidification and nutrient cycling, rather than biodiversity.

The results of this analysis further emphasise the importance of N deposition as a threat to global biodiversity and the urgent need for more detailed research in ecoregions with high N deposition to assess local sensitivity and to determine whether policy interventions to reduce N deposition are needed in these regions.

Quantification of atmospheric deposition of nitrogen in the North China Plain

Lui Xuejun[1], He Chun-E[1], Shen Jianlin[1], Zheng Lixia[1], Zhang Fusuo[1] and Keith Goulding[2]

[1]*College of Resources and Environmental Sciences, China Agricultural University, Beijing, China;*

[2]*AEN division, Rothamstead Research, Harpenden, Herts, UK*

Atmospheric deposition of nitrogen (N) is a critical part of the global N cycle that provides an important nutrient resource in many natural and semi-natural ecosystems. Here we report evidence on the significance of N deposition to agroecosystems in the North China Plain (NCP). We used a manual ITNI (Integrated Total Nitrogen Input) system, based on the ^{15}N dilution method, to quantify the magnitude of atmospheric N deposition at Dongeiwang, Quzhou and Wuqiao research centres in the NCP during a single maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.) rotation in 2005-2006. Total annual N deposition averaged 88.2 kg N ha^{-1}, of which 50.4 kg N ha^{-1} was utilized by plants, accounting for 57% of the total deposition and 25% of the total N uptake by plants, across the three sites; N deposition did not differ significantly between the sites. Separate measurements of total annual N uptake (82.8 kg N ha^{-1}) obtained from zero-N plots of a Long-term Experiment, and direct measurements of wet and dry deposition of N (70-86 kg N ha^{-1} yr^{-1}) in Beijing, strongly supported the N deposition results from the maize/wheat ITNI systems. Our results show that atmospheric N deposition in the NCP is very large and a very significant input to ecosystems, and should be taken into account in the nutrient management in local agroecosystems

Disruption of Biogeochemical cycles in soils by road salting alters the fate of N deposition

Sophie Green

Environment Department, University of York

Episodic introductions of road salt severely disrupt soil biogeochemical cycles. Road salting activities aim to minimise and restrict accidents during adverse weather conditions, but associated runoff can lead to substantial soil cation exchange reactions displacing ammonium, hydrogen ions and divalent base cations, and thus, cause pH shifts. Results from a field study highlight large impacts on base cation and nitrogen cycling in soils, soil solution and river samples. Sodium occupation of the CEC can reach up to 35 % in heavily salt-affected soils and soil solution concentrations can be in excess of 5800 mg l^{-1}, compared to 0.35 % and 4.4 mg l^{-1} in control soils. Sodium and chloride ion affects decline as the distance from the road increases. There is evidence of substantial ammonium leaching from the soil profile.

Of several impacts that road salts might have upon roadside soils, the potential disruption of the nitrogen cycle and microbial functionality has been largely ignored. The fates of low-level ammonium-N and nitrate-N inputs to roadside soils that have been impacted by salting over an extended period (decades) in the field have been studied. The use of road salts disrupts the proportional contributions of nitrate-N and ammonium-N to the mineral inorganic fraction of roadside soils and depletes the soil organic N pool. It is highly probable that that the degree of salt exposure of the soil, in the longer term, drives the outcome of microbial N transformation processes primarily by increasing soil pH. However, salinity effects on microbial function may also occur. Additional influxes of ammonia-N from the atmosphere to salt impacted soils are rapidly nitrified and, thereafter, increased leaching of nitrate-N to the local waterways occurs. This has particular relevance in the context of the Water Framework Directive, and understanding the link between atmospheric pollution, and soil and water quality. The results reported are important when assessing the fate of inputs of ammonia to soils from atmospheric pollution.

Sensitive *Sphagnum* – does enhanced N Deposition represent a threat to *Sphagnum* and thus the sustainability of the Scottish peatlands?

Sanna K. Kivimäki[1,3,4], Patricia Bruneau[2], John Grace[3], Bob Rees[4], Lucy J. Sheppard[1]

[1] Centre for Ecology and Hydrology (Edinburgh), Bush Estate, Penicuik, EH26 0BQ
[2] Scottish Natural Heritage, 2 Anderson Place, Edinburgh, EH6 5NP
[3] University of Edinburgh, Crew Building, King's Buildings, West Mains Road, Edinburgh, EH9 3JG
[4]Scottish Agricultural College, King's Buildings, West Mains Road, Edinburgh, EH9 3JG

As the research has shown so far, increased N deposition can have different effects on the functioning of peatland ecosystems and *Sphagnum* mosses. My aim is to assess the effects that it can have on Scottish blanket bogs.

The specific aims of my study are to: 1) compare the effects of different N loads and different N forms (nitrate and ammonium) on blanket bogs using *Sphagnum* mosses, and their productivity and decomposition, as indicators, 2) develop a tool/toolbox that can be used to assess the state of a bog regarding N deposition and its effects with simple measurement/measurements, 3) examine potential for recovery when N source is removed, and 4) use N_{15} –labelling/stratification to look at fate of N, i.e. where the excess N goes in *Sphagnum* mosses. I also show how P and K additions influence N use and might offer a management tool particularly for endangered *Sphagnum* species and examine the role of pH and nutrients in determining the rate of *Sphagnum* production and decomposition.

The project is divided into 5 experiments: productivity, decomposition, tissue N%, recovery and N_{15}/stratification. Three *Sphagnum* species, *S. capillifolium*, *S. fallax* and *S. papillosum*, will be used for the experiments. The experiments will be carried out in three study areas. Most of the experiments will be done at Whim bog situated about 20 miles outside Edinburgh. Whim is N manipulation experiment site where the effects of reduced and oxidized forms and different loads of N are being studied. Part of my experiments will be done in two other bogs which have higher and lower N deposition and different rainfall than Whim, in Flanders moss near Stirling (high N deposition) and near Ullapool (low deposition, high rainfall). The experiments will be carried out between March 2007 and March 2009.

Carbon and nitrogen cycling in ericaceous peatlands

Chris Field, Nancy Dise, Simon Caporn, Jackie Carroll and Chris Evans

Manchester Metropolitan University

Centre for Ecology and Hydrology, (Edinburgh), Bush Estate, Penicuik, EH26 0BQ

N availability in the United Kingdom has been significantly increased by anthropogenic activities, main pollutant N sources being fossil fuel combustion from industry and road traffic (NO_x) and agricultural livestock ammonia (NH_3) production. Recent research has shown that increases in N availability increase soil C stores in heathlands through maintenance of C:N ratios and limited N leaching (Pilkington *et al*, 2005) and modelling has predicted that large amounts of additional C may have already accumulated due to post industrial revolution increases in N (Evans *et al*, 2006).

This study compares the interactions of the N and C cycles at three contrasting peatlands each subject to different climatic regimes; lowland heath (Budworth), upland heath (Ruabon) and a raised bog (Whim). The objective of the study is to understand the effects of increased N on C sequestration at each location. At each site N treatments have been added for between 5-10 years in a randomised block design and measurements are made of key components of the N and C cycles.

The study is very much work in progress and this presentation will focus on reporting the results from extensive field soil respiration measurements made to date and present the initial findings of mineralisation and leachate analysis. N treatments have not conclusively affected soil respiration at a field level though laboratory experiments suggest that N may increase soil respiration in the short term however, at Budworth very high levels of N addition have reduced N addition. Soil respiration rates have responded strongly to temperature and seasonal change with greater levels witnessed during the warm summer season. At Whim Bog nitrate and ammonium treatments are applied separately, this has led to increasing soil and soil water pH and a suggested increase in soil respiration under nitrate addition. Whim soil leachate has also been monitored and this too has been responsive to increasing pH with greater levels of DOC as nitrate application is increased.

Physiological responses of bryophytes to long term nitrogen deposition and rates of recovery in grassland ecosystems

María Arróniz-Crespo[1], Jonathon R Leake[1], Peter Horton[2] and Gareth Phoenix[1]

[1]*University of Sheffield, Department of Animal and Plant Sciences, Western Bank, Sheffield S10 2TN*

[2]*University of Sheffield, Department of Molecular Biology and Biotechnology, Western Bank, Sheffield S10 2TN*

Here we report the physiological responses of two common bryophytes to both long-term simulated N deposition and their recovery following cessation of enhanced N treatments. Both species (*Rhytidiadelphus squarrosus* and *Pseudoscleropodium purum*) are widely distributed in grassland ecosystems in UK.

The study was undertaken in semi-natural grassland (Peak District National Park, UK) where increased atmospheric N deposition has been simulated since 1995. Nitrogen (N) and phosphorus (P) treatments have been applied to plots in a randomised block design (3N x 2P x three blocks). N has been applied as NH_4NO_3 at 0, 3.5 and 14 g N m^{-2} yr^{-1} with and without P (as NaH_2PO_4.H2O) at 3.5 g Pm^{-2} yr^{-1}. To study recovery, in August 2005 plots were split in half, with the treatments being ceased in one half. Bryophytes responses to continued N deposition and recovery have been determined through measurement of species cover, nitrate reductase and surface phosphatase activities; tissue N and P, photosynthetic pigment composition (by HPLC), concentration of secondary metabolites; chlorophyll fluorescence and sclerophylly.

Cover of bryophytes showed a strong decrease under enhanced N deposition, however, there is currently only weak evidence of recovery on this. In contrast, many physiological parameters showed both large responses to N deposition and clear recovery, for example enzyme activities, Fv/Fm and photosynthetic pigments.

Finally, we discuss the use of such key physiological variables as early indicators of bryophyte sensitivity and recovery to N pollution. The sensitivity of physiological parameters to N deposition means they have excellent potential as tools for providing the earliest indicators of reductions in N deposition impacts within the context of reduced N loading in the UK.

Simulated nitrogen deposition and temperature manipulations in a montane heathland: Microbial Responses

Niki Papanikolaou[1,2], Dave Johnson[2], Andrea Britton[1], Rachel Helliwell[1]

[1]*Macaulay Land Use Research Institute*

[2]*School of Biological Sciences (Plant and Soils Sciences), University of Aberdeen*

The impact of atmospheric nitrogen deposition and climate change on carbon and nutrient dynamics was studied on a montane heathland in the Cairngorm Mountains dominated by the ericaceous shrub *Calluna vulgaris*. Regular additions of NH_4NO_3 (0, 10, 20, 50 kg $ha^{-1}y^{-1}$) and warming chambers were used to simulate atmospheric nitrogen deposition and climate change, respectively. We determined carbon (C), nitrogen (N) and phosphorus (P) in microbial biomass and the activity of four enzymes, phosphomonoesterase (PME), β-glucosidase, β-xylosidase and phenol peroxidase in soil. PME is a widespread extracellular soil enzyme that catalyses the hydrolysis of phosphate monoesters to inorganic phosphates. β-Glucosidase, β-xylosidase and phenol peroxidase are three key enzymes in carbon turnover, participating in cellulose, hemicellulose and lignin breakdown, respectively. The size of the microbial population and microbial N and P pools were not affected by any of the treatments, with the exception of microbial P biomass that increased in the high N treatment and for the warmed plots during summer. For enzyme activity, only phenol peroxidase was sensitive to temperature changes, increasing after warming. PME activity increased with each increment of nitrogen addition indicating a greater phosphorus demand by plants and microorganisms. Glucosidase, xylosidase and phenol peroxidase activities were not influenced by nitrogen treatments although there was a trend for cellulolytic activity to increase at the high N plots, and lignolytic activity to decrease. The results indicate that in montane ecosystems N deposition may lead to increased phosphorus turnover, whereas climate change may increase mineralization rates of recalcitrant carbon. Carbon, nitrogen and phosphorus microbial pool do not seem to be affected by environmental change. Further studies are underway to determine how environmental change may affect litter decomposition, nitrogen mineralization and the composition of the microbial community.

The role of phosphorus in heathland response to nitrogen deposition

Alan Jones and Sally Power

Division of Biology, Imperial College London, Silwood Park Campus, Ascot, Berkshire, SL5 7PY

The response of *Calluna*-dominated heathland systems to nitrogen deposition may be influenced by a variety of environmental factors, including climate, geology and soil nutrient status. Our study aims to evaluate: a) the relationship between N and P availability in lowland heaths using field and mesocosm manipulation experiments; b) spatial patterns of heathland P availability; and c) the effect of management on soil N and P status.

Data have been obtained using the long term nitrogen addition experiment at Thursley Common, a mesocosm experiment involving N and P addition to P-limited heathland cores and a survey of 30 lowland heaths across southern and eastern counties in England.
N addition had no effect on either soil or foliar P concentrations at Thursley Common. A significant increase in shoot N concentrations did, however, result in a small increase in foliar N:P ratios of *Calluna* in response to N addition. N addition to P-limited mesocosms resulted in an increase in soil N concentrations, with a small increase in soil P. An associated increase in foliar N concentrations was linked with an increase in N:P ratios (17.5 control – 21.8 high N). Nutrient ratios even in control plots were above those associated with P limitation (Koerselman & Mueleman, 1997) and growth response to P addition continues to be demonstrated. Addition of nitrogen also resulted in an increase in soil phosphomonoesterase (PME) activity in both Thursley plots and the P-limited mesocosms, indicating an increased demand for P in response to N in both systems.

Analysis of soil and foliar material collected from a survey of >30 lowland heathland sites in 2005 indicated a significant (P <0.05) negative relationship between foliar P concentration and soil PME activity in young (pioneer phase) *Calluna* stands. Analysis of the relationship between soil chemistry and modelled N deposition values for the survey sites demonstrated a significant (P <0.05) positive relationship between foliar N concentration and oxidised N deposition in pioneer phase stands. The relationships between N deposition and foliar N:P ratios or soil PME activities were not, however, significant. Management clearly plays an important role in terms of soil nutrient status, with a clear relationship between stand age and both the nitrogen and phosphorus concentration of the soil.

Taken together, experimental manipulations indicate that N addition increases demand for P in both N-limited (Thursley) and P-limited (mesocosm) systems. However, whilst survey results indicate a wide variation in foliar N:P ratios, and thus relative nutrient limitation, relationships between N deposition and plant nutrient status were weak.

Interactions between Atmospheric Nitrogen Deposition and Carbon Dynamics in Peatlands

Pauline Currey[1,2], Rebekka Artz[1], Lorna Dawson[1], David Johnson[2] ,Rene van der Wal[3] and Lucy Sheppard[4]

[1]*Macaulay Land Use Research Institute, Aberdeen, AB15 8QH*

[2]*Biological Interactions in Soils, SBS, University of Aberdeen, St. Machar Drive, Aberdeen, AB24 3UU*

[3]*Centre for Ecology and Hydrology, Hill of Brathens, Banchory, AB31 4BW*

[4]*Centre for Ecology and Hydrology, (Edinburgh), Bush Estate, Penicuik, Midlothian, EH26 0QB*

The impact of increased levels of atmospheric nitrogen deposition on carbon cycling in peatlands is uncertain and limits our understanding of the future role of peatlands as global carbon sinks. Deposition of nitrogen from the atmosphere has the potential to alter processes influencing carbon accumulation, including inputs of recalcitrant organic matter from litter, labile carbon from plant photosynthates, and microbial activity. Because ombrotrophic bogs are adapted to very little nitrogen availability, they may be particularly susceptible to increased loads of inorganic nitrogen. Here we test the hypotheses that nitrogen deposition affects i) the vegetation composition and subsequent inputs of carbon into soil, ii) the activity of key soil enzymes involved in organic matter turnover, and iii) the fate of recent plant assimilates.

The Whim Moss Experiment Site is our main study site; it is an ombrotrophic bog in which inputs of nitrogen (NH_4^+ and NO_3^-) were manipulated since 2002. Plant wax profiling is proposed as a tool for studying the past changes in vegetation in peat cores due to nitrogen amendments. This method was shown to differentiate between many peatland vegetation species, and its prediction accuracy is currently being tested. Preliminary data from a temporal study of four soil enzymes revealed that microbial activity increased when soil pH increased as a consequence of nitrogen amendments. To determine the fate of carbon from decaying litter and rhizodeposition into different pools, CO_2 and CH_4 emissions, microbial biomass and dissolved organic carbon will now be monitored in combination with a series of ^{13}C tracer studies.

The British Flora in a changing world

Phil Grime

How do plants respond to nitrogen?

Philippine Vergeer[1], Leon van den Berg[2], Mike Ashmore[2] and Bill Kunin[1]

[1]*School of Biological Sciences, University of Leeds*

[2]*Environment Department, University of York*

In this study, we focus on plant responses to abiotic stress at range margins, using *Arabidopsis lyrata petraea* as model species. We studied the species across its range and observed large differences in life history strategies which are strongly correlated with the nutrient availability in the soil as well as the local atmospheric nitrogen deposition rate. The question is: What causes these differences in life history strategy? To test whether the observed differences in life history strategy are caused by plastic responses to nutrient availability, rather than evolutionary adaptations to local conditions, we grew plants from different regions under controlled conditions with varying atmospheric deposition rates. The results clearly demonstrate that nitrogen deposition strongly affects the plant's life history strategy, although the differences observed are not solely caused by plastic responses to nutrient availability. Plants from regions with different atmospheric nitrogen deposition rate respond differently to nitrogen addition, and plants from areas with low nitrogen deposition rates seem to use nitrogen more efficiently than plants from areas with high nitrogen deposition rate.

Lichen biomonitoring at Burnham beeches special area of conservation (SAC), Buckinghamshire, UK

O W Purvis[1], W Dubbin[1], P D J Chimonides[1], G C Jones[1], H Read[2]

[1]*Natural History Museum, Cromwell Rd, London SW7 5BD*

[2]*City of London, Burnham Beeches Office, Hawthorn Lane, Farnham Common, Slough SL2 3TE*

Acid rain throughout the 20th Century has resulted in severe acidification of woodlands, leading to cation depletion and mobilisation of Mn, Fe and Al through clay weathering, enhanced bioavailability of these elements and higher plant tissue concentrations (Blake et al., 1999). The importance of exchangeable cations and soil pH in governing the physiology and distribution of vascular plants is well established, although considerably less studied in lichens. Perhaps the most dramatic evidence for the effects of particulate deposition on plant communities has come from Oliver Gilbert's studies carried out near a lime dust source in Derbyshire where he identified zones according to lichen diversity (Gilbert, 1976). Heavily dusted trees had fewest lichens, but this was followed by a zone containing lichens that are normally saxicolous together with species typical of nutrient enriched bark. These species eventually declined and were replaced by those characteristic of acidified bark in a moderately polluted environment, including *Hypogymnia physodes*. This lichen was recorded by the late Francis Rose as being by far the dominant macrolichen at Burnham Beeches at a time when SO_2 conditions were high. Stimulated by Gilbert's and Rose's research, lichen biomonitoring commenced at Burnham Beeches in 1989 in response to gravel extraction nearby. This study attempts to put element concentrations recorded in the lichen *Parmelia sulcata* and bark samples into context with historical deposition by comparing element contents with those in soil sampled from Burnham Beeches on 9 May 2005 (Purvis et al. 2006). The influence of pH, acid deposition and significance of element ratios are also considered. Conservation agencies are required to identify, monitor and protect sites designated for conservation under UK and European legislation (Leith et al. 2005). This study highlights the importance of understanding soil chemistry and a pollution legacy, even at the small scale.

Blake, L., Goulding, K.W.T., Mott, C.J.B. & Johnston, A.E. (1999) Changes in soil chemistry accompanying acidification over more than 100 years under woodland and grass at Rothamsted Experimental Station, UK. European Journal of Soil Science 50, 401-412.

Gilbert, O.L. (1976) An alkaline dust effect on epiphytic lichens. *Lichenologist*, 8, 173-178.

Leith ID, van Dijk N, Pitcairn CER, Wolseley PA, Whitfield CP, Sutton MA. (2005) Biomonitoring methods for assessing the impacts of nitrogen pollution: refinements and testing. Peterborough: JNCC. Report no 356. 386 p.

Purvis, O.W., Chimonides, P.D.J., Dubbin, W. (2006) Burnham Beeches: Element Concentrations with respect to lichens, soils and bark samples. June 2006. Report for the City of London. pp 33

Nitrogen enrichment promotes phosphatase activity in Cladonia portentosa

Erika Hogan, Gulnaz Minnullina and Peter Crittenden

The School of Biology, The University of Nottingham, University Park, Nottingham, NG7 2RD

The common heathland lichen *Cladonia portentosa* (Dufour) Coem. expresses both acid phosphomonoesterase (PME) and phosphodiesterase (PDE) activity. A capacity to utilise the organic fraction of phosphorus in atmospheric deposits might be advantageous to *C. portentosa* growing in oligotrophic heathlands in competition with vascular plants. Nitrogen enrichment of such habitats is widespread in some regions of the British Isles and under these conditions the availability of phosphorus is reduced. We hypothesised that under such conditions, *C. portentosa* might increase N investment to the synthesis of phosphatase enzymes in order to help maintain N:P stoichiometry. Therefore we measured PME activity in *C. portentosa* growing in heathlands subject to different rates of N deposition and different mean N concentrations in precipitation. Phosphatase activity was strongly up-regulated at N-enriched sites and was positively correlated to thallus N:P.

Relevance of work for Defra's environmental policy

- Phosphatase activity in *C. portentosa* was more closely correlated with wet N deposition rates than mean N concentration values in precipitation.
- Phosphatase activity in *C. portentosa* could provide a reliable indicator for wet N deposition rates in UK heathlands with sensitivity greatest over the range 4 – 16 kg N ha^{-1} yr^{-1}.

The effects of road traffic on the quality of urban green spaces

Elizabeth Jones, Dr Sally Power and Dr Simon Leather

Imperial College London, Silwood Park, Park Campus, Ascot, Berkshire, SL5 7PY

Green spaces in urban areas have been shown to be important nature reserves for arthropods, yet they are typically in areas of relatively high traffic density, with associated pollutant emissions. As an important ecological theory, the species-area relationship is essential for use of these spaces as conservation sites. Another imperative factor for conservation is the effect on arthropods of vehicle emissions in urban areas. This study plans to investigate the impacts of these factors on arthropod groups on 23 roundabout and road-enclosed sites in the town of Bracknell, Berkshire. The project is just getting underway and there are no data to present so far. However, the experimental approach will involve: measurement of nitrogen dioxide concentrations along transects away from roads; sampling of arthropod abundance and diversity, using pitfall traps and sweep nets. The focal arthropod groups will be Collembolla, woodlice, Hemiptera, Carabidae, spiders, ants and Coccinellidae. Soil and selected plant species will be sampled in transects away from the roadside and analysed for nitrogen content. This study will try to evaluate the importance of different factors on arthropod groups in urban areas and allow for these findings to feedback into the management of green spaces as conservation areas.

Assessing constraints on tree line advance due to nutrient availability

T G Sanders[1], P Crittenden[1] and S Young[2]

[1]*School of Biology, University of Nottingham, University Park, Nottingham, NG7 2RD*

[2]*School of Bioscience, University of Nottingham, University Park, Nottingham, NG7 2RD*

The EU-project CARBONorth is aiming to quantify carbon dynamics in the taiga-tundra ecotone in northern Russia. One of the work packages includes tree line dynamics as this will have a major impact on overall carbon sequestration.
Tree growth in the boreal zone is mainly limited by nitrogen availability; however, due to anthropogenic impact, nitrogen loads have risen in this ecotype over the last few decades. According to Bashkin *et al.* (1995) the critical load for these northern systems is around 100 mol N ha^{-1} yr^{-1}. Modelled loads for the study area in northern Russia reach these values (Ryaboshapko *et al.* 1998). Combined with the predicted increase in temperature, leading to earlier snowmelt and a prolonged growing season a tree line advance to the north is assumed.

The major input of nitrogen to the soil occurs in spring during snowmelt (Tye *et al.* 2005); however, for seedling survival the nitrogen available during the winter is crucial (Weih and Karlsson 1997). It is therefore important to quantify the overall and seasonal need for nitrogen to predict seedling growth. Therefore we will undertake growth experiments under different temperature regimes and nitrogen treatments in controlled environments. The trial will include birch (*Betula pubescens*) and spruce (*Picea obovata*) as the northernmost trees in the study area.

Consecutively we will investigate trees of all age groups including seedlings at the current tree line with dendroecological methods to plot age structure and cohort development.

Nitrogen and grazing impacts in sand dune grassland – A manipulation experiment

M L M Jones, K Plassmann, E Rafaluk and G Edwards-Jones

Centre for Ecology and Hydrology, (Bangor), Deiniol Road, Bangor, Gwynedd, LL57 2UP

The manipulation experiment was set up in 2002 on a large sand dune system: Newborough Warren in Anglesey, North Wales. There are five nutrient treatments, applied monthly as NH_4NO_3: Unwatered Control, Watered Control, Low N (+7.5 kg N ha^{-1} yr^{-1}), High N (+15 kg N ha^{-1} yr^{-1}), and High N (+15 kg N ha^{-1} yr^{-1}) with Phosphorus (+10 kg N ha^{-1} yr^{-1}). The N treatments are on top of a calculated background deposition of 11 kg N ha^{-1} yr^{-1} and aim to bring deposition up to the middle and just above the critical load range for dune grasslands. There are three grazing treatments: Ungrazed, Rabbits only, Rabbits and Ponies. These are achieved with grazing exclosures as the site has a high rabbit population and a managed grazing regime with Ponies. Nutrient treatments are nested within grazing treatments, in three replicate blocks.

After four years of treatments, the biggest effects on the vegetation occur in the grazing treatments, with sward height increasing significantly in the ungrazed treatment within four weeks of the exclosures being put up. There is no difference in sward height between the rabbit-only and rabbit-and-pony treatments, even after four years, suggesting that at current population density the rabbits are the dominant grazing influence on this part of the site. There have been no significant changes yet in species composition in either the grazing or the nutrient treatments. However, tissue N content of the mosses is significantly greater in the high N and high N+P treatments, which indicates that some of the nitrogen is being taken up by the soil-plant system. In addition, rhizomes of the sand sedge, *Carex arenaria*, had higher tissue N content in the high N than in the other N treatments.

Nitrogen mineralisation increased in the highest N treatment, when soil thickness was taken into account as a covariate. Regression analysis showed that thickness of the organic horizon and the extent of moss cover both had a significant effect on nitrogen mineralisation. Although soil pools of total N are relatively small in a sand dune system, compared with other semi-natural systems, no changes in either available N or total N have been seen so far.

Policy relevance:

- Sand dune grasslands have a high biodiversity value and N deposition to many in the UK exceeds the critical load.
- This is the only Nitrogen x management field experiment on sand dunes in the UK.
- Understanding the impact of N deposition on the soil-plant system in sand dunes is vital to understanding how to manage the important biodiversity in this system. Together with the grazing manipulation, this experiment helps us understand how best to mitigate some of the adverse effects of N deposition in this system.
- Due to their embryonic soils, the input of atmospheric nitrogen to the system is proportionately large in relation to the soil N pools. Thus, sand dunes provide an ideal model system to understand the mechanisms controlling the accumulation of nitrogen and carbon in soils.

Impacts of long-term nitrogen pollution on grassland vegetation

Odhran O'Sullivan and Jonathan Leake

Department of Animal and Plant Sciences, University of Sheffield, Western Bank, Sheffield S10 2TN

High nitrogen deposition loads have been correlated with losses in biodiversity in semi-natural grasslands (Stevens *et al*. 2004, 2006). In order to understand the processes underlying these losses it is important to examine what is happening to community structure and plant chemistry in response to enhanced N deposition. Here we report the effects of simulated N deposition on plant population numbers and shoot chemistry. Detailed surveys on a number of targeted species were conducted on limestone and acid grasslands that have received simulated enhanced N deposition since 1995 (at rates of 0-140 kg N ha^{-1} yr^{-1}). Plots were divided in January 2005 with only one half continuing to receive treatment while the other is in recovery. Losses in cover or abundance of many forbs such as *Anemone nemorosa*, *Potentilla erecta* and *Conopodium majus* have occurred in the acid grassland plots receiving 35 kg and 140 kg N ha^{-1} yr^{-1}. Flowering of forbs was even more seriously affected than cover or abundance of plants per unit area. Similar losses have occurred on the limestone grassland species *Scabiosa columbaria*, *Gentianella amarella* and *Thymus polytrichus* whereas most grasses and sedges (e.g. *Carex flacca*) have increased or remained largely unaffected by the N deposition. Encouragingly, after only 16-18 months of recovery, a trend of increase in numbers of flowers was observed in *A*. *nemorosa*, *P*. *erecta* and *S*. *columbaria*. Vegetation samples were collected to test for changes in plant cation uptake as well as differences in leaf N and P in response to N deposition.

Importance for DEFRA's environmental policy:

- This long-term field experiment provides definite proof of a causal relationship between N deposition and losses in biodiversity.
- Reduced flowering of forbs due to N deposition threatens the amenity value of species rich grasslands and provides a mechanism by which some key N-sensitive plant species may be declining.
- Examination of soil and plant chemistry aids in our understanding of underlying processes and their potential to recover.
- Long-term studies of impacts and recovery from N deposition are essential for understanding the time scales of these processes and their likely long-term consequences.

Nitrogen deposition impacts on phosphorus limitation in calcareous grasslands: A key driver of floristic change?

Gareth Phoenix and Jonathan Leake

Department of Animal and Plant Sciences, University of Sheffield, Western Bank, Sheffield, S10 2TN

The role of P in mediating the impacts of atmospheric N deposition on plant biodiversity may be particularly important in ecosystems where productivity is limited by P rather than N. In UK calcareous grasslands which are P limited, understanding what regulates species change is particularly important since these grasslands represent some of our most floristically rich ecosystems and have considerable conservation and amenity value.

Long-term (>15 years) experiments that simulate increased N deposition on P-limited calcareous grasslands at Wardlow Hay Cop (Peak District National Park) have allowed insight into the effects of N deposition on availability of P to plants and the mechanisms by which such effects occur. In these systems, increased atmospheric N deposition can reduce the plant available soil P pool and may therefore exacerbate P limitation to plants. Such increase in P limitation is seen further in the greater activity of root surface phosphatase enzymes in calcareous grassland plants under increased N deposition, indicating the increased P demand those plants are experiencing. Such exacerbation of P limitation may be further increased by (or partially caused by) the reduced functioning of mycorrhizal fungi (which play a central role in P acquisition) seen to occur in some calcareous grassland plants under enhanced N deposition. Many forb species of calcareous grassland are heavily mycorrhizal and so a reduction in their functioning could provide one mechanism by which forbs decline in these P limited systems. In contrast, sedges are known to increase their production of dauciform roots (specialist structures that are believed to enhance the uptake of P) under enhanced N deposition. Interestingly, sedges increase in abundance under enhanced N deposition. Following these lines of evidence, the possibility that it is tolerance of increasing P limitation -rather than a direct response to increases in N supply- that regulates species change in P limited calcareous grassland is discussed.

Reassessment of critical levels for atmospheric ammonia

J N Cape[1], L J Van der Eerden[2], L J Sheppard[1], I D Leith[1] and M A Sutton[1]

[1]*Centre for Ecology and Hydrology, (Edinburgh(, Bush Estate, Penicuik, EH26 0BQ*

[2]*Foundation OBRAS, Centre for Art and Science, Evoramonte, Portugal*

At the UNECE Ammonia Workshop held in Edinburgh in December 2006, new Critical Levels (CLE) were proposed for exposure of vegetation to gaseous ammonia. The annual value set in 1993, of 8 μg NH_3 m^{-3}, provides little additional protection compared with the Critical Load, because deposition rates of ammonia are such that dry deposition of the gas alone at these concentrations would lead to exceedance of the Critical Load. Evidence was presented from recent experiments and measurements close to large agricultural sources indicating effects of ammonia at much smaller concentrations. Although physiological and biochemical effects can be observed, only ecologically relevant effects such as changes in species composition demonstrate not only the potential, but actual adverse effects of ammonia on vegetation. For sensitive species such as lichens and bryophytes, a new long-term CLE based on changes in species composition was proposed, at 1 μg NH_3 m^{-3}. For higher plants there is less available evidence, but a value of 2-3 μg NH_3 m^{-3} was proposed. If these new CLEs are adopted, most of western Europe will exceed the CLE for ammonia. Although the data underpinning these proposals are mostly from the UK, confirmatory data are available from Portugal, Italy and Switzerland.

Elevated o_3 affected the mibcrobial community in a meadow soil

Sirkku Manninen[1], Hermanni Aaltonen[2], Ansa Palojärvi[3], Kaisa Rämö[1], Teri Kanerva[1]

[1]*Department of Biological and Environmental Sciences, University of Helsinki, Finland*

[2]*Department of Ecological and Environmental Sciences, University of Helsinki, Finland*

[3]*MTT Agrifood Research, Jokioinen, Finland*

Mesocosms mimicking a lowland hay meadow with two graminoid species (*Agrostis capillaris, Anthoxanthum odoratum*), three herbaceous species (*Campanula rotundifolia, Fragaria vesca, Ranunculus acris*) and two leguminous species (*Trifolium medium, Vicia cracca*), and pot-grown monocultures of *A. capillaris* and *Lathyrus pratensis* were exposed to elevated O_3 in open-top chambers (OTCs) at Jokioinen, SW Finland (60°49'N, 23°28'E), in the summers 2002-2004. The 9-hour average O_3 concentrations during the fumigations ranged between 31-33, 27-31 and 39-52 ppb at the open-field plots (AA), non-filtered air OTCs (NF) and non-filtred air + supplemental O_3 OTCs (NF+O_3), respectively. There were three replicates in each treatment. The soil was a mixture of coarse sand and low-fertility peat (1:1) , and we inoculated the legumes with approriate *Rhizobium*. The mesocosms and pots were fertilized twice in July 2002 and irrigated according to need.

The total PLFA (phospholipid fatty acid) biomass in mesocosm bulk soil samples increased markedly during the 3-year experiment in all treatments. In mid-September 2004, the bacterial and fungal PLFA biomasses were measured and found to be positively correlated with root biomass and with each other. On the other hand, we observed a decrease in actinobacterial PLFA biomass (-8%) and a decreasing trend in fungal PLFA biomass (-16%) in the NF+O_3 treatment compared to the NF treatment. Ozone did not affect bacterial and mycorrhizal PLFA biomass. The above-ground plant biomass was decreased by -40% and root biomass by -35%.

The results on pot-grown plants showed that both rhizosphere and bulk soil of *L. pratensis* had markedly higher PLFA biomass compared to those of *A. capillaris*. Elevated O_3 only had a marked negative effect on the total PLFA biomass of *L. pratensis* bulk soil (-25%). The decrease in the total PLFA biomass in the bulk soil of *L. pratensis* was related to reductions in signature indicators for the bacterial, actinobacterial and mycorrhizal PLFA biomass in the NF+O_3 treatment compared to the NF treatment.

We conclude that relatively low O_3 concentrations may induce (direct and/or indirect) changes in the microbial community in meadow soils. These changes depend, among other factors, on plant species composition and may lead to functional changes in soil ecosystem processes.

Plant and soil responses to ozone in a lowland raised mire

Sylvia Toet[1], Mike Ashmore[1], Phil Ineson[2] & Jeremy Barnes[3]

[1]*Environment Department, University of York, Heslington, York, YO10 5DD*

[2]*Department of Biology, University of York, Heslington, York, YO10 5YW*

[3] *School of Biology, University of Newcastle, Newcastle upon Tyne, NE1 7RU*

Ozone causes damage to sensitive crops, trees and semi-natural vegetation in Europe and other parts of the world at current levels. Background ozone concentrations are expected to increase further during the next decades. Risk assessment of ozone impacts on mires is essential, since (1) little data are available on the effects of ozone on plant communities of mires and on ecosystem functioning in general, and (2) mires are of conservation importance in the UK. The aims of this study were to assess the effects of elevated ozone on a mire ecosystem, including changes in methane emission, ecosystem respiration and plant processes.

Mesocosms from a lowland raised mire (Roudsea Wood and Mosses, Cumbria) with vegetation dominated by the peat moss *Sphagnum papillosum* and *Eriophorum vaginatum* (cotton sedge), were exposed for 18 months to control and elevated levels of ozone in open-top chambers. The control treatment received non-filtered air, whereas the elevated ozone treatment consisted of non-filtered air plus 75 ppb during the growing season, and an increased level of 10 ppb in winter (enhanced levels only for 8 hours during the daytime).

Methane emissions were significantly reduced by elevated ozone during the growing season of both years. Ecosystem respiration showed a small, but overall significant increase in response to elevated ozone. These ozone responses could not be related to changes in the plant community, since aboveground abundance and physiology of *Sphagnum papillosum* and *Eriophorum vaginatum* were not significantly influenced by increased ozone. Only length growth of *Sphagnum* tended to be negatively affected by elevated ozone, particularly in winter.

Hence, the results imply that increases in global background ozone concentrations that are predicted by models in the northern hemisphere over the 21st century may lead to a negative feedback on methane emissions from mire ecosystems. This study will be continued and more detailed studies of the underlying mechanisms of the observed carbon flux responses will provide key information for long-term predictions of ozone impacts on mire ecosystems.

Is our upland vegetation at risk from rising background ozone pollution?

Dr Gina Mills, Ms Felicity Hayes and Philip Williams

Centre for Ecology and Hydrology, CEH Bangor, Deiniol Road, Bangor, Gwynedd, LL57 2UP

Recent analysis has indicted that whilst there has been a gradual decline in the peak ozone concentrations over the last few decades, the background ozone concentration is steadily rising. Most ozone exposure experiments have investigated responses of vegetation to peak ozone concentrations, usually with a profile mimicking rural ozone (high mid-afternoon peak, low overnight concentrations). In our experiments, we have exposed plants and simulated communities typical of upland UK to ozone profiles that represent those currently experienced in Snowdonia, North Wales, together with those predicted for this area in 2040 and 2080.

Ozone exposure experiments were conducted in the CEH solardome facility at Abergwyngregyn, near Bangor, North Wales. Seven species typically found in upland grassland were exposed together with three species mesocosms (*Anthoxanthum odoratum, Viola rivinina and Carex flacca*) Plants were exposed to the following weekly regimes for ten weeks: “Pristine” (10 ppb for 3 days rising constant 30 ppb for 4 days), “Current polluted” (35 ppb for 3 days, 55 ppb for 4 days), “Current +25 ppb” (60 ppb for 3 days, 85 ppb for 4 days) and “Current + 50 ppb” (85 ppb for 3 days rising to 105 ppb for 4 days). Within four weeks, plants from the two highest treatments were showing signs of accelerated senescence. By the end of the exposure, *Viola riviniana* and *Carex flacca* showed the greatest response to ozone, with 26.5 and 20.5% respectively more senescence than the plants in the “pristine” treatment. When grown in a mesocosm, the dominant species, *Anthoxanthum odoratum* indicated a comparable response to ozone when grown alone. However, the low growing species, *Viola riviniana*, showed 50 % less response to ozone. The possible reasons for this and implications for policy will be discussed in the presentation. When the data for all exposures were combined, the threshold for response was an AOT40 of ca. 20 ppm h which was accumulated after ca. four weeks in the “Current+50” treatment and after ca. 8 weeks in the “Current +25 ppb”.

In summary, this study has the following relevance to Defra and international policy:

- Furthers our understanding of how ecosystems might respond to future ozone profiles
- Provides information on the mechanisms of plant responses within communities
- Gives an insight into factors that need to be taken into account for the identification of (semi)natural communities at risk of damage from ozone
- Provides valuable data for the potential revision of critical levels for (semi-)natural vegetation.

Derivation of detoxification algorithm for improved ozone risk assessment

Jeremy Barnes[1], Agnieszka Kaminska[1,5], Matthias Plöchl[2], Holly Smith[1], Daniel De la Torre[6], Mike Ashmore[3,4], Lisa Emberson [4]

[1] *Institute for Research on the Environment and Sustainability, Newcastle University*
[2] *Institute of Agricultural Engineering Bornim (ATB), Potsdam-Bornim, Germany*
[3] *Stockholm Environment Institute at York, University of York*
[4] *Environment Department, University of York*
[5] *Institute of Plant Physiology, Polish Academy of Sciences, Cracow, Poland*
[6] *Department of Ecology, University of Salamanca, Spain*

Existing approaches for modelling and mapping critical ozone fluxes employ an empirically-derived 'blanket' flux threshold, because there is presently no means to simulate the manner in which ozone detoxification potential is influenced by key environmental drivers. There is, however, growing recognition that impacts are governed by the balance between stomatal ozone uptake and cell wall-localised sinks for ozone (and its reactive derivatives) which also act as signalling mechanisms controlling injury expression. For many years, the Newcastle team have been interested in the role played by apoplast ascorbate (Vitamin C) as a forward defensive barrier against ozone – both as a sink for the pollutant (i.e. antioxidant; see Maddison et al., 2002 *Planta* **214**: 383-391) and as a sensor of oxidative-related stresses (i.e. redox signal governing the stimulation of a suite of defence reactions) (Pignocchi *et al.*, 2006 *Plant Physiol.* **141**:423-435). Using independent datasets where we recorded diel shifts in apoplast/symplast ascorbate pools in wheat flag leaves over a range of conditions, we have computed, using SODA (Plöchl *et al*., 2000 *Planta* **210**: 454-469) diel shifts in mesophyll resistance (and thus, conductance) to ozone. Taking the approach one stage further, we have been able to derive – within the limits of the available datasets - a multiplicative detoxification algorithm representing the manner in which key environmental drivers influence mesophyll conductance to ozone using an approach similar to that used (and accepted) for stomatal conductance by Emberson (Emberson *et al.*, 2000 *Environ. Poll*. **109**: 403-413). Employing this algorithm, which could be (and needs) further improvement through the generation of additional data, we can improve the existing computations of flux-response relationships for wheat, based on empirically-derived (ie non-biologically-based) flux thresholds.

This work has been funded by DEFRA, throughout..

Ozone effects on an upland grassland community

Neil Cape[1], Kerstin Wedlich[2], Mike Ashmore[2], Sylvia Toet[2], Simon Peacock[3], Jeremy Barnes[3]

[1]*Centre for Ecology and Hydrology,(Edinburgh), Bush Estate, Penicuik, EH26 0BQ*

[2]*Environmental Department, University of York;* [3]*University of Newcastle*

Grasslands cover large areas of upland Britain, where ozone exposures are predicted to increase over the next 50 years. A number of grassland species have been reported to be sensitive to ozone, and chamber experiments have shown shifts in species composition in grassland mesocosms in response to ozone. However, the relevance of these studies to the effects of ozone on species composition and ecosystem function in real grassland communities remains uncertain.

We report here plans for the first free-air fumigation experiment with ozone in an intact community in the UK. The experiment will be carried out on a mesotrophic grassland at an elevation of about 350m in Northumberland, which is under a management regime designed to increase biodiversity. The experiment, which is due to start in May 2007, aims to determine changes in species composition and ecosystem processes due to ozone concentrations typical of those expected in 2050-2080. The design of the free-air fumigations system and the results of pre-fumigation site surveys will be described in this paper.

Evidence of impacts of ambient ozone on vegetation across Europe

Felicity Hayes, Gina Mills, David Norris

Centre for Ecology and Hydrology,(Bangor), Deiniol Road, Bangor, Gwynedd, LL57 2UP

In 2007 there will be a review of the Gothenburg Protocol, the 1999 Protocol of the Convention of Long-range Transboundary Air Pollution, aiming to abate acidification, eutrophication and ground-level ozone (WGE, 2004). To coincide with this review, the ICP Vegetation is collating evidence of damage to vegetation in Europe caused by ambient ozone pollution over the time-scale 1990 – 2006 with the aim of quantifying the link between field observations and critical level exceedance. Three main types of data exist in published papers and reports: records of ozone injury recorded during field surveys, effects detected during biomonitoring exercises such as the ICP Vegetation clover network and effects detected experimentally by comparing responses of plants grown in ambient air with those exposed to air with reduced ozone content.

To date, over 500 records of incidences of ozone injury on vegetation are included in the ICP Vegetation database, although collection of data is still ongoing. Each record includes the country, grid reference, year of observation, species and species type. The database indicates that ozone-injury has been detected in 17 countries across the width and length of Europe and provides a clear indication that ozone injury is indeed very prevalent in countries experiencing high ozone fluxes. These results are backed up by ICP Vegetation biomonitoring studies in which an ozone-sensitive biotype of white clover has been exposed to ambient ozone at sites in ca. 15 countries each year. Ozone injury has been detected at almost every site in every year, with the extent of injury reflecting the fluctuating ozone climate. From all the studies conducted so far, it has been shown that trends in impact reflect the spatial and temporal variation in ozone concentration, with no marked decline or increase evident.

A comparison of plant responses in ambient air compared to filtered air experimental exposures is also being made as part of this study. Data collection is ongoing and the dataset currently comprises information for approximately 25 species in five countries. Responses noted include the development of visible ozone injury such as small yellow or bronze spots on the leaf surface, reductions in growth, seed production and/or ability to over-winter (for perennial species). Literature reviews and monitoring programmes conducted by the ICP Vegetation have therefore shown that over 100 species of crops and (semi-)natural vegetation are responding to ozone pollution at the concentrations currently experienced within the ECE region.

- Assessment of effects of ambient ozone on crops and semi-natural vegetation that are growing in natural conditions in the UK and Europe
- Linkage of observed effects with ozone concentrations and fluxes
- Identification of trends in impacts (over the last 15 years)
- Validation of Critical Level Exceedance Maps for Europe

A QTL for grain yield on 7AL of wheat is activated by ABA and low nutrient treatments during flag leaf ontogeny

Agnieszka Kaminska[1,2], Steve Quarrie[1], Ali Dodmani[1], Jeremy Barnes[1]

[1] *Institute for Research on the Environment and Sustainability (IRES), Newcastle University, U.K*

[2] *Institute of Plant Physiology, Polish Academy of Sciences, Cracow, Poland*

Little research has targeted the genetic control of traits governing ozone effects on cereals. In 2003 and 2005 we used open-top chambers to identify quantitative trait loci (QTLs) for ozone tolerance in 95 wheat doubled haploid lines generated from Chinese Spring x SQ1. Four plants per line were grown in non-filtered air (NFA) and NFA+50 ppb ozone, with four chambers/treatment. Considerable genetic variation between lines was evident in both years in both treatments, and there was good correlation between the response of lines in the different years. Ozone reduced yields from 0% to 56% (average by 18%) mainly due to significant reductions in grains/ear and thousand grain weight. Coincident QTL clusters governing yield in both treatments were identified on chromosomes 2AL, 2BS, 3AS, 3BS, 4BS, 4BL, 4DL, 5AS, 5DL, 6B and 7AL.

Interestingly, a homologous QTL (associated with a locus for SSR *psp3094*) governing yield on 7AL has been reported in many previous studies with the Chinese Spring (CS) x SQ1 mapping population during trials over 24 year x treatment x locations, with the QTL principally expressed in stressed environments. The QTL appears to be associated, in some way, with plant biomass and flag leaf (FL) width. To probe the nature of the QTL, near-isogenic lines (NILs) for the 7AL yield QTL were generated with CS or SQ1 alleles in an SQ1 background, selecting with *psp3094*. In field trials, the SQ1 allele was associated with 21% higher yield/ear, significantly higher FL chlorophyll content and wider FLs due to more cell files across the leaf. Subsequent controlled environment experiments on targeted CS-allele and SQ1-allele NILs, in which two replicate plants/NIL were subject to no treatment, low-light, low-nutrient or abscisic acid (ABA) spray treatments for two weeks during flag leaf emergence on the main stem of tillers 1 and 2, revealed no significant differences between CS-NILs and SQ1-NILs in FL width when treatments were administered when FL cell division was already complete. However, for FLs still undergoing cell division, final leaf width differed significantly between CS-NILs and SQ1-NILs, in ABA- and low-nutrient treatments (by 11.0% and 13.9%, respectively). Therefore, the 7AL yield QTL probably results from allele differences in a nutrient-regulated gene which determines termination of FL lamina lateral meristematic activity during leaf ontogeny, perhaps via an ABA-signalling pathway. A rice *AINTEGUMEN* candidate gene homologue which has an ABRE -607 bp upstream, is the principal candidate.

Impacts of ozone on semi-natural vegetation

Simon Peacock[1], Mike Ashmore[2] and Jeremy Barnes[1]

.....

[1]*Institute for Research on Environment and Sustainability, Newcastle University, Newcastle-upon-Tyne, NE1 7RU*

[2]*Environment Department, University of York, Heslington, York YO10 5DD*

.....

An update of ongoing DEFRA-funded work investigating impacts of present and future (2050) upland ozone climates on productivity and composition of i) long-established upland mesotrophic (NVC MG3b) grassland mesocosms, representative of contrasting management regimes, and ii) a legume-rich, fixed-dune (NVC SD9) grassland community.

We also report on preliminary outcomes of an ongoing OTC experiment investigating a range of ozone climates on several UK spring bulb species (*Liliaceae*) found in woodland, Wood margins and hedgerows.

Development of ozone flux modelling for semi-natural grasslands

Tim Morrissey[1], Mhairi Coyle[2], Andrew Terry[3], Lisa Emberson[1], Patrick Büker[1] and Mike Ashmore[3]

[1]*Stockholm Environment Institute, University of York, York, YO10 5DD*

[2]*Centre for Ecology and Hydrology (Edinburgh), Bush Estate, Penicuik, Midlothian, EH26 0QB*

[3]*Environment Department, University of York, York, YO10 5DD*

Ozone is an important photo-oxidant pollutant that has been shown to have an impact on semi-natural communities, which are important in the UK due to the large area they cover, much of which comprises pasturelands important for grazing as well as habitats high in conservation status. The development of the flux approach for risk assessment for semi-natural grasslands has been identified as a priority by UNECE for establishing emission control policy. At present, however, modelling risk of ozone impacts to semi-natural grasslands is problematic due to the diverse nature of functional groups within the canopy.

A deposition of ozone and stomatal exchange (DO_3SE) model has been developed by SEI for European scale flux-based risk assessment of ozone impacts on vegetation. This model has been coupled with a grassland growth model to simulate seasonal leaf are index (LAI). The DO_3SE model has been parameterised for the grass component of productive semi-natural communities. Here, provisional parameterisation of this grass component is evaluated using data (including stomatal conductance, soil water content, LAI and ozone flux variables) obtained at a grassland site in southern Scotland dominated by *Lolium perenne*.

Model estimates of bulk stomatal conductance and ozone deposition velocity were improved using climate specific parameterisation compared to "generic", Europe-wide values. Estimated bulk stomatal conductance had a strong relationship with modelled LAI, emphasising the importance of accurate simulation of LAI in estimates of ozone impacts.

The grassland DO_3SE model showed good agreement with measured values for bulk conductance early in the growing season (where average maximum values were in the rane 400-500 nmol O_3 m^{-2} PLA s^{-1}) but tended to overestimate conductance during summer by as much as 600 nmol O_3 m^{-2} PLA s^{-1} , most likely due to overestimates in either LAI or g_{max}. Where ozone deposition velocity observations were available for entire 24 hour periods, the DO_3SE model shoed good agreement with measured values, which were in the range 0.001-0.004 m s^{-1}. From this comparative study priority areas for the continued development of the grassland DO_3SE model were identified.

Turning the clock back - research into restoring the Southern Pennines after 200 years of air pollution

S J M Caporn, R Sen, N B Dise, C Field, J A Carroll and J J Rothwell

Department of Environmental & Geographical Sciences, Manchester Metropolitan University, Manchester M1 5GD

The Peak District moorlands in the Southern Pennines have suffered heavily from human activities over many centuries. Surrounded by major industrial cities and high populations these upland landscapes have been exposed to SO_2, soot, acid rain and metal deposition for over 200 years. In recent decades nitrogen based air pollutants and ozone have become of greater significance and continue to threaten sensitive ecosystems. In addition to pollution, humans have encouraged over-grazing and over-burning. Many square km of the Peak District moorlands are now highly eroded and bear no surface vegetation; the habitat quality is extremely poor and the continued erosion results in loss of stored carbon, colouration of drinking water and increased sediment loading to reservoirs.

The primary factor limiting ecological restoration on bare peat surfaces in the region appears to be soil acidity since liming benefits efforts to restore plant life. In the presence of lime the addition of nutrients (NPK) also has a positive influence. But what are the consequences of these agricultural-style additions to an already delicate moorland landscape? Are the advantages of restoring vegetation to the surface of the peat outweighed by the potential damage to wildlife and soils sensitive to lime and fertilizer?

In summer 2006 we started a new experiment to examine some of the consequences of liming and fertilizer treatments on the soil and plant communities. To date, lime has stimulated nurse grass growth especially when nutrients were also added. We expected that the rates of soil CO_2 loss would increase in the treated plots but this happened in only one of the eight months since the experiment and measurements began. The longer term consequences of the soil treatments on mineralization of stored carbon and other elements will depend to a large extent on the development of the soil microbes in the barren peat surfaces.