Understanding the interactions between water and carbon within terrestrial and freshwater ecosystems

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Introduction

- Twenty-65 project
- The carbon cycle and aquatic C pools
- Trends in dissolved organic carbon
- Managing peatland soils?
- Implications for water treatment
Twenty-65

• 5-year EPSRC funded ‘grand challenge’

• ‘Minimising carbon emissions through synergistic water-energy systems’

• ‘Adapting to changing catchments’

• https://twenty65.ac.uk/
Carbon in surface waters considered an inactive ‘pipe’ which moves C to ocean

Cockell et al. (2007)
A more accurate model includes accumulation in surface waters and degassing/mineralisation to atmosphere.

Battin et al. (2009)
Trends in dissolved organic carbon (DOC)

Figure 1 | Trends in dissolved organic carbon (mg l⁻¹ yr⁻¹). Data are shown for monitoring sites on acid-sensitive terrain in Europe (upper panel) and North America (lower panel) for the period 1990–2004.

Monteith et al. 2007 (Nature)
Explanations

- Acid deposition
- Temperature
- CO$_2$ enrichment
- Hydrology
- Land use
- Burning
- N fertilisation

Clark et al. 2006 (ES&T)
Future drivers

• S deposition returning to pre-industrial levels

• N deposition means DOC likely to be higher than pre-industrial levels

• Catchment specific

Sawicka et al. 2017 (STOTEN)
Land use and DOC

\[ y = 4.8634x - 60.873 \]
\[ R^2 = 0.992 \]
\[ p < 0.0001 \]

Aitkenhead & McDowell (2000)
Managing peatland soils?

- Organic-rich soils formed due to high water tables limiting decomposition

- 15–30% of the world’s total soil carbon

- Most in the UK are degraded through land management and acidic deposition
Peatlands are either…

• ‘wastes, which are at present a disgrace and reproach to the inhabitants of this county’ Fraser (1794)

Or

• ‘crucial source of ecosystem services, such as provision of food and fibre, water supply, climate regulation, maintenance of biodiversity, as well as providing opportunities for recreation, inspiration and cultural heritage’ Bonn et al (2010)
Historical management

Photos: South West Water

Drainage, liming, peat cutting, grazing, burning
Vegetation change

Burning, drainage and nitrogen availability

Grazing intensity

Sphagnum moss

Moor grass

Expanded and redrawn from Bragg and Tallis (2001)
Exmoor Mires Project

- Total area restored = 1,019ha
- Total ditch length blocked = 99,097m
- Total number of ditch blocks = 10,546
- Payments for ecosystem services possible?

Photo: South West Water
Exmoor Mires: initial results

Geophysical Research Abstracts
EGU General Assembly 2014
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Restoration of shallow peatlands on Exmoor (UK): initial effects on water quality

Emilie Grand-Clement (1), David Luscombe (1), Karen Anderson (2), Naomi Gatis (1), Josie Ashe (1), and Richard Brazier (1)
(1) Geography, University of Exeter, UK, (2) Environmental and Sustainability Institute, University of Exeter, UK

[six months post-restoration] “…significant changes in water quantity, such as a reduction in storm flow following restoration, means that, overall, DOC loads have decreased at the scale of the catchment.”
Exmoor Mires: initial results

In the Bog Conference September 2014

Exmoor Mires Project: Initial analyses of post restoration vegetation monitoring data

David M. Smith\(^1,3\), Conrad Barrowclough\(^2\), Andrew D. Glendinning\(^3\) and Anne Hand\(^3\)

South West Water\(^1\), First Ecology (Somerset Wildlife Trust)\(^2\), Exmoor Mires Project\(^3\)

“Where restoration structures have remained intact, botanical communities have significantly changed, reflecting rewetting of underlying peat at all but one site. This indicates that the use of ditch blocking to re-wet peatlands is a successful hydrological rehabilitation strategy.”
Vegetation DOC production

Figure 3: DOC production from different peatland sources (letters indicate statistical subsets).

Error bars at one standard error (n = 5).

Ritson et al. 2016
Loss of DOC in the catchment

Molinia and Juncus producing the most DOC and it is the most recalcitrant

Ritson et al. 2016
Seasonality and litter quality

- After ten months decomposition in the field, 1.2% loss of *Sphagnum* but 21.3% loss for *Molinia*.

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>Litter production (g m(^{-2}) year(^{-1}))</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sphagnum spp.</em></td>
<td>35–156</td>
<td>Year-round</td>
</tr>
<tr>
<td><em>Calluna vulgaris</em></td>
<td>40–261</td>
<td>Year-round, peaks in autumn/winter</td>
</tr>
<tr>
<td><em>Juncus effusus</em></td>
<td>690–800</td>
<td>Sept–Nov</td>
</tr>
<tr>
<td><em>Molinia caerulea</em></td>
<td>536–633</td>
<td>Sept–Nov</td>
</tr>
</tbody>
</table>

Ritson et al. 2016
Figure 4: Conceptual diagram showing changes to size, speed of cycling and seasonality of litter carbon pool on transition from *Sphagnum* to *Molina* domination of uplands.
Implications for water treatment

- Taste, odour, colour
- Microbial growth
- Coagulant demand, sludge production
- Filter run times
- Disinfectant demand, disinfection by-products (DBPs)
Influence on coagulation

Figure 1: DOC removal by coagulation for different peatland sources.

Error bars at one standard error (n = 3).

Ritson et al. 2016
Energy and chemical demand

Jones et al 2015

- Chemical demand small in comparison to energy demand
- If coagulation can cope, only small increases
- Around 14.5% increase in total embodied energy in peak DOC events (Santana et al. 2014)
- Change in water quality envelope- If new treatment processes required could be large increase in energy/chemical demand
- Possibility of C sequestration via sludge
Likely impacts and responses

Review

The impact of climate change on the treatability of dissolved organic matter (DOM) in upland water supplies: A UK perspective

J.P. Ritson a,b,*, N.J.D. Graham b, M.R. Templeton b, J.M. Clark c, R. Gough d, C. Freeman d

a Grantham Institute for Climate Change, Imperial College London, South Kensington, London SW7 2AZ, UK
b Department of Civil and Environmental Engineering, Imperial College London, South Kensington, London, SW7 2AZ, UK
c Walker Institute for Climate Systems Research and Soil Research Centre, Geography and Environmental Science, School of Human and Environmental Sciences, University of Reading, Whiteknights, Reading, RG6 6DW, UK
d Wolfson Carbon Capture Laboratory, School of Biological Sciences, Bangor University, Bangor, Gwynedd, LL57 2UW, UK
The future?

• One of the largest consumers of electricity in Scotland

• Energy efficiency, generating and hosting private investment

• 29 hydro turbines, 24 PV sites, 18 wind turbines, 2 CHP plants
• 420 GW hours in private wind turbines
• Overall £7 million in annual savings
Conclusions

- Interaction between peatland management for food, sport shooting, tourism and carbon in water

- Restoration of peatlands can improve many ecosystem services

- Carbon in water means higher treatment costs and energy usage

- Not covered: pesticides, nutrients