Institution: Manchester Metropolitan University (MMU)

Unit of Assessment: B7 Earth Systems and Environmental Sciences

Title of case study: The influence of MMU research on protecting and restoring ecosystems affected by air pollution.

1. Summary of the impact

This case study describes the impact of the research of the Centre for Earth and Ecosystem Responses to Environmental Change (CEEREC), MMU, on the protection and restoration of native ecosystems and upland semi-natural habitats that are affected by nitrogen pollution. CEEREC investigates the harm caused by nitrogen pollution to a range of semi-natural habitats. We also explore the impact of historic pollution in upland Britain and the potential for recovery through ecological restoration. Our research has informed evidence-based changes to UK, EU and US emission control policy and on the mitigation and restoration methods (e.g. 'BeadaMoss™) of pollution affected landscapes.

2. Underpinning research

Historic and current air pollution emissions from power generation, industry, transport and agriculture, remain a major threat to the provision of important ecosystem services from our natural capital. Since 1994, CEEREC has investigated the consequences of nitrogen pollution, acid rain and ozone on semi-natural vegetation in particular heathlands, grasslands and bogs. The research of CEEREC utilises field experiments and national surveys to show the harm caused by nitrogen pollution to a range of semi-natural habitats. Research is rooted in work on Welsh moorlands where long term nitrogen experiments since 1993 have highlighted the sensitivity to nitrogen pollution of ecological processes including raised nitrogen leaching, base cation depletion, increased winter injury, loss of lichens and bryophytes **[1]**. This work has been undertaken within the context of NERC and DEFRA research programmes **[G1]**, **[G2]**.

The arrival of Dise in 2005 broadened CEEREC's interests to include landscape studies of nitrogen impacts on various plant communities. Research on acid grasslands found a decline in species richness of western European grasslands in response to pollutant nitrogen (ESF BEGIN consortium project, 2006-2009, €760k) **[2], [3]**. MMU led a project on pollution indicators within the DEFRA programme with York, Imperial, Sheffield Universities, Centre for Ecology & Hydrology and the James Hutton Institute on the effects of acidification and eutrophication on terrestrial ecosystems and their recovery' **[4]**, **[G1]**, **[G3]**. Our research demonstrated the similar vulnerability to air pollution of five very distinct habitats across the UK. Our research on plant community composition expanded when Dise lead a European consortium of 50 academics and practitioners exploring the impacts of pollution, precipitation and temperature on peatland biodiversity and biogeochemistry from southern Europe to the Arctic **[G4]**, **[G5]**. Caporn's research on heathlands **[5]** showed that these systems impacted by nitrogen pollution would only recover slowly due to the effects of long-term nitrogen accumulation. In the Pennine moorlands where acute historic pollution contributed to catastrophic degeneration, CEEREC demonstrated that intervention measures were required to restore plant communities and some degree of ecosystem function, **[7]**.

In the southern Pennines, air pollution has played a significant historical role in peatland degradation. Our research reported in Bonn et al 2009, **[A]**, on the natural recovery of *Sphagnum* in the southern Pennines **[T1]**, **[T2]**, showed that air quality in the Peak District National Park is now at least adequate for restoration of *Sphagnum*. This is the keystone species of active, healthy peatlands providing vital ecosystem services including water management and carbon sequestration. In collaboration with Moors for the Future **[G6]**, Sen demonstrated that microbial succession accompanies vegetation re-establishment of bare peat, crucial knowledge underpinning the costly peatland restoration procedure. Sen has applied DNA-based functional micro-biomics to improve understanding of functional nitrogen-cycling in soil and the associated plant root microbial drivers in peatland restoration. CEEREC has explored novel techniques to restore *Sphagnum* moss on many degraded peat soils and its research and knowledge transfer is leading scientific approaches to *Sphagnum* bog restoration in the UK. Indeed the *Sphagnum* project had impact imbedded into it from the outset being commissioned by Moors for the Future and biotechnology SME Micropropagation Services Ltd **[6]**

Key staff:

Simon Caporn (Reader, 1994 – present), Nancy Dise (Professor, 2005-present),

Robin Sen (Reader, 2006 -present)

Esteem and recognition:

Caporn: Natural England Upland Evidence Review, invited panel member 2012-2013.

Dise: Associate Editor, Biogeochemistry (2005-12); Ecosystems (2003-5); Review Panels for EU 7th framework, EU 6th framework, US National Science Foundation, NERC Directed Programme QUEST; member NERC College, 2005-8

Sen: Editorial board ISRN Soil Science (2011-onwards). Editorial Advisor to the *New Phytologist* 1994 - 2008.

3. References to the research (CEEREC scientists in bold font)

[1] Carroll J.A., Caporn S.J.M., **Cawley, L**., Read D.J., Lee J.A. 1999.The effect of increased atmospheric nitrogen deposition on *Calluna vulgaris* in upland Britain. *New Phytologist* 141:423-431. **DOI:** 10.1046/j.1469-8137.1999.00358.x, *(67 citations)*

[2] Payne R, Dise NB, Stevens CJ, Gowing DJ, Begin partners (2013). Impact of nitrogen deposition at the species level'. Proceedings of the National Academy of Science 110:984–987.

DOI: 10.1073/pnas.1214299109, *(6 citations)*

[3] Stevens CJ, Dupre C, Dorland E, Gaudnik C, Gowing DJG, Bleeker A, Diekmann M, Alard D, Bobbink R, Fowler D, Corcket E, Mountford JO, Vandvik V, Aarrestad PA, Muller S and **Dise NB** (2010) Nitrogen deposition threatens species richness of grasslands across Europe. *Environmental Pollution* 158: 2940-2945. **DOI:** 10.1016/j.envpol.2010.06.006, *(53 citations)*

[4] Phoenix GK, Emmett BA, Britton AJ, **Caporn SJM, Dise NB**, Helliwell R, Jones MLM, Leake JR, Leith ID, Sheppard LJ, Sowerby A, Pilkington MG, Rowe EC, Ashmore MR, Power SA (2012). Impacts of atmospheric nitrogen deposition: responses of multiple plant and soil parameters across contrasting ecosystems in long-term field experiments. *Global Change Biology* 18: 1197–1215

DOI: 10.1111/j.1365-2486.2011.02590.x, *(17 citations)*

[5] Edmondson J, Terribile E, Carroll JA, Price EAC & Caporn SJM (2013) The legacy of nitrogen pollution on heather moorlands: ecosystem response to simulated decline in nitrogen deposition over seven years. The Science of the Total Environment 444:138–144 **DOI:** 10.1016/j.scitotenv.2012.11.074

[6] Hinde S, Rosenburgh A, Wright N, Buckler M & **Caporn** S. 2010 *Sphagnum* re-introduction project: A report on research into the re-introduction of *Sphagnum* mosses to degraded moorland. *Moors for the Future Research Report No. 18,* Edale, Derbyshire.

[7] Sen R, Elliott D, Nwaishi F, Smith G, Caporn S (2011). Impacts of moorland restoration on diversity and distribution of plant growth promoting root symbiotic mycorrhizal fungi and associated soil nitrogen cycling bacteria/archael communities in the southern Pennines. Research Report to Moors for the Future, Peak District National Park, Edale. Derbyshire. March 2011.

Key Grants (Indicators of Research quality):

[G1] DEFRA/NERC Terrestrial Umbrella research programme on the effects of eutrophication and acidification on terrestrial systems (2001-2011). Work package leader (2007-11): Caporn (£110,000) Defra contract nos. AQ0802

[G2] NERC thematic programmes 'Environmental Diagnostics' and 'Global Atmospheric Nitrogen Enrichment' (1998-2004), MMU direct funding. PI: Caporn (£50k)

[G3] Natural England Assessing effects of small increments of atmospheric nitrogen deposition (above the critical load) on semi-natural habitats of conservation importance. (2011) PI: Caporn. (£21,000), SAE03-02-406

[G4] EU FP7, Framework Biodiversa programme PEATBOG (Pollution Precipitation & Temperature Impacts on Peatland Biodiversity & Biogeochemistry) 2009-12. NE/G002363/1 PI: Dise (€1.6 M) (http://www.biodiversa.org/484)

[G5] NERC studentship Climate change and salinity impacts on coastal peatlands PI: Dise, £73,000, (Sept 1st 2013-2016, NE/L501992/1)

[G6] Five grants from Moors for the Future (2008 - 2013). PIs: Caporn & Sen (£20K)

4. Details of the impact

Principal impacts arising from our research were evidence to government and NGOs on the risks to biodiversity from air pollution and the development of methods and policies for upland peatland restoration and re-establishment of *Sphagnum* moss.

Impacts on policy of air pollution effects on ecosystems:

Critical loads are used by government and NGOs to inform decision-making on planning applications for industry and agriculture. A report commissioned by Natural England **[B]**, in which CEEREC were lead authors, assessed the effectiveness of nitrogen critical loads, **[T3]**, and CEEREC jointly authored a DEFRA report (June 2013) evaluating the effect of N deposition reduction on ecosystems. "[CEEREC research] *has made an important contribution to the body of evidence … used in supporting our advice to government on the risks to biodiversity, in the context of the … new Common Agricultural Policy programme and .. the Government's commitments to enhancing biodiversity under Biodiversity 2020."* (Natural England, **[T4]**). CEEREC played a key role in evaluating pollution bio-indicators for the protection of biodiversity for the *Joint Nature Conservation Committee* **[C]**. Dise co-authored the influential paper in PNAS, **[2]**, calling into question the basis of the Critical Loads policy for protecting biodiversity: "In some cases, such as the Payne *et al*. paper ....advances may cause us to reconsider the fundamental concepts that underlie the policy" **[D]**. MMU field research was used as evidence for setting critical loads of nitrogen pollution for heathlands in the 2010 European *Review and revision of empirical critical loads and dose-response relationships*, Bobbink and Hettelingh 2010, ISBN: 978-90-6960-251-6.

Caporn and Dise have provided expertise and advice to UK DEFRA policy advisors at twice-yearly consortium meetings, 2001-2011. Dise was lead author on a chapter of the 2011 European Nitrogen Assessment on 'Nitrogen as a threat to European terrestrial Biodiversity' **[5]**, **[E]**, informed by her grassland research. A work package *Indicators of N deposition and its ecological impact* lead by Caporn and Dise, **[F]**, also led to them authoring sections on nitrogen impacts in the 2012 UK Review of Transboundary Air Pollution report (ROTAP, 2012, **[I]**) which is the background to DEFRA's strategy on air quality and ecosystems. Caporn sits on the steering committee for CAPER (UK Committee for Air Pollution Effects Research) which has met six times, 2008-13. CAPER holds annual conferences to communicate outcomes to end users (e.g. DEFRA, EA, Natural England and Natural Resources Wales). In July 2013 the PEATBOG project was one of only two EU funded projects from the 'Biodiversa' 1ST round to provide the basis for policy briefs to the EU. These briefs were prepared by Dise for environmental policy representatives all Member Nations, the EU Environmental Attaché and other parties for direct input into policy on mitigating climate change and air pollution emissions. *"MMU have been instrumental in considering complex, multidisciplinary responses to restore habitats to favourable conservation status"* (Chair, Air Pollution Information System Steering Group and Senior Pollution and Climate Advisor, Natural Resource Wales, **[T3]**.

Mitigation and restoration of pollution affected landscapes:

Natural England is working closely with MMU on an innovative and productive project to re-establish *Sphagnum* moss at a landscape scale across the uplands of England, **[T1]**. Moors for the Future commissioned a report from CEEREC advising on restoration strategies, **[G]**. CEEREC provided key advice on the potential for successful *Sphagnum* restoration and extensive technical advice on an advisory group which oversees this work. Atmospheric pollution leaves a legacy of negative environmental effects. A consortium including MMU advised Natural Resources Wales in April 2013 on management options to reduce the impact of nitrogen accumulation in different habitats. The collaborative work on *Sphagnum* moss with Moors for the Future (2008-2013) and Micro-Propagation Services Ltd (2008-2013) has provided commercial impact since October 2012 proving that that planted *Sphagnum* in a novel form called BeadaMoss™ produced by Micropropagation Services Ltd, could establish and grow in harsh upland conditions. *"MMU has enabled our business to commercially develop our new Sphagnum product and have been greatly assisted by having sound scientific data. It has enabled us to be seen with credibility and to*

successfully deal with NGOs, large businesses and government bodies" **[T5]**. This knowledge gives valuable underpinning to the £5.5 M EU-funded 'Moorlife' moorland restoration project (2010-2015). (http://www.moorsforthefuture.org.uk/sphagnum-project) as articulated by Moors for the Future, "*this programme of research by MMU has provided an incredibly valuable body of evidence that has enabled us to effectively communicate to policy makers and funding bodies to successfully secure funding to continue restoration and land management and informed the development of restoration methods to increase efficiency and efficacy",* **[T2]***, Letter from Research Manager, Moors for the Future).* The impact of CEEREC's research has been to support the re-vegetation of around 2500 hectares of previously bare and degraded upland peat soils in the Peak District National Park. In 2012 our research gained media exposure through interviews on BBC Radio 4 (Costing the Earth, 14.3.2012); local BBC stations (Radio Stoke, 25.9.2012; Radio Manchester, 26.9.2012) and articles in The Sunday Times (23.9.2012). Our expertise was acknowledged by Natural England who appointed Caporn as one of two academics to the Upland Evidence Review panel on upland restoration (2012-2013), (http://www.naturalengland.org.uk/ourwork/uplands/reviewgroups.aspx)

5. Sources to corroborate the impact

Testimonials available on file from:

[T1] Upland Ecology Specialist, Natural England

[T2] Research Manager, Moors for the Future Partnership, Peak District National Park *(Letter corroborating claims of landscape-scale restoration of moorlands with sphagnum)*

[T3] Senior Pollution Impacts Adviser, Natural Resources Wales *(Letter corroborating impacts on air pollution conservation)*

[T4] Senior Air Quality Specialist, Land Use Strategy and Environmental Specialist Services Unit, Natural England

[T5] Managing Director, Micropropagation Services Ltd, Leicestershire *(Letter corroborating claims of scientific underpinning of BeadaMoss)*

Impact References (Reports to end user community, CEEREC scientists in bold font)

[A] Bonn A, Allott T., Hubacek K., Stewart J., 2009. *Drivers of Environmental change in Uplands*, Abingdon, Routledge.

[B] Caporn, S., Field, C., Payne, R., Dise, N., Britton, A., Emmett, B., Jones, L., Phoenix, G., Power, S., Sheppard, L., Stevens, C. (2011). Assessing the effects of small increments of atmospheric nitrogen deposition (above the critical load) on semi-natural habitats of conservation importance. A commissioned *Report to Natural England, contract SN218. London.*

[C] Stevens, C.J., **Caporn**, **S.J.M**., Maskill, L.C.' Smart, S.M., **Dise, N.B**. and Gowing, D.J. 2009. Detecting and Attributing Air Pollution Impacts during SSSI Condition Assessment. *Joint Nature Conservation Committee Rpt. No*:426. (http://jncc.defra.gov.uk/page-4961), accessed 11/11/ 2013

[D] Lovett GM., (2013) Critical issues for critical loads, Proceedings of the National Academy of Science 110, 808-9

[E] Sutton MA, Howard C, Erisman J-W, Billen G, Bleeker A, Grennfelt P, van Grinsven H, and Grizzetti B (eds.) (2011) *The European Nitrogen Assessment*. Cambridge UK: Cambridge University Press (http://www.nine-esf.org/ENA-Book), accessed 11/11/ 2013

[F] UKREATE 2010 Terrestrial Umbrella: Effects of eutrophication and acidification on terrestrial ecosystems. CEH contract report NEC03425. Defra contract nos. AQ0802.

[G] Carroll JA, Anderson P, **Caporn**, S., Eades, P., O'Reilly, C. & Bonn, A. 2009. *Sphagnum* in the Peak District: Current Status and Potential for Restoration. A commissioned report for *Moors for the Future, Report* No 16, Edale, Derbyshire.

[H] Associate contributors **Dise** and **Caporn** 2012 UK Review of Transboundary Air Pollution (www.ROTAP.ceh.ac.uk) report to DEFRA, accessed 11/11/ 2013