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The role of peatlands in regulating water quality

Pippa Chapman

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Structure of presentation

- Peatlands and regulation of water quality
  - Drinking water provision
- Factors controlling water quality in peatlands,
  - Hydrology
  - Atmospheric deposition & pollutant retention
  - Land management
- Potential for peatland restoration/changes in land management to change water quality

‘The National Ecosystem Assessment (NEA) says that for decades, the emphasis has been on producing more food and other goods, but this has harmed other parts of nature that generate hidden wealth.’ Quote from BBC News on 2/6/11

Inland wetlands are valued at £263 million/year (or £436/ha/yr) by the NEA mainly because they help to produce clean water.

Photo: Joanna Clark

Ecosystem Services of Peatlands with regard to regulating water quality

1. Significant source of drinking water in the UK due to:

•High rainfall amount

•Low evapotranspiration

•Remote location

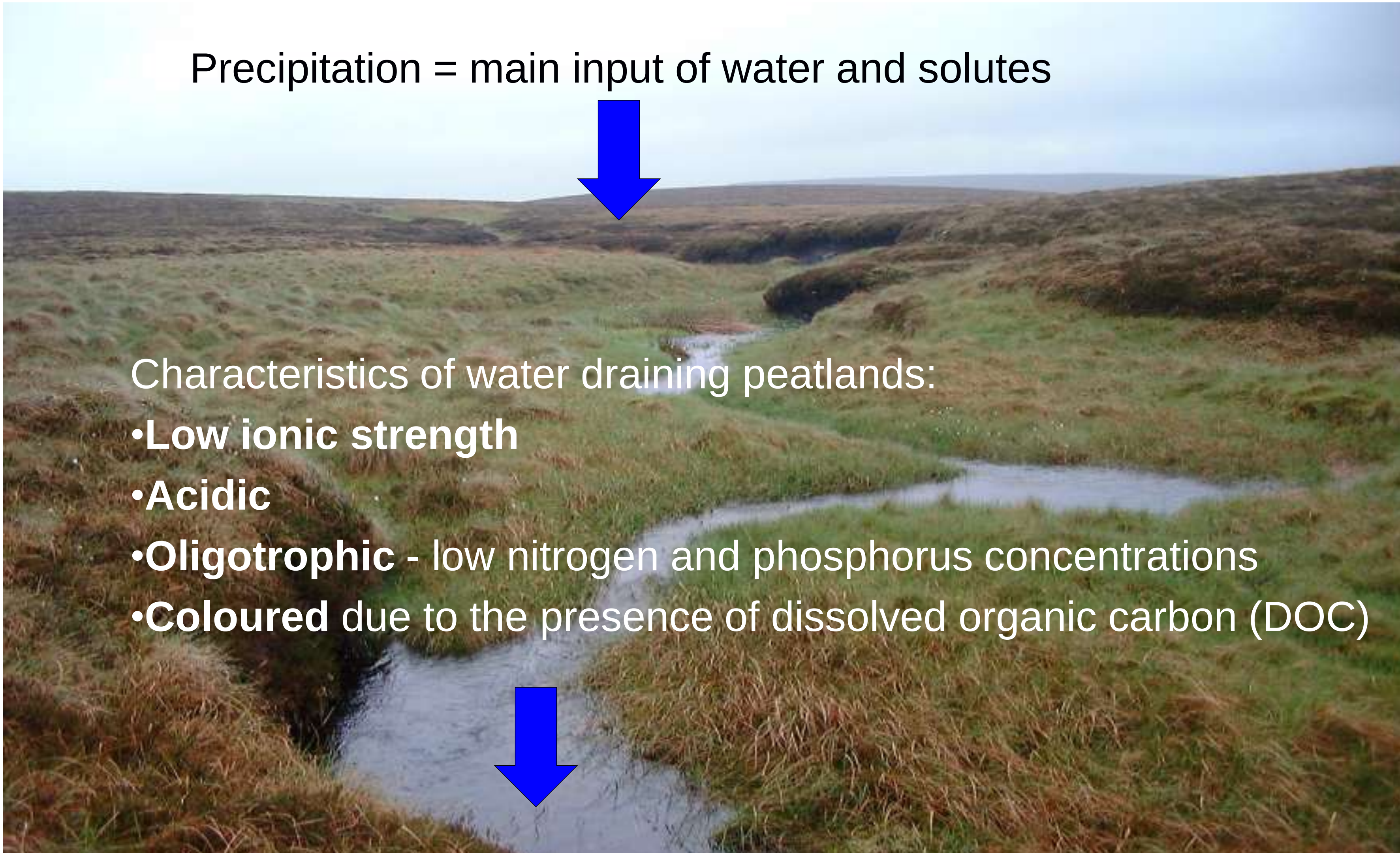
•Low intensity land use

•High water quality

2. Retain pollutants

3. Source of dilute water: can be used for the dilution of point source and diffuse pollution in downstream agricultural, urban and industrial areas of the catchment





Precipitation = main input of water and solutes

Characteristics of water draining peatlands:

- **Low ionic strength**
- **Acidic**
- **Oligotrophic** - low nitrogen and phosphorus concentrations
- **Coloured** due to the presence of dissolved organic carbon (DOC)

Photo: Joanna Clark

Influence of Hydrology

Photo: Joanna Clark

High water table results in:

1. Rapid response to rainfall with runoff occurring predominately in top 5 cm of peat.
2. **Anaerobic conditions** within the peat which leads to:

(i) **Slow decomposition** of organic matter

(ii) **Reduction of SO_4** and NO_3, e.g.

$$2H^+ + SO_4 + 2CH_2O = H_2S + 2CO_2 + 2H_2O$$

Bacterial SO_4 reduction (BSR) consumes acidity (H^+) and thus neutralizes acidity associated with acid rain and stores S & N. Peatlands are effective at retaining pollutants.

Impact of changes in atmospheric deposition

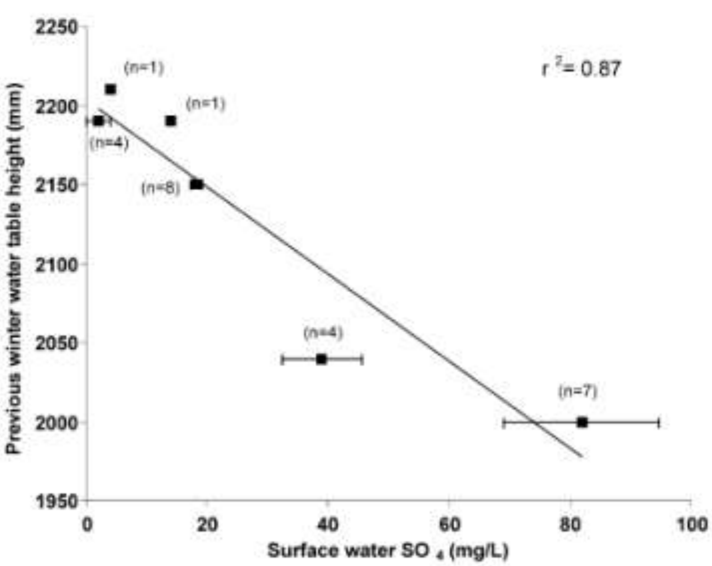
•Extremely vulnerable to the effects of acid rain as all water and nutrients supplied via precipitation.

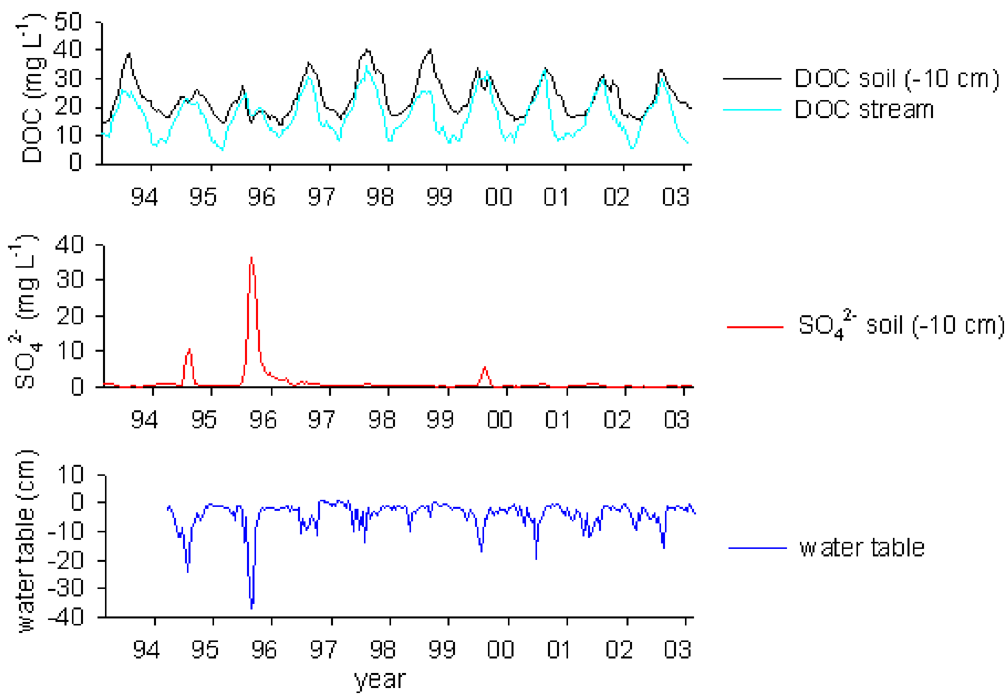
•Over last century, dominant driver of water quality change in the UK uplands has been atmospheric pollution

• **Impact** of atmospheric inputs of sulphur (S) and nitrogen (N) on water chemistry **dependent on water table position.** Peats with high water table can retain S and N, so buffering the impacts on water quality.

•Recent research also suggests that atmospheric deposition influences DOC.

Relationship between water-table and surface water sulphate concentration



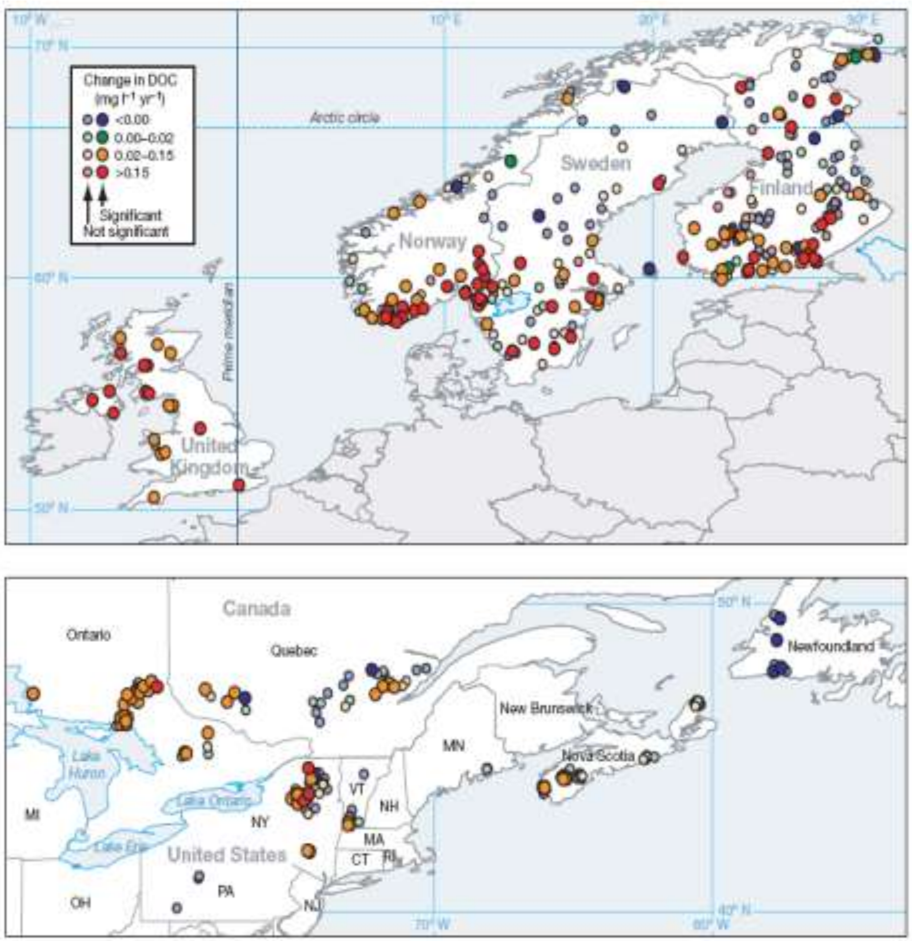


Thorne Moors, lowland raised bog

Bottrell et al., 2004. Applied Geochemistry

Moor House, upland blanket peat

Clark et al., 2005. Global Change Biology.



Monteith et al., 2007. *Nature* 450: 537-541.

Monteith et al. found that the increasing trend in DOC could be explained by a simple regression model based on changes in deposition chemistry (SO_4 and Cl).

Why should recovery from acid rain influence DOC?

Solubility of DOC controlled by pH and ionic strength

$\downarrow SO_4$ = $\uparrow$pH and $\downarrow$ionic strength = $\uparrow$DOC solubility

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Impact of land management

- Peatlands are sensitive habitats that are affected by human activities such as:
  - Peat cutting for fuel/horticulture
  - Drainage for agriculture & forestry
  - Burning
  - Over grazing
- What impact do these activities have on the quality of water draining peatlands?

Impact of drainage = lower water table

Photo: Joanna Clark

Net DOC production (µg DOC/g of soil/day) at 10 ^{o}C

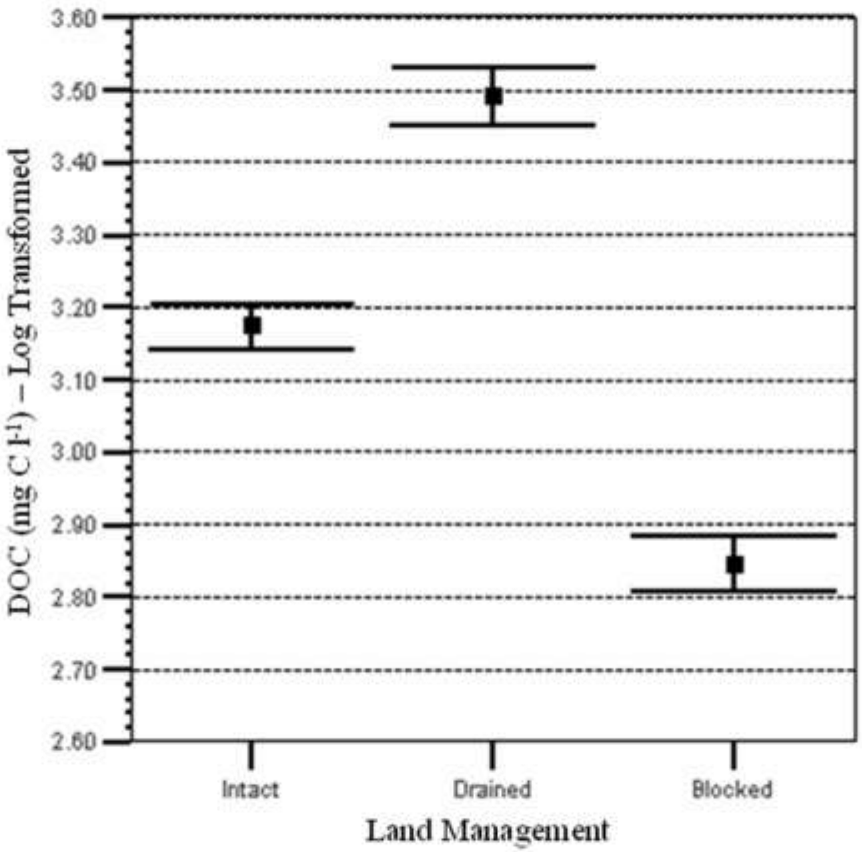
Soil depth	Anaerobic	Aerobic
-10 cm	0.51	1.83
- 20 cm	0.69	1.95
- 30 cm	0.52	2.69
- 40 cm	0.36	1.09
Median	**0.52**	**1.89**

Clark et al., 2009. Global Change Biology.

Q_{10} for anaerobic peat = 1.8

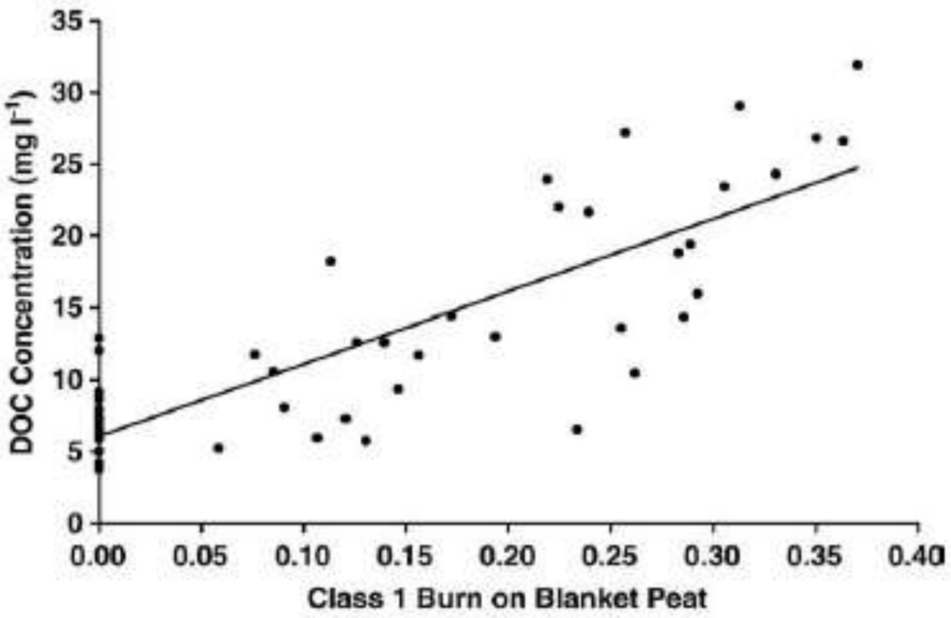
Q_{10} for aerobic peat = 3.5

Drainage and Dissolved organic carbon (DOC)



Wallage et al., 2006. Science of the Total Environment.

Heather Burning and DOC



Yallop & Clutterbuck, 2009. Science of the Total Environment

However, plot scale experiments have not observed an increase in soil solution DOC following burning (e.g. Clay et al., 2009; 2010).

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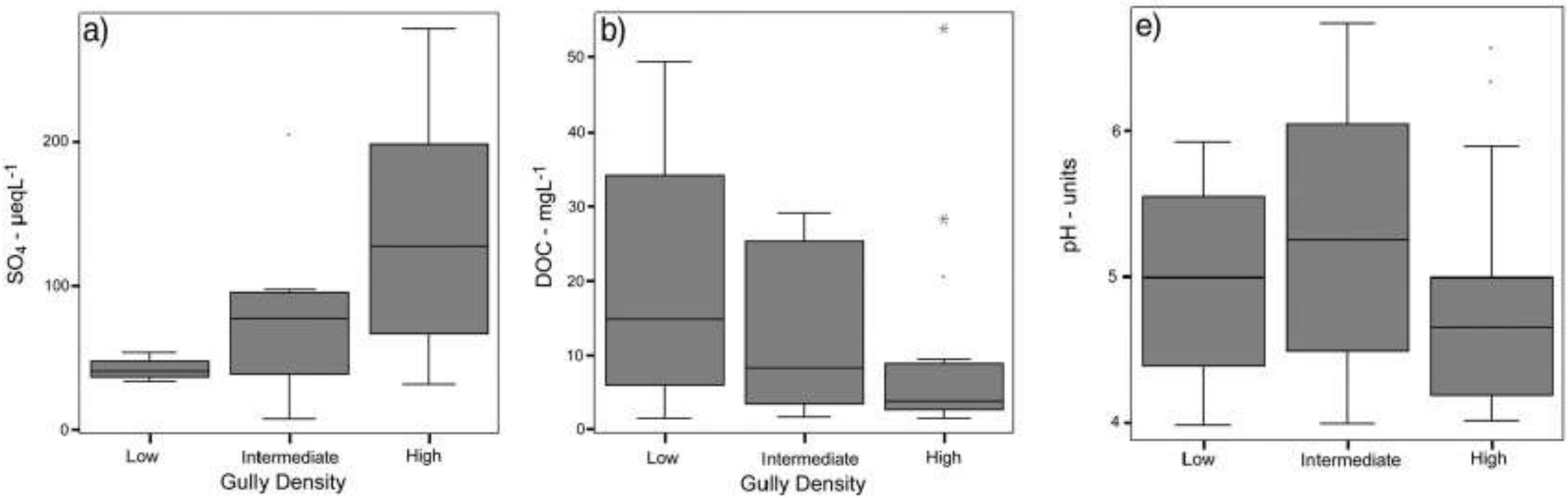
Impact of gullying on water chemistry



Headwater streams from the Peak District. Gullying lowers water table which results in the oxidation of S and N which leads to a decline in pH and DOC. Also connectivity of streams and peat reduced in highly gullied catchments.

Daniels et al., 2008. Science of the Total Environment

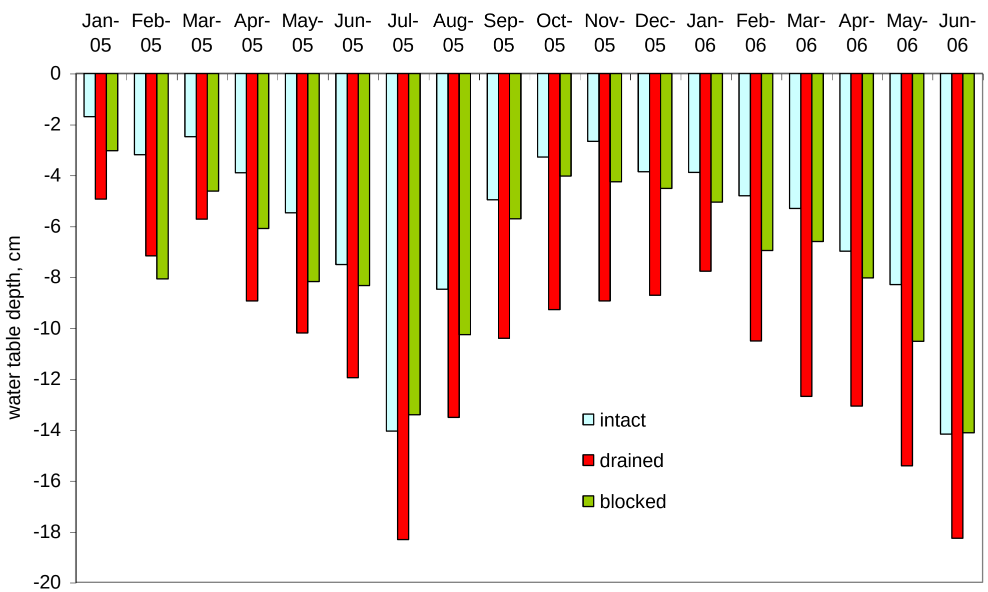
Summary – impact of land use on water quality

- Drainage leads to increase in aerobic conditions
  - Oxidation of reduced S and N
  - Increase in DOC production
  - Depending on S chemistry this may or may not result in an increase in DOC/water colour
- Water companies spend considerable amounts of money, treating potable water supplies to comply with EU drinking water standards.
- In an attempt to reduce water treatment costs, UK water companies are looking at the role peatland restoration can play in improving water quality.

Impact of restoration – Drain blocking

- England - 4.3% of drains blocked over past 10-15 years (Natural England, 2010)
- Funders tend to pick an area and then block all drains in the area.
- Practical techniques have evolved over time – e.g. Armstrong et al., 2009, J. Env Management.
- Short-term responses may be different to long-term response

Drain- Blocking and water table



Wallage (2007). PhD Thesis, University of Leeds

- Many studies have focussed on recovery of water table post- blocking.
- All studies report an increase in water table, e.g. Wallage et al., 2006; Worrall et al., 2007; Wilson et al., 2010.
- Recover can be slow, e.g. as shown here for a site in Wharfedale, 6 years after blocking.
- Full hydrological recovery unlikely to be immediate (see Wallage and Holden, 2011). Hydraulic conductivity 1.5 times greater than intact or drained blanket peat.

Impact of drain-blocking on DOC & POC

Photo: Michael Bell

- Many studies observed an increase in DOC shortly after blocking (e.g. Worrall et al. 2007).
- Large study showed that blocking generally reduced DOC (Armstrong et al., 2010). But not always. Impact of local conditions
- Much less focus on POC. Wilson et al. (2011) observed a decline in POC flux but at least 1 year of monitoring needed to see benefit.
- Re-vegetation of gullies also shown to reduce POC (Evans and Warburton, 2005)

Stean Moor, Upper Nidderdale

At what scale is the impact of drain-blocking observed?

- Hillslope
- First order stream
- Second, third order stream
- Catchment

Most studies, to date, have concentrated on the hillslope scale.

Need for more catchment studies. E.g. Vyrnwy study – see papers by Wilson et al., 2010 and 2011.

Investigation of Peatland Restoration (Grip Blocking) Techniques to Achieve Best Outcomes for Methane and Greenhouse Gas Emissions / Balance, funded by Defra (2010-2014)

- Blanket peatland, Migneint Hills, Upper Conwy, North Wales
- 12 Grips to include three treatments – control, dams and reprofiling
- Pre-restoration monitoring, plus three years post restoration
- Water, GHG, dissolved and particulate organic carbon fluxes, plus vegetation surveys

University of Leeds, Centre for Ecology and Hydrology and Open University




Conclusions

- Both changes in atmospheric deposition and land management influence the chemistry of peatland drainage water.
- It is important that we evaluate the impact of peatland restoration on stream water quality in relation to other controlling factors (e.g. recovery from acid rain, climate change) and not in isolation.
- Impact of **scale and time** important to consider when evaluating influence of peatland restoration on runoff generation and water quality.
- There is need for more **catchment studies** and studies that investigate the impact of peatland restoration on **multiples ecosystem services**.