Sphagnum-Specific Structural Polysaccharides Play an Important Role in Decay Resistance and Active Depression of Decomposition in Bogs

Tomáš Hájek*[1,2], Simon Ballance[3], Juul Limpens[4], Mink Zijlstra[4], and Jos T.A. Verhoeven[5]
[1]Institute of Botany of ASCR, Dukelská 135, 379 82 Třeboň, Czech Republic (hajek@botany.cas.cz)
[2]Faculty of Science, University of South Bohemia, Branišovská 31, 370 05 České Budějovice, Czech Republic [3]Norwegian Biopolymer Laboratory (NOBIPOL), Department of Biotechnology, Norwegian University of Science and Technology (NTNU), N-7491 Trondheim, Norway[4]Nature Conservation & Plant Ecology Group, Wageningen University, Droevendaalsesteeg 3a, 6708 PB Wageningen, The Netherlands [5]Landscape Ecology Group, Utrecht University, Prof. dr. F.A.F.C. Wentgebouw. Sorbonnelaan 16. 3584 CA Utrecht, The Netherlands

***Sphagnum*-dominated peatlands head the list of ecosystems with the largest known reservoirs of organic carbon. The bulk of this carbon (C) is stored in decomposition-resistant litter of one bryophyte genus: *Sphagnum*. Understanding how *Sphagnum* litter chemistry controls C mineralization is essential for understanding potential interactions between environmental changes and C mineralization in peatlands.**
We aimed to separate the effects of phenolics from structural polysaccharides on decay of *Sphagnum* litter. Four experiments were set up in which we measured aerobic microbial respiration of different moss litter types in a lab environment. For the first three experiments we used chemical treatments to step-wise remove or de-activate the chemical compounds thought to be important in decay-resistance in three taxonomically distant moss genera (*Sphagnum*, *Leucobryum* and *Polytrichum*). In the last experiment we focused on the effect of *Sphagnum*-specific cell-wall pectic polysaccharides (sphagnan) on C and N mineralization.

Removing phenolics, be they extractable (poly)phenols or insoluble lignin-like polymers, had only negligible effects on C mineralization of *Sphagnum* litter, but increased mineralization rate of the other two bryophyte genera suggesting a minor role of phenolics in decay resistance of *Sphagnum* but a major role of cell-wall polysaccharides. Further experimentation showed that the carboxyl groups of cell-wall-bound pectin-like polysaccharides represented a C-source in non-*Sphagnum* litters but resisted decay in *Sphagnum*. Finally, isolated *Sphagnum*-specific sphagnan did not serve as C-source but instead, it inhibited C and N mineralization of cotton grass litter, reminiscent of the effects reported for phenolics in other ecosystems.

Our results emphasize the role of polysaccharides in resistance to, and active inhibition of, microbial mineralization in *Sphagnum*-dominated peatlands. It remains speculative whether this biochemical alternative to phenolics in the plant world will respond differently to environmental processes. It is possible that primary metabolites such as cell-wall polysaccharides are less controlled by environmental factors than secondary plant metabolites, such as monomeric phenolics, presumably making a polysaccharide-dominated litter system more resistant to environmental changes.

Multiproxy Records of Holocene Climate and Carbon Dynamics from a Subarctic Permafrost Peatland, Northern Québec

Marilou Hayes*[1,2], Alexandre Lamarre[1,2], Michelle Garneau[1,2] and Jean-François Hélie[2]
[1]Geography department, Université du Québec à Montréal, Montréal, QC, Canada (marilhayes@hotmail.com). [2]Centre de recherche en géochimie et en géodynamique (GEOTOP UQAM-McGill, Université du Québec à Montréal, Montréal, QC, Canada

The present research project aims at evaluating the influence of Holocene climate variations on carbon dynamics in a discontinuous permafrost peatland at Kuujjuarapik, northern Quebec. The objectives of the study are to reconstruct relative changes in temperatures and hydrology during the mid- and late-Holocene in order to identify the influence of climate on peat accumulation. Analyses of pollen, stable isotopes in *Sphagnum* cellulose, and testate amoebae were completed on cores from palsa, thermokarstic filled pond, and along the forest-peatland transition. This studied palsa field has evolved from shallow ponds to fen and bog in some sectors (Arlen-Pouliot & Bhiry, 2005). The development of the peatland has been mainly controlled by autogenic processes, while permafrost aggradation was associated to the LIA cooling as shown by the macrofossils assemblages. Stable isotopes signature in cellulose moss material (Ménot-Combes et al., 2002) and testate amoebae water table reconstructions (Booth, 2008) have improved the paleoecologic interpretation and added information about climatic conditions that influenced palsa development. Few studies have been conducted about carbon in permafrost peatlands (Vardy et al., 2000) and the consequences of temperatures warming on those ecosystems. More studies are needed to better understand.

Literature Cited

Arlen-Pouliot, Y. and Bhiry, N. (2005) Palaeoecology of a palsa and a filled thermokarst pond in a permafrost peatland, subarctic Queébec, Canada. *Holocene* 15: 408-419.

Booth, R. (2008) Testate amoebae as proxies for mean annual water-table depth in *Sphagnum*-dominated peatland of North America. *Journal of Quaternary Science* 23: 43-57.

Ménot-Combes, G., Burns, S.J. and Leuenberger, M. (2002) Variations of 18O/16O in plants from temperate peat bogs (Switzerland): Implications for paleoclimatic studies. *Earth and Planetary Science Letters* 202 : 419-434.

Vardy, S.R., Warner, B.G., Turunen, J. and Aravena, R. (2000) Carbon accumulation in permafrost peatlands in the Northwest Territories and Nunavut, Canada. *Holocene* 10: 273-280.

Flow Through Macropores of Different Size Classes in Blanket Peat

Joseph Holden
School of Geography, University of Leeds, Leeds, UK (j.holden@leeds.ac.uk)

Blanket peats are important source areas for runoff in many northern European headwaters. Water flowpaths are important in transporting dissolved organic carbon from within the peat mass to the stream system. The upper peat layer (20 cm) is dominant in producing flow in blanket peat catchments. However, little information exists on the relative roles of different size classes of macropore in water movement in this upper peat layer. This study uses tension infiltrometer experiments to assess the role of different size classes of macropores in runoff generation. Infiltration measurements were performed under four surface cover types (bare, *Eriophorum, Calluna* and *Sphagnum*-dominated), at four soil depths (0 cm, 5 cm, 10 cm and 20 cm) and at four water tensions (0 cm, -3 cm, -6 cm and –12 cm). Macropore flow was found to be an important pathway for runoff generation. Only 22 % of the flow in the upper 20 cm of peat occurred in pores smaller than 0.25 mm in diameter. The remaining portion of flow was equally divided between those pores between 0.25 mm and 1 mm in diameter those pores greater than 1 mm in diameter. Most of the flow in upland blanket peat was generated from only a small volume of the peat. At the surface around 80 % of flux was generated through only 0.26 % of the peat volume while at 5 cm depth, while percolation rates were an order of magnitude slower than at the surface, 85 % of the flux was generated from only 0.01% of the peat volume. Infiltration and effective porosity both declined by over two orders of magnitude over the top 20 cm of the peat. The variability in flow and effective porosity was found to be similar between different pore size classes.

Microbial Activity and Dissolved Organic Carbon Production in Drained and Rewetted Blanket Peat

Zoe E Wallage[1,2], Joseph Holden*[1], Timothy D. Jones[1], and Adrian T. McDonald[1]
[1]School of Geography, University of Leeds, Leeds, UK (j.holden@leeds.ac.uk). [2]Low Carbon Innovation Centre, University of East Anglia, Norwich, NR4 7TJ, UK

Heightened levels of peat degradation in response to environmental change have resulted in an increased loss of dissolved organic carbon (DOC) in many peatland catchment waters. One significant threat to peatland sustainability has been the installation of artificial drainage ditches, and although recent restoration schemes have pursued drain blocking as a possible strategy for reducing degradation and fluvial carbon losses, little is known about the influence of drainage and drain blocking on the intimate biological processes operating within these soils. This paper investigates how disturbance, in the form of drainage and drain blocking, influences the rate of microbial activity within a peat soil, and the subsequent impact this has on DOC production potential. Peat samples were extracted from three treatment sites (intact peat, drained peat and drain-blocked peat) in an upland blanket peat catchment in the UK. Microbial activity was measured via laboratory experimentation that incorporated the use of dehydrogenase enzyme assays to assess the level of electron transport systems (ETS) activity occurring within each

treatment. Drain blocking had rewetted the peat by raising the height of the water table relative to the drained site. Mean microbial activity at the drained site was 33 % greater than the undisturbed intact peat and almost double that at the restored, drain-blocked site. These results correspond well with previously published data observing significantly greater DOC concentrations in the pore waters of the drained site and significantly lower concentrations at the blocked site, relative to the intact peat. Data from the drain-blocked treatment provides evidence contradictory to the commonly quoted hypothesis that an enzyme-latch reaction may be sustained in drained peat even once it has been rewetted following water table restoration. The paper also notes how earlier research measuring INT-Formazan concentrations in peat that has not involved any correction for humic interference should be treated with caution.

Effects of Peatland Burning on Hydrology, Fluvial Carbon Fluxes, Water Quality and Aquatic Ecosystems

Lee Brown, Joseph Holden* and Sheila Palmer
School of Geography, University of Leeds, Leeds, UK (j.holden@leeds.ac.uk)

Controlled burning is used worldwide for the management of vegetation, yet there is serious concern about the environmental implications of such practices. Across the UK many peatlands are burned to encourage and maintain heather growth. However, detailed evaluations of the costs, benefits and sustainability of burning are hampered by a lack of basic scientific data. This paper will present the outline of a new three year NERC-funded project called EMBER which provides the first co-ordinated evaluation of vegetation burning on peatland hydrological and ecological processes. Case study sites influenced by prescribed burns will be established in internationally important sites in the Peak District and North Pennines, UK. EMBER will increase understanding of the processes linking prescribed peat vegetation fires, hydrology, fluvial carbon flux, water quality, and stream invertebrate communities in upland peat dominated catchments. Four work packages will aim to: 1) increase understanding of the effects of moorland patch burning on the hydrology and physicochemistry of peat, through examination of changes in soil hydrology and water quality; 2) provide a better understanding of the effects of moorland patch burning on basin runoff quantity and quality, through examination of river flow regimes, suspended sediment concentration, dissolved organic carbon flux, and water chemistry; 3) assess the influence of changes in stream hydrology, water quality, and sediment fluxes on stream ecosystems through examination of stream invertebrate community biodiversity and fish abundance and 4) gain a more fundamental understanding of some environmental drivers of upland aquatic community response to burning by experimentally manipulating fine sediment flux (mainly particulate organic carbon) under controlled conditions using a series of streamside mesocosms. Taken together these packages will provide a holistic patch- to basin-scale evaluation of burning from the perspective of peat hydrology, fluvial carbon flux, chemistry, river water quantity, and quality, and stream ecosystems, thus providing the balanced knowledge base that is currently lacking for peatlands.

Minimal Impact Oil Disturbance in Alberta: Revegetation as an Indicator of Function Return

Melissa K. House[1], Dale H. Vitt[1], R. Kelman Wieder[2] and Sara C. Koropchak[1]
[1]Department of Plant Biology, Southern Illinois University Carbondale, Carbondale, IL 62901 (mhouse@siu.edu) [2]Department of Biology, Villanova University, Villanova, PA USA

Peatlands play an important role in the global carbon cycle as a sink. Peatlands store about 1/3 of the world's terrestrial carbon and only cover 3-4% of the land surface (Gorham 1991). Peatland carbon sequestration capabilities are impeded by disturbance. In Alberta, a minimal impact technique is being used for oil exploration and natural gas extraction. Water is pumped onto the site in winter so that an ice layer forms and stabilizes the surface. The process removes the tree layer, and leaves only a layer of compacted, dead peat at the ground layer. The ice melts in the spring, and it is assumed that the bog revegetates. We have studied the revegetation of winter access/exploration sites. We compare this revegetation process to the revegetation of burned bog sites by comparing the natural response of older disturbance sites (1993-1994) to recently disturbed sites (2008). The reestablishment of *Sphagnum fuscum* is a useful measure of the return of function, as a carbon sink, to the sites. The genus *Sphagnum* includes important peat forming species, specifically 50 species tend to account for most of the peat accumulation globally (Gunnarsson 2005). In continental bogs in Alberta, *Sphagnum fuscum* is arguably the most important peat forming moss as it often accounts for 80-100% of the ground cover. Thus, the success of *Sphagnum fuscum* is directly linked to the success of the bog ecosystem. We also monitored the return of *Picea mariana*, the tree layer, within our sites. We predict that the revegetation of bogs having undergone the minimal impact oil disturbance will be different from the revegetation of burned bogs. We focus specifically on microtopography, water chemistry, and shade; we expect these factors to drive the expected differences between anthropogenic disturbance and fire disturbance sites. Here we present our preliminary results focusing on *Sphagnum* return due to its peat accumulating ability, and *Picea mariana* return due to its role as the only tree species in bogs in North America, comprising the aboveground carbon sequestration.

Literature Cited

Gorham, E. and Rochefort, L. (2003) Peatland restoration: A brief assessment with special reference to *Sphagnum* bogs. *Wetlands Ecology and Management* 11: 109-119.

Gunnarsson, U. (2005) Global patterns of Sphagnum productivity. *Journal of Bryology* 27: 269-279.

Scaling Plant Nitrogen-Use and Uptake Efficiencies in Response to Nutrient Addition in Peatlands

Colleen M. Iversen*[1], Scott D. Bridgham[2], Laurie E. Kellogg[3]
[1]Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge TN 37831, (iversencm@ornl.gov) [2]Center for Ecology and Evolutionary Biology, University of Oregon, Eugene, OR 97403 [3]University of Minnesota Law School, University of Minnesota, Minneapolis, MN 55455

Nitrogen (N) is the primary growth-limiting nutrient in many terrestrial ecosystems, and therefore plant production per unit N taken up (i.e., *N-use efficiency, NUE*) is a fundamentally

important component of ecosystem function (Aerts & Chapin 2000). The amount of nutrients required to support plant growth determines the competitive hierarchy of species within and among communities, which could in turn determine ecosystem carbon (C) balance. *NUE* comprises two components: N-productivity [*AN*, plant production per peak biomass N content] and the mean residence time of N in plant biomass [*MRTN*] (Berendse & Aerts, 1987). We utilized a 5-year fertilization experiment to examine how increases in N and phosphorus (P) availability affected plant *NUE* at multiple biological scales (i.e., from leaf to community level). We fertilized a natural gradient of nutrient-limited peatland ecosystems in the Upper Peninsula of Michigan, USA with 6 g N m-2 yr-1, 2 g P m-2 yr-1, or a combination of N and P. Our objectives were to determine how changes in C and N allocation within a plant to leaf and woody tissue, and changes in species composition within a community, both above- and belowground, would affect (i) *NUE*; (ii) the adaptive tradeoff between the components of *NUE*; (iii) the efficiency with which plants acquired N from the soil [*N-uptake efficiency*]; and (iv) plant community production per unit soil N availability [*N-response efficiency, NRE*] (cf. Pastor & Bridgham 1999). As expected, N and P addition generally increased aboveground production and N uptake. In particular, P availability strongly affected the way in which plants took up and used N. *NUE* response to nutrient addition was not straightforward. *NUE* differed between leaf and woody tissue, among species, and across the ombrotrophic-minerotrophic gradient because plants and communities were adapted to maximize either *AN* or *MRTN*, but not both concurrently. Increased N availability strongly decreased plant and community *N-uptake efficiency*, while increased P availability increased *N-uptake efficiency*, particularly in an N-fixing shrub. *N-uptake efficiency* was more important in controlling overall plant community response to soil N availability than was *NUE*, and above- and belowground community *N-uptake efficiencies* responded to nutrient addition in a similar manner. Our results demonstrate that plants respond to nutrient availability at multiple biological scales, and we suggest that *N-uptake efficiency* may be a more representative measurement of plant responses to nutrient availability gradients than plant *NUE*.

Note: *All experimental work was conducted while the authors were affiliated with the University of Notre Dame, Notre Dame, IN, 46556.

Literature Cited

Aerts, R. and F. S. Chapin. (2000) The mineral nutrition of wild plants revisited: A re-evaluation of processes and patterns. *Advances in Ecological Research* 30: 1-67.

Berendse, F. and R. Aerts. (1987) Nutrient-use-efficiency: A biologically meaningful definition? *Functional Ecology* 1: 293-296.

Pastor, J. and S. D. Bridgham. (1999) Nutrient efficiency along nutrient availability gradients. *Oecologia* 118: 50-58.