1. **The forested-to-open bog ecotone in naturally and artificially forested peatlands (PEATEDGE).**
Group leader: Dr Richard Payne, University of Stirling, UK.
Sites of Research: Mukhrino, Russia (plus Caithness, Scotland and North American sites TBC)
Project Duration: 10 days (30 man-days) mid-August 2014.
Call date: 30/9/2013.

2. **Background**

Peatlands are the largest terrestrial carbon (C) store by area. Covering 2-3% of the global land surface, they store the equivalent of half the carbon that is in the atmosphere as CO_2 (Dise 2009). Peatlands develop due to an imbalance between primary production and decomposition, with anoxic, acidic and nutrient-poor conditions leading to the accumulation of carbon as peat. During the Holocene global peatlands have exerted a net cooling effect on global climate through the sequestration and storage of atmospheric CO_2 (Frolking & Roulet 2007). The global peatland carbon pool is currently estimated at 547 PgC (Yu et al. 2010); release of even a relatively small proportion of this pool has the potential for important climate feedbacks, particularly if released as methane (Smith et al. 2004). Uncertainties about the direction and magnitude of these feedbacks constitute one of the greatest unknowns in climate modelling (Friedlingstein et al. 2006). In the United Kingdom peatlands are an important carbon resource storing more than 30X as much C as vegetation (Milne & Brown 1997). Peatlands in many parts of the world contain trees, however in contrast to more continental northern regions most UK peatlands are not naturally forested. Since the 1920s almost a tenth of UK peatland area has been planted with non-native conifers due to increased timber requirement, reduced imports and tax breaks for planting (Hargreaves et al. 2003). These artificially-afforested peatlands are not equivalent to naturally-forested peatlands in other regions of the world or to the forests which existed on UK peatlands earlier in the Holocene (Pennington 1974). In artificially-afforested peatlands tree species composition differs and ditches were dug and fertilizer applied. Afforestation affects the crucial carbon storage function of peatlands as carbon biomass is shifted from peat to trees, peat accumulation ceases and relict peat is respired leading to increasingly negative carbon balance (Cannel & Milne 1995; Hargreaves et al. 2003). Globally there is evidence for greater tree cover in boreal regions during warmer periods in the Holocene and suggestions that tree cover is currently expanding (MacDonald et al. 2008). Studies have suggested increasing tree recruitment and survival on previously open tundra (Esper & Schweingruber 2004; Shiyatov et al. 2005) and a systematic increase in tree cover in Russian peatland areas (Shiyatov et al 2005). It is conceivable that increasing tree cover might endanger the carbon storage function of peatlands by shading out *Sphagnum* species and their replacement by non-peat-forming species with more labile litter, but this process is poorly understood and little-studied.

Our research investigates the potential impacts of plantation forestry and climate-induced tree encroachment on the ecology and biogeochemical functioning of northern peatlands. We are currently researching the impact of afforestation on peatland carbon stock and peatland microbial communities in northern Scotland as part of research funded by the Carnegie Trust, The Conservation Volunteers, Royal Society and British Ecological Society. The particular focus of our proposal to INTERACT is the forested-to-open bog ecotone. This ecotone is an important biodiversity hotspot in the boreal landscape hosting a high diversity of species at multiple trophic levels (Avery & Leslie 1990, Walker et al. 2003, Spitzer 1999) and forming an important carbon sink function (Rapalee et al. 1998). We aim to characterise the forested-to-open bog ecotone, identify warning signs of tree encroachment and compare ecotones in afforested and naturally forested bogs. Current guidance from the UK Forestry Commission requires the creation of natural transition zones at the forested-to-open bog margin (Paterson & Anderson 2000). Subsequently, there is a great deal of interest in how these ecotones compare between afforested and naturally forested peatlands in other regions of the world. This research will establish a baseline ‘natural’ state to inform management of UK peatland margins in order to maximise the benefits of ecotones for biodiversity and ecosystem services.

3. Objectives

The aims of the project proposed here are to:

- Characterise the open-to-forested bog ecotone in naturally forested peatlands in terms of biodiversity and ecosystem function.
- Compare this ecotone to those in artificially afforested peatlands.
- Establish a baseline state to inform management of afforested peatland margins.
- Develop ideas for future collaborative research with Russian colleagues

The key hypotheses we will test are:

- There are distinct above-ground (vascular plant and bryophyte) and below-ground (testate amoeba) biota associated with forested and open-bog habitats (**H1**).
- Above-ground and below-ground biodiversity are maximised at the ecotone with higher diversity than both forested and open habitats (**H2**).
- Naturally forested peatlands support higher plant and microbial diversity than afforested peatlands (**H3**).
- There are systematic differences in peat physical conditions (pH, conductivity, soil moisture, humification) and ecosystem function (soil respiration) between naturally forested and artificially-afforested peatlands (**H4**).
- The structure of natural forested-to-open bog ecotones is fundamentally different from those in afforested peatlands (**H5**).

The project will directly contribute to the goals of INTERACT. The proposal addresses both a question of global environmental change –tree encroachment on open peatlands- and a more focussed management question –how to improve ‘naturalness’ of afforested peatland margins. The PI is relatively early-career (7 years post-PhD), none of the team have received previous INTERACT funding and the project focuses on comparison of UK and International field sites and therefore contributes to the INTERACT aim of promoting and integrating transnational research. The project will build capacity by training young researchers and providing pilot data for future larger research projects and funding applications.

4. Research Methods

To address these questions we propose a study based on comparison of sites where we are currently working in northern-most Scotland and Mukhrino, Russia. We request INTERACT support for the Russian component of the project as the UK work will be supported by other funding sources. We aim for this work to form part of a global study and are currently seeking funding for other comparative work at non-INTERACT sites in North America and Northern Europe. Mukhrino makes a particularly suitable site as it includes both open and forested bog habitats in close proximity to the field station, these peatlands are essentially pristine and representative of the vast Western Siberian peatlands (the largest in the world), and the region is at a similar latitude (60°N) to our UK site (58°N) and candidate American sites (~60°N).

Research will be carried out during a single sampling campaign in August 2014. We will:

- Locate approximately eight transects from forested bog to open bog which are representative of peatlands in the immediate vicinity of the Mukhrino station. These transects will bisect the full gradient from treeless open bog to forested bog and will be positioned to sample the variability within the site.
- We will conduct vegetation surveys along these transects. 1x1m vegetation quadrats will be positioned at regular and consistent intervals, vascular plant and bryophyte plant species identified to species level using published taxonomic literature and cover estimates recorded on the DOMIN scale. This vegetation survey will allow us to address H1-H3.
- For at least two transects at the same positions as the vegetation survey, bryophyte samples will be extracted for testate amoeba analysis. Testate amoebae (TA) dominate the eukaryotic biomass of the *Sphagnum* bryosphere, constituting more than a third of total microbial biomass in some studies (Gilbert et al. 1998). TA have been shown to respond to a variety of experimental treatments and

environmental gradients with important roles in the microbial food-web and nutrient cycling. Recent studies have suggested intimate associations between TA and DOC production (Jassey et al. 2013), mycorrhizal fungi (Wilkinson & Mitchell 2010) and perhaps methanotrophy (Payne 2012). Testate amoebae will be extracted using a water-based preparation method and microscopically identified to species level based on the established literature. This data will allow us to assess the below-ground diversity of sampling locations to address H1-H3.

- At the same locations we will record a number of physical parameters. Porewater samples will be extracted using rhizon samplers and pH, electrical conductivity and colour recorded. Sub-surface peat samples will be extracted and humification recorded on the von Post scale. Water table depth will be recorded after adequate equilibration time. This data will both aid interpretation of biotic gradients (H1-H3) and allow us to address gradients in peat physical condition (H4).
- Along at least three of these transects (more if possible) we will conduct measurements of soil respiration using an infrared gas analyser (PP-systems EGM-4) with a dark, fan-equipped closed chamber. Fluxes will be calculated and normalised for variability in temperature. This data will allow us to address H4.
- Data will be analysed using a combination of appropriate statistical techniques including: 1) linear and non-linear regression (e.g. piecewise regression) to identify correlations and structure within transects (H2, H4, H5). 2) General linear models to test difference between sites and locations (H1, H3, H4). 3) Ordination techniques for multivariate data to test links between biota and physical conditions (e.g. redundancy analysis: H1-H4) and to summarise gradients in multivariate data (e.g. principle response curves: H1-H3).
- All of these measurements will be compared to new and existing data *following exactly the same methodology* for comparative afforested sites in Scotland. We aim also to produce further comparative data from other boreal regions. This comparison will allow us to address H3-H5.
- By discussion with stakeholders in peatland science, conservation and land management we will use these data to consider methods by which peatland plantation margins can be better managed.

We believe Mukhrino is the most appropriate INTERACT station to conduct this work due to the presence of both forested and open bog and the availability of comparative data from other INTERACT-supported projects. We are however happy to discuss the possibility of working at other stations if required.

5. Implementation

The INTERACT-funded portion of the project will be conducted by a team of three (the PI, testate amoeba specialist Angela Creevy and peatland carbon specialist Joshua Ratcliffe) in a ten-day research trip in late summer 2014. We propose to coordinate our visit with that by colleagues from the University of the Highlands and Islands (PI: Dr Roxane Andersen) who are carrying out INTERACT-funded research on BVOC and DOC concentrations at Mukhrino. To allow comparability of results we will sample in the same locations wherever possible and jointly coordinate logistics. We also plan to coordinate our work with previous sampling by Prof Mariusz Lamentowicz (University of Poznan, Poland) who has sampled some of the same variables in the Mukhrino site. We budget the project at a total of €4100 (below). This constitutes excellent value for money as testate amoeba analysis, data analysis and UK fieldwork will be supported by grants from the Carnegie Trust, Royal Society, British Ecological Society and The Conservation Volunteers totalling more than £67,000GBP. Logistical needs of the project are relatively simple. As the core work will be done in the field import and export licenses should not be required, the main permitting requirement will be for appropriate visas.

Budget (total for 3 people)

Item	Cost (Euros)	Justification
Visa	340	Visa cost based on standard rates.
International travel	2400	Air fares from London to Khanty-Mansiysk.
UK travel	600	Based on flights from London.

Russia travel	200	Travel between airport and field site
Hotel accommodation	560	Due to flight timings overnight accommodation in Khanty-Mansiysk is required
Total	4100	

6. Expected Results

This project will contribute novel data on the forested-to-open bog ecotone and how it varies between naturally and artificially afforested peatlands. Our project is highly applied, focussed in particular on the question of how to make the margin of peatland plantations more 'natural' as mandated by the UK Forestry Commission. Results will therefore directly inform practise in the UK and will be of widespread interest to stakeholders in peatland conservation and land management. We work extensively with stakeholders and will use these personal contacts as well as forums such as the Flow Country Conference to disseminate the results. We anticipate the project leading to at least one high-profile publication in an international journal. The project makes use of well-established methods and builds on our previous research to give a very low risk of failure. We will make use of online appendices and data repositories to publish complete datasets where possible. As the results of the project will be particularly interesting to stakeholders who do not usually have subscription journal access we will aim to publish the paper in an open access journal. The University of Stirling have funding available for open access publication. We anticipate the project leading to future research avenues. We plan to apply for funding from other sources (RGS, RSGS, BES) to produce further comparative datasets from Alaska, Quebec and Finland. We also anticipate contacts with Russian colleagues leading to collaborative projects. We are particularly interested in the possibility for a network proposal (COST or Leverhulme Trust) bringing together peatland OTC warming experiments as there is such an experiment at Mukhrino and we maintain our own very similar experiment in the UK.

7. Key Literature

<u>Publications by user-group:</u>

Payne, R.J. (in press) Seven reasons why protists make useful bioindicators. *Acta Protozoologica*.

Payne, R.J., Jassey, V.E.J., Leith, I.D., Sheppard, L.J., Dise, N.B. & Gilbert, D. (2013) Ammonia exposure promotes algal biomass in an ombrotrophic peatland. *Soil Biology and Biochemistry* 57, 936-938.

Payne, R.J., Stevens, C.J., Gowing, D.J. & Dise, N.B. (2013) Impact of nitrogen deposition at the species level. *Proceedings of the National Academy of Sciences of the* USA 113, 984-987.

Payne, R. (2011) Can testate amoeba-based palaeohydrology be extended to fens? *Journal of Quaternary Science*, 26, 15-27.

Payne, R., Charman, D. & Gauci, V. (2010) The impact of simulated sulfate deposition on peatland testate amoebae, *Microbial Ecology*, 59, 76-83.

<u>Cited Literature:</u>

ACIA (2004) Cam Uni Press **Avery** & Leslie (1990) Birds and Forestry. London, UK: T. & A.D. Poyser. **Dise** (2009) Science 326 810-811**Gorham** (1991) Eco Applications 1 182–195 **Cannell & Milne** (1995) Forestry 68 361-378 **Dise** (2009) Science 326 810 **Esper & Schweingruber** (2004) Geophys Res Let, 31 **Friedlingstein** (2006) 19 3337-3353 **Frolking & Roulet** (2007) Glo Change Bio 13 1079-1088 **Gilbert** et al (1998) Microb Ecol 5 83-93 **Hargreaves** et al (2003) Forestry 76 299-317 **Jassey** et al (2013) Glob Change Biol 19 811-823. **Karel** et al (1999) J Insect Conserv, 3: 97-106. **MacDonald et al** (2008) Phil Trans Royal Soc Bio Sci 363 2283-2299 **Milne & Brown (1997)** Enviro Manage 49 413-433 **Paterson & Anderson** (2000) Forestry Comission **Payne** (2012) Quat Int 268 98-110. **Pennington** (1974) English University Press **Spitzer** (1999) Insect Cons 3: 97-106 **Rapalee** et al (1998) Glob Biogeo Cycles 12 687-701 **Shiyatov** (2005) Russ. J. Ecol. 36, 69–75 **Smith et al** (2004) Sci 303 353-356. **Walker** et al (2003) Veg Sci 14 579-590 **Wilkinson** *&* Mitchell (2010) Geomicrobiol, 27, 520-533 **Yu et al** (2010) Geophys Research Let 37 L13402.