Forest Research

Forests, Fish and Freshwater Pearl Mussel: Water Quality Monitoring for Ecological Protection

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Atlantic salmon (*Salmo salar*)
Salmonids are vulnerable to suspended and deposited sediment, particularly during the incubation and larval phase.

Impacted by high nutrient levels, acidity.

Freshwater Pearl Mussel (*Margaritifera margaritifera*)

Found only in clean rivers and streams; now threatened with extinction throughout its holarctic range. In Scotland viable populations still remain and are the focus of conservation action across the UK.

Forest Operations

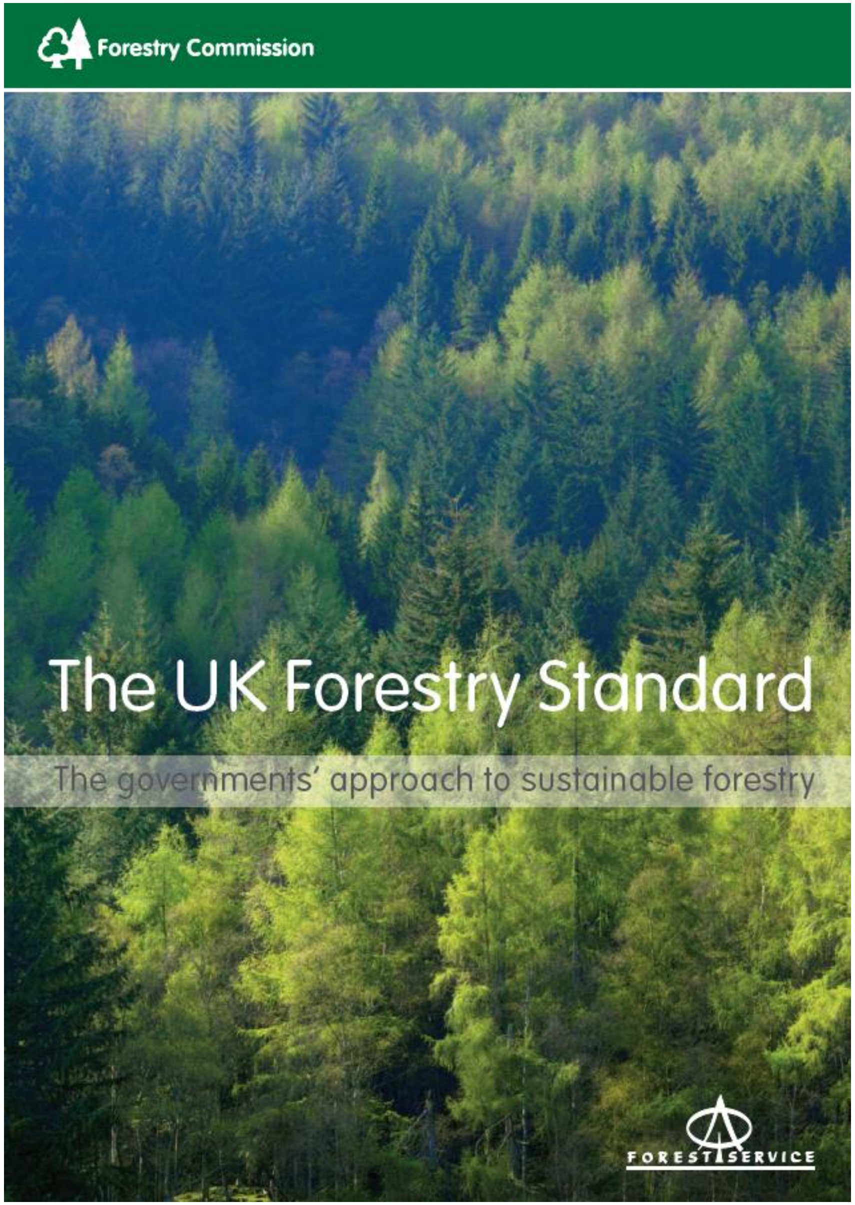
Ploughing in deep blanket peat; Sutherland, Scotland, 1950

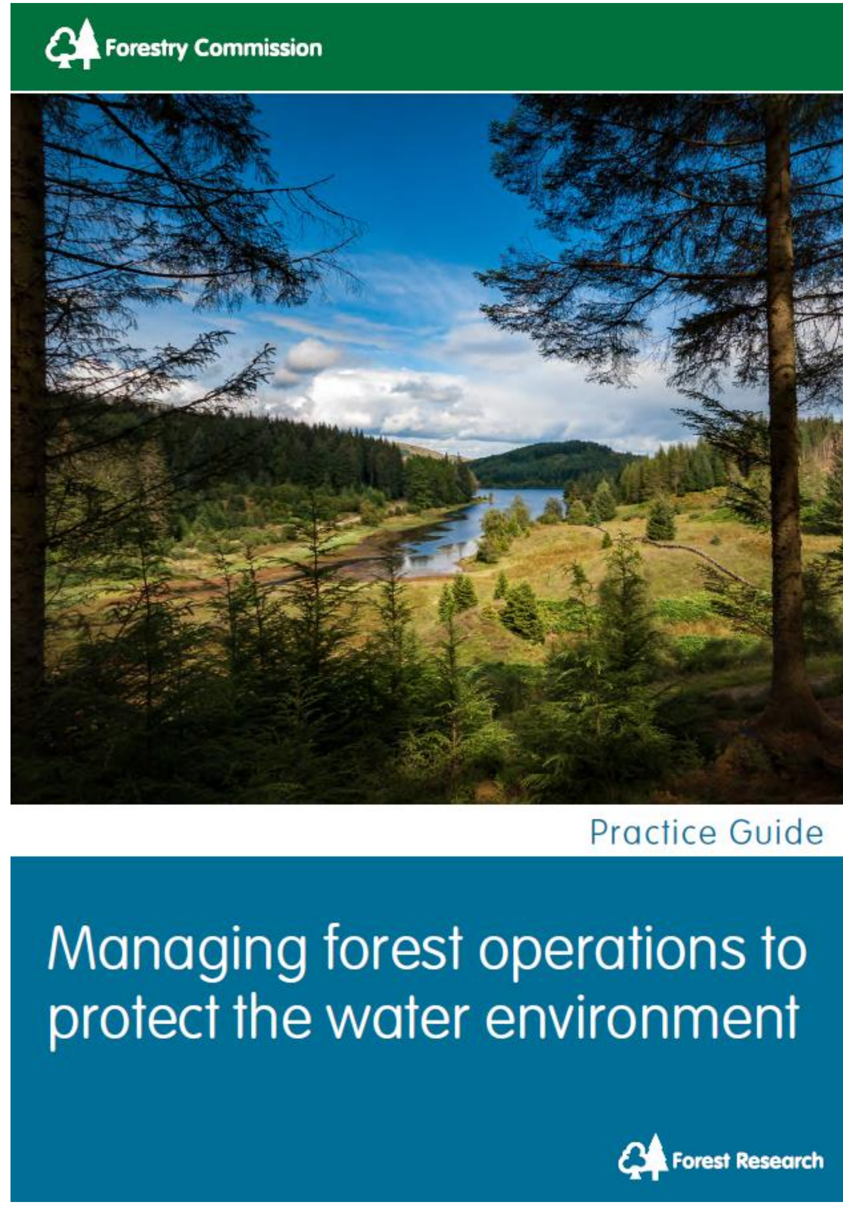
Forests are generally good for water quality.

Forests play an important role in the hydrological and nutrient cycles, and are important for drinking water provision.

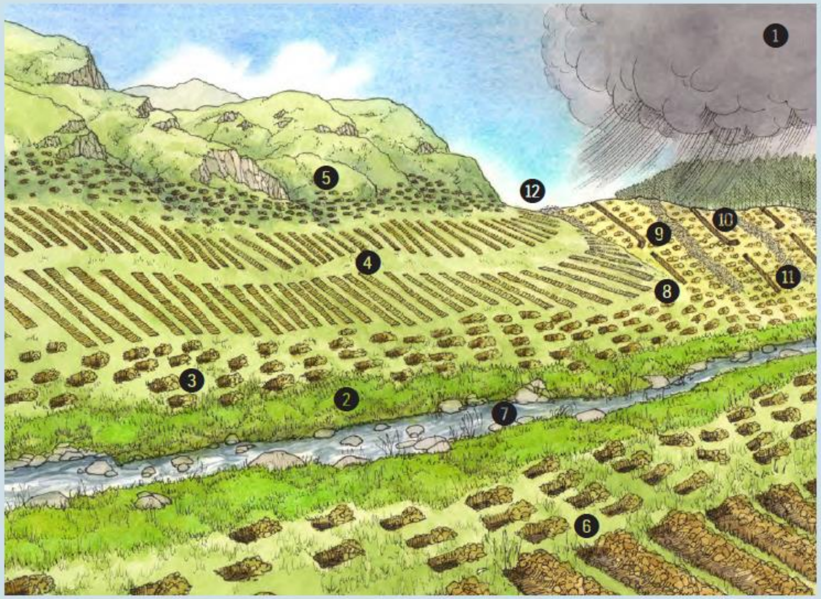
Need appropriate forest management to protect the water environment.

Guidelines and Guidance



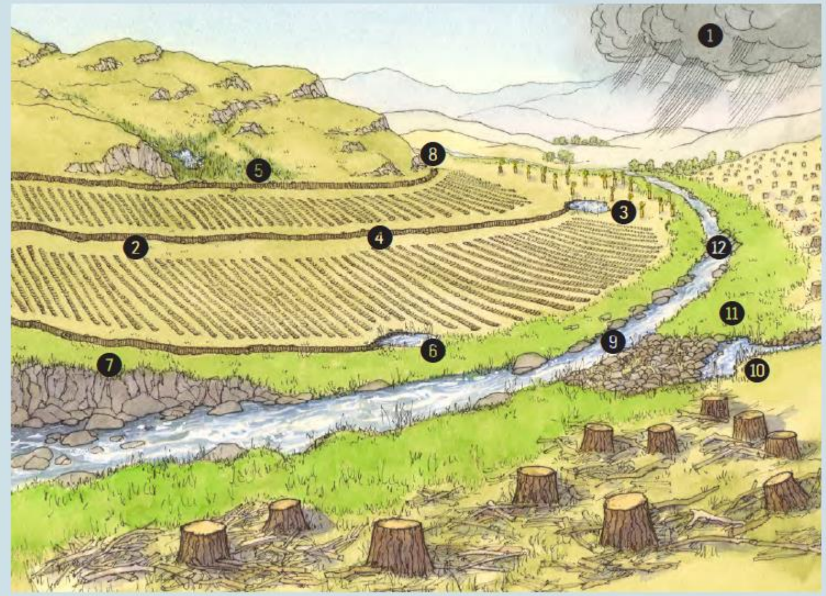


1. Protecting the water environment from cultivation operations



1. Consider the weather and aim to carry out cultivation operations during dry periods.
2. Do not cultivate ground within 2 m of a watercourse or 5 m of a spring, well or borehole.
3. Limit cultivation to hinge or inverted mounding within buffer areas.
4. Leave 2–5 m breaks in plough lines (and any associated subsoiling) at regular intervals (e.g. every 40 m on moderate slopes and every 70 m on gentle slopes).
5. Only use discontinuous forms of cultivation on steep slopes.
6. Restrict the depth of ploughing (e.g. to 30 cm) to reduce soil disturbance.
7. Avoid fording streams and rivers, unless there is an existing purpose-built ford.
8. Do not dig spoil trenches that can discharge directly into watercourses.
9. Orientate spoil trenches so that they cannot intercept or carry large volumes of water; turn out the bottom 2 m length of each trench to alternate sides to dissipate flows.
10. Do not fill trenches created for mounding with fresh brash.
11. Restrict the length of trenches to less than 30 m; if this is not possible, fully integrate trenches into the drainage system – do not exceed 2° gradient limit.
12. Install drains at the same time or immediately after cultivation operations.

2. Protecting the water environment from drainage operations



1. Consider the weather and aim to carry out drainage works (including drain maintenance and silt trap cleaning) during dry periods.
2. Cut drains to run at a even gradient of 2° (3.5%) or less leading towards the head of the valley; ensure water does not discharge into lower cultivation channels.
3. End drains in a shallow turnout.
4. Space drains so that the volume of run-off does not exceed the capacity of the drainage system.
5. Provide ‘cut-off’ drains so that plough furrows do not carry significant volumes of water from wet areas above.
6. Stop drains at the edge of buffer areas, preferably on flat ground where water can fan out.
7. Ensure drains do not discharge to the edges of steep gully sides or unstable slopes.
8. Avoid drains diverting water to adjacent catchments.
9. Do not end drains in natural channels, ephemeral streams or old agricultural drains.
10. Redesign existing drainage systems to meet current standards and correct any erosion problems; ensure restock drains discharge to a minimum 10 m wide buffer area.
11. Where an existing drain has become a sizable and stable watercourse, treat as a natural watercourse and establish buffer areas along its length; if in doubt, seek advice.
12. Avoid fording streams and rivers, unless there is an existing purpose-built ford.

Aims

- To investigate the effects of forest operations on water quality, protect the water environment and improve our understanding of forest-water interactions.
- To separate out the effects of forest operations from natural changes in water quality and climatic effects.
- To inform the need for further improvements to forest management and guidance (UKFS Water Guidelines and associated guidance).
- Work together with stakeholders to protect the freshwater environment (SEPA, Fisheries and RSPB).
- A proactive approach to water quality monitoring and research.

WQ monitoring

Sites across Scotland

Long and medium-term monitoring, partly driven by ecological considerations

Effects of operations such as cultivation, fertilisation and harvesting

Land use change: native woodland including riparian planting

Peatland restoration: forest to bog effects on water quality

Improving our understanding through monitoring and research

Peatland Restoration

- The importance of peatland conservation, protection and restoration is recognised; large-scale restoration underway at a number of sites in Scotland and around the world. £14m from Scotgov; climate change mitigation strategy with multiple benefits.

- Much restoration on the NFE; involves forest removal but also drain blocking and ground smoothing.

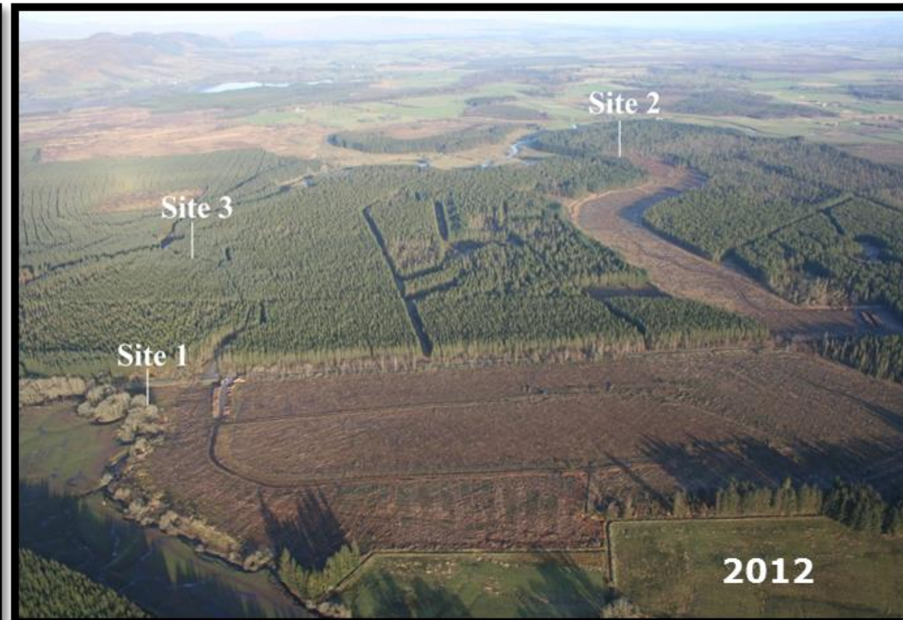
- The impact of peatland forest clearance/restoration on soil, water and ecology has not been fully investigated.

- The scale of felling is an issue; management techniques (forest materials in-situ).

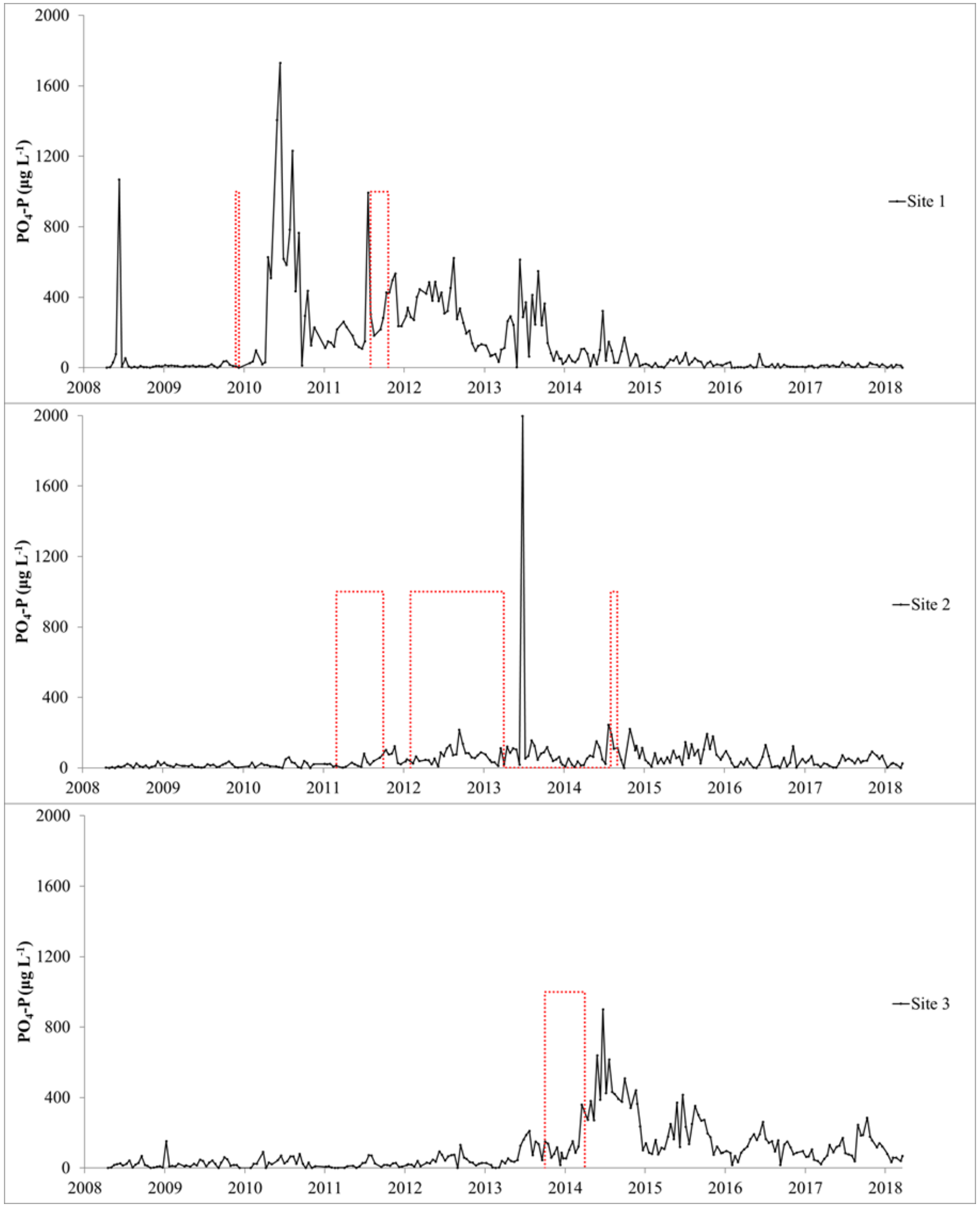
- Knowledge gap - long term studies into peat bog restoration following felling to determine impacts on GHG, water and biodiversity (IUCN UK Committee Peatland Programme).

Forest Research

Flanders Moss



Phosphate

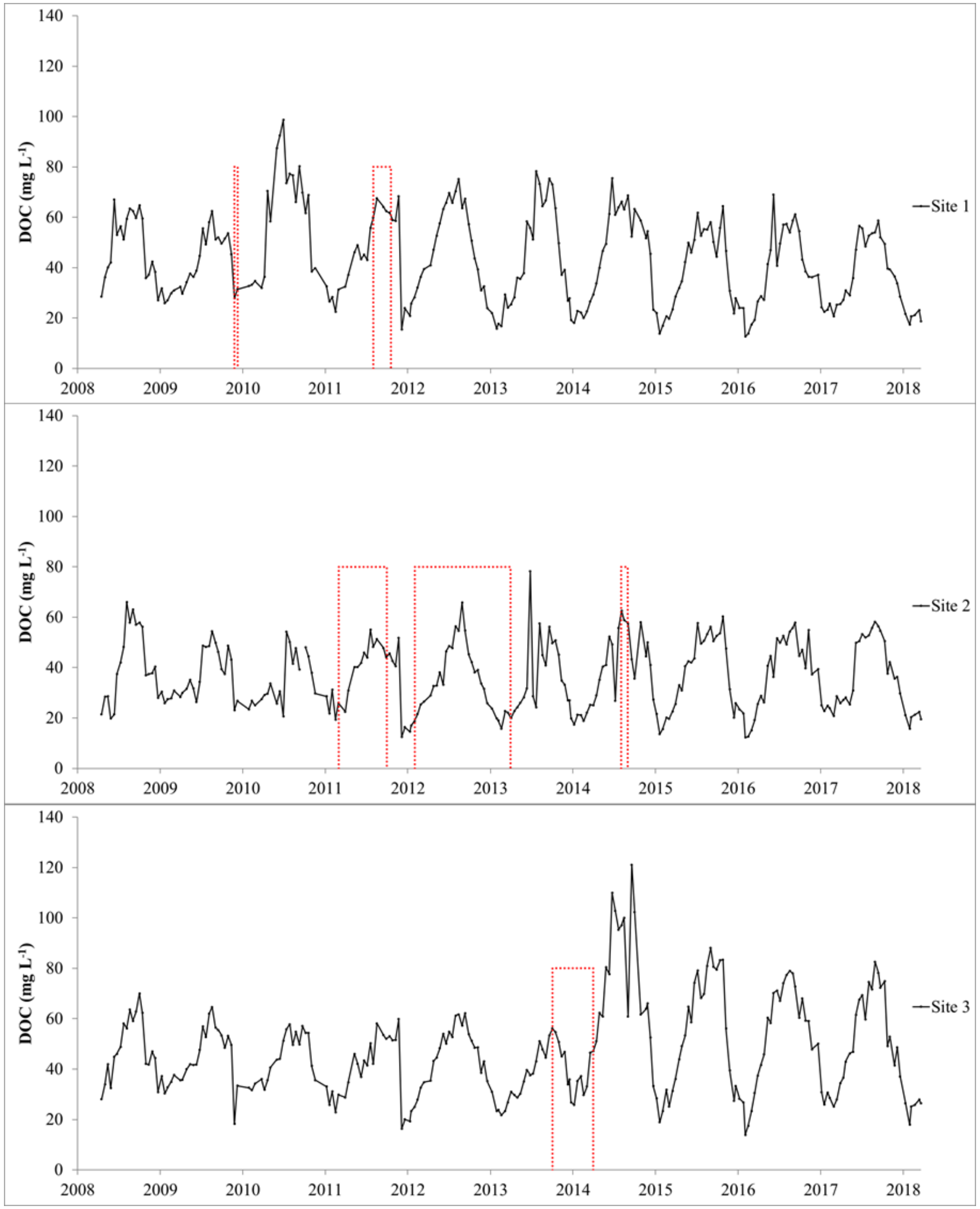


- Phosphate release at all sites.
- Phased felling reduced water quality impacts (Site 2).
- Low-impact techniques and removal of forest materials reduced phosphate signal.

Low impact techniques

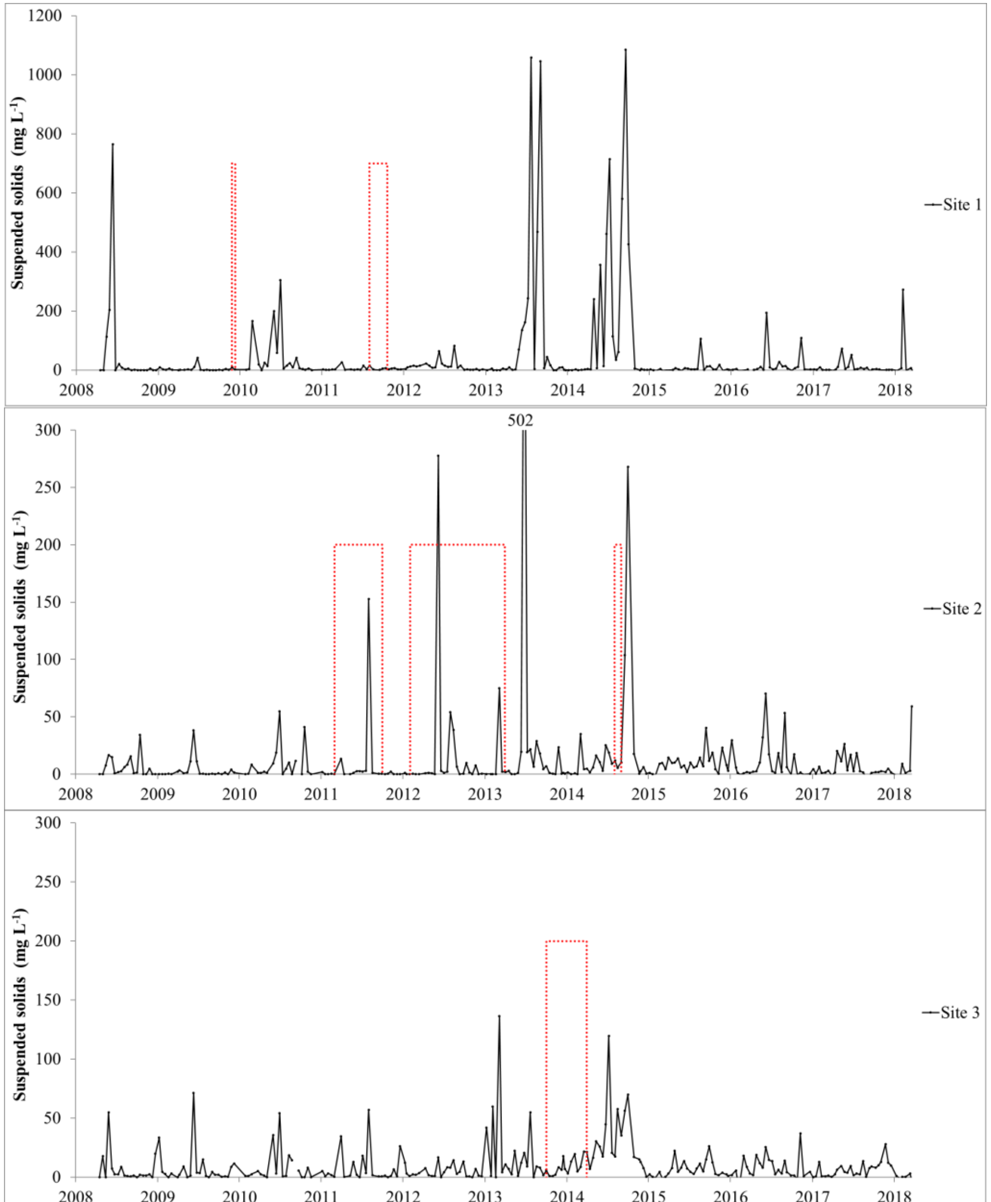
Removing forest residues including brash reduced phosphate concentrations.

DOC



- DOC concentrations increased at two sites, mainly in the first year after felling.
- Little or no impact with phased felling.
- Reduced signal with low impact techniques and removal of forest materials.

Suspended solids



- Very little sediment delivery during clearfelling operations.
- The highest SS peaks at Sites 1 and 2 occurred during dry summer periods in 2013 and 2014 when stream flows were low.
- Climatic effects play a significant role in phosphate and sediment release, particularly drying-rewetting cycles and periods of extended drought.
- These small watercourses drain directly into large river systems and so rapid dilution will result in very little if any impact on river water quality and ecology.
- More concern where watercourses flowed from clearfelled peatland into small lochs or headwater streams with sensitive ecology.

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The effects of forest clearance for peatland restoration on water quality

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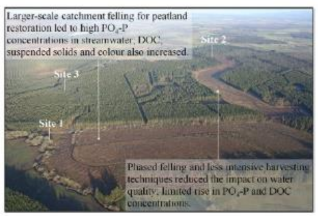
HIGHLIGHTS

- Peatland restoration by forest clearance led to a release of PO_4-P to streams.
- Colour, DOC and SS concentrations increased but to a relatively limited degree.
- pH impacts varied; a 1.6 unit rise moved one site from poor to high WFD status.
- Climatic factors affect the timing and degree of water quality impacts.
- Phased felling and low impact harvesting can effectively control negative impacts.

GRAPHICAL ABSTRACT



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ABSTRACT

Recognition of the importance of peatlands has led to increased efforts to protect and restore these environments but there are concerns about the impact of restoration on water quality, particularly in terms of sediment delivery, nutrient transport and carbon losses. In this study we present the results of almost 10 years of water quality monitoring in 3 catchments at a lowland raised bog that was afforested with conifers in the 1960s and 1970s and cleared over the 2010s.

Phosphate concentrations increased after clearfelling with the main peaks seen in the summer after forest clearance; the use of low ground impact harvesting methods, removal of forest residues and especially phased felling tempered phosphate losses. Annual mean phosphate concentrations returned to pre-felling levels 3–5 years after felling finished. Nitrate concentrations increased slightly from baseline levels during and after felling. DOC concentrations increased at two sites with mean annual concentrations still elevated at one site after 4 years; little increase in DOC was recorded with phased felling. Colour levels increased and remain elevated at all sites relative to pre-felling. In only one stream, pH increased improving the WFD water body status from 'poor' to 'high' in the space of 3 years.

Our results show that forest clearance for peatland restoration can impact negatively upon water quality due to phosphate, DOC, colour and suspended sediment releases. The mechanisms by which the releases occur require further investigation but are thought to be driven by nutrient leaching from forest residues, soil disturbance by machine trafficking and indirect effects of forest clearance, such as water table rise following cessation of forest water use. Climatic effects also play a significant role, particularly drying-rewetting cycles and periods of extended drought. To prevent negative impacts, phased felling and less intensive forest harvesting techniques should be employed.

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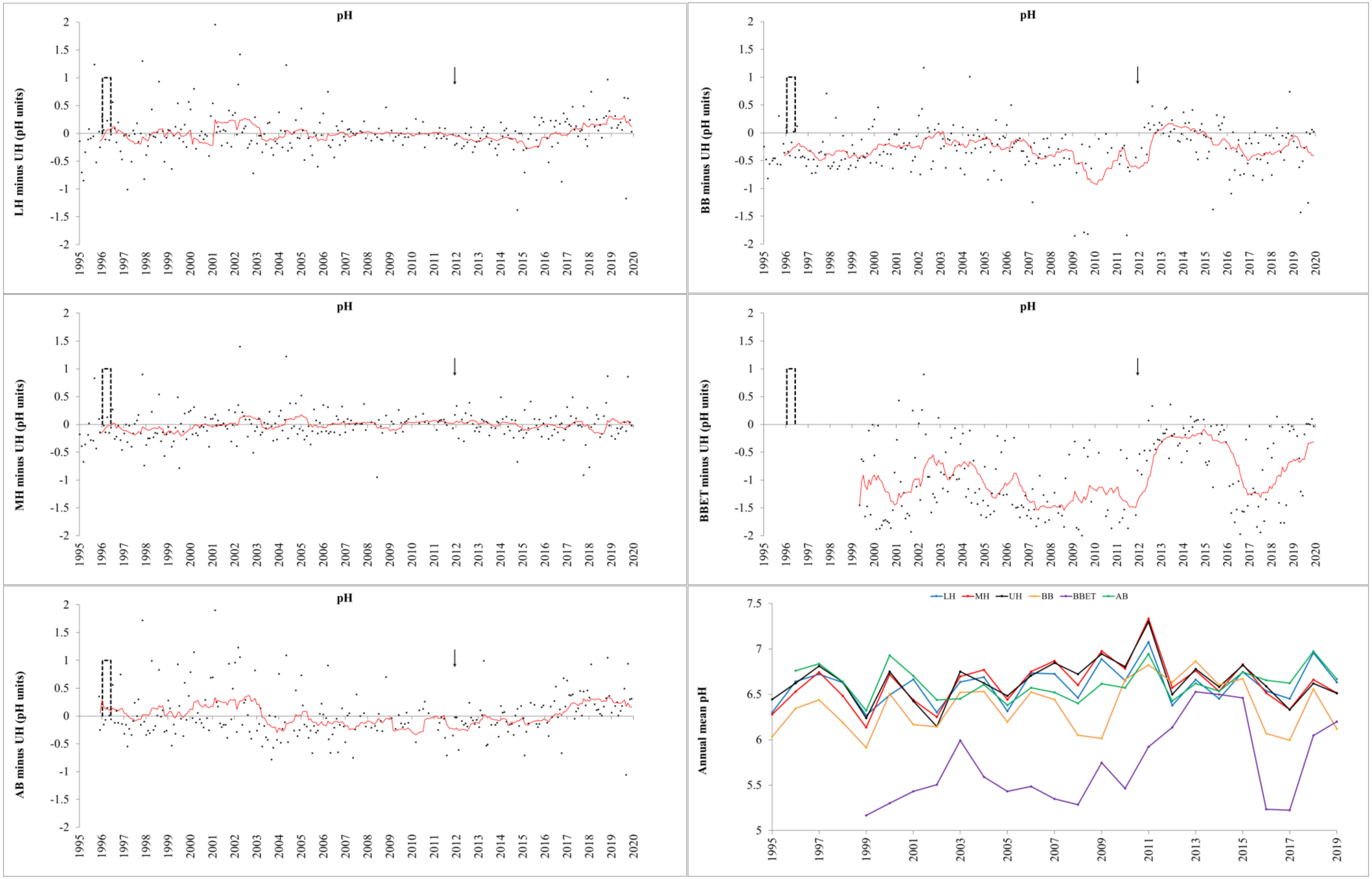
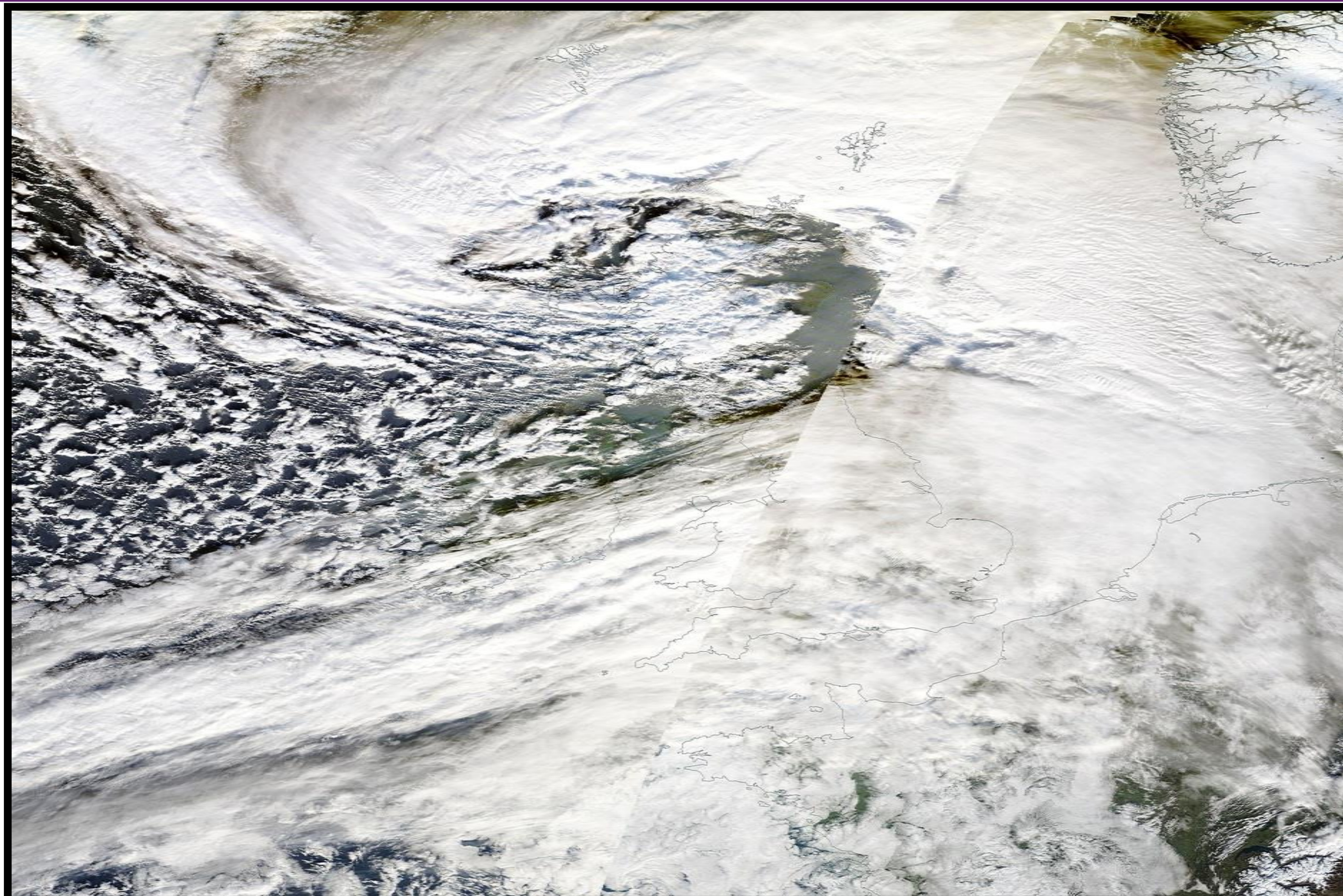

pH
LH minus UH (pH units)
MH minus UH (pH units)
AB minus UH (pH units)
BB minus UH (pH units)
BBET minus UH (pH units)
Annual mean pH
LH
MH
UH
BB
BBET
AB

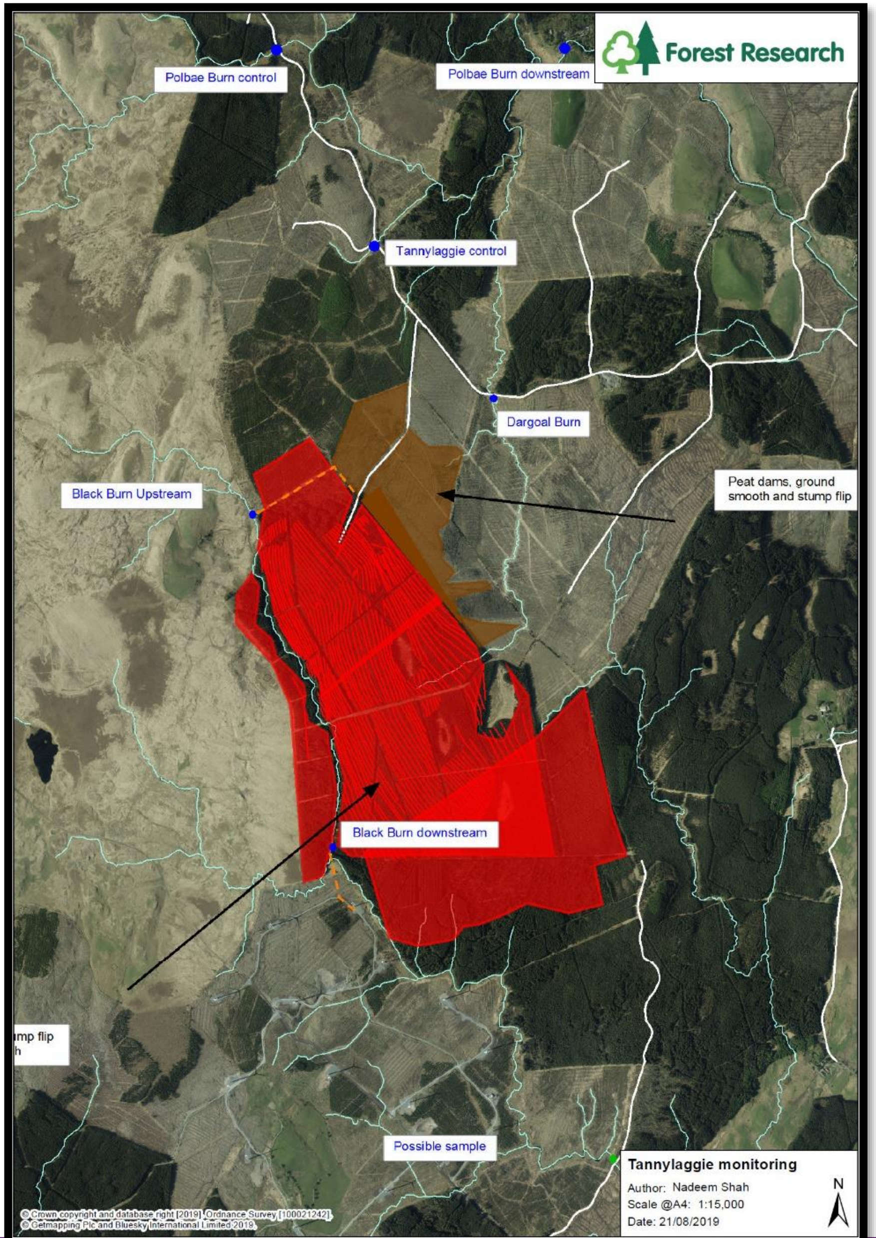
Climatic effects



On 8 Dec 2011 Hurricane Freidhelm hit Scotland; an intense extratropical cyclone with winds of up to 165 mph (265km/h)

Emphasises the benefit of long-term monitoring to distinguish between land-use and climatic effects.

Bladnoch



- Investigating the effects of peatland restoration on water quality.
- Different phases/techniques of restoration: clearfelling, drain blocking and ground smoothing.
- Partnership project with FR, FLS, SEPA and GFT.