Wetland: wise after-use at terminated peat cuttings

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Summary

Restoration is highlighted in European land-use exploration. Peatland used for peat harvesting is one such priority land use. Wise after-use of terminated peat-cuttings includes considerations of the landscape, hydrology, biodiversity and climate change. Considerable changes in site conditions, from the pre-cutting mire surface, exist after extraction of peat. Peat layers of several thousand years old are now facing current water and atmosphere contact. Such conditions have been investigated in two rewetted sites with different nutrient conditions. Ecological characteristics are reflecting peat conditions, resulting hydrology and water chemistry, evidentely influencing established vegetation and limnic life and greenhouse gas emissions.

Key index words: Greenhouse gas, limnic life, peat cutting, restoration, water quality

Introduction

Wise after-use at terminated peat cutover areas should consider a number of important issues such as landscape and biodiversity conditions as well as topographical location and hydrology. One such option is wetland rewetting. Effects of this relate to hydrology, vegetation, water quality, biology and greenhouse gases. Vegetation and limnic life show a great part of the success for biodiversity. Restoration of hydrology for wetland formation attracts increasing interest. Large areas have earlier been claimed for land-uses which resulted in only few natural mires remaining (Vasander *et al*., 2003). Land-use is often combined with drainage having effects on water quality. Natural wetlands are considered as retention areas for many elements (Sallantaus, 1989). Restoration would not mean turning conditions back to those before utilization. Instead, rewetting as after-use furnishes new soil, water and land properties. In Sweden, investigations on peat conditions, hydrology, water chemistry, wetland vegetation and greenhouse gas emissions are ongoing in two projects of peat cutover rewettings. The two areas differ in nutrient status, which is most evidently reflected in vegetation development.

Materials and methods

Two peatlands close to each other were investigated before and up to eight years after rewetting. In one of them, designed as the nutrient poor Porla site (c. 15 ha), peat chemistry is characterised by pH 4.5, C/N 45, K_{HCl} 600 mg kg^{-1} and P_{HCl} 600 mg kg^{-1}. The underlying ground is moraine material with small scale broken topography. A consequence of the uneven ground is the varying thickness of peat remains from almost no peat to a thickness of up to two metres and made up of both *Carex* and *Sphagnum* peat. After rewetting in year 2000, the peat increased in volume by swelling. Also floating peat appeared, mainly being Sphagnum peat, but with fen peat still resting on the wetland bottom.

The other experimental peatland is the West Fen (Västkärr - VK) site, enclosing an approximately 80 ha of cutover peat which formed originally a lagg area to the large Skagerhult bog. At the end of peat excavation activities in 1997, 0.2 m of fen peat was left on top of marine clay. This peat was fairly rich in nutrients characterised by pH 6,5, C/N 21, K_{HCl} 1200 mg kg^{-1} and P_{HCl} 320 mg kg^{-1}. This bottom peat was stable and stayed grounded as an organic bottom layer after rewetting.

Climate (annual temp. +6) and hydrology of the region is influenced by a winter period (100 days snow cover) but recently with frequent snowmelt. The hydrological pattern shows an ordinary precipitation (800 mm), evapotranspiration (500 mm) and runoff (300 mm).

Results

Water levels and vegetation

In the West Fen site (nutrient rich), the low-lying location in the landscape allowed good rewetting conditions due to inflowing ground water and surface waters. Mostly the water depth ranged from 0.8 m to 1.0 m. Vegetation establishment was fairly fast and a few years after rewetting we found close to 40 species of plants. Conditions have been fairly stable up to 2007 with 10 species dominating. The main species were *Glyceria fluitans L.* (with a 10 to 15% coverage), *Juncus effuses* (1-15%), *Potamogeton natans* (1-5%), *Phragmites australis* (5-40%), *Glyceria fluitans* (10-30%), *Carex rostrata* and *Carex spp.* (5-20%) *and occurrence of Equisetum limosum, Alisma Plantago-aquatica, and Bidens tripartite* (Fig. 1).

At the Porla site, maybe as a result of the fairly poor nutrient conditions, the spontaneous plant recolonization was dominated by *Eriophorum vaginatum* (5-40%) tussocks with a good presence of *Eriophorum angustifolium* (2-30%) at many locations (Fig. 2). Other occurring species were *Drosera rotundifolia, Scipus caespitosus, Betula pubescens* and *Polytrichum commune.* In a few places *Sphagnum* colonisation started in 2006 and increased in 2007 with patch sizes ranging from 0.01 to 0.02 m^2.

Figure 1. The West fen before and eight years after rewetting. Main vegetation occurred on the shorelines.

Water quality and discharge

After rewetting, the first years average discharges from the wetlands were lower by 5 to 24% compared to pre-rewetting conditions. However, after four years an increase by about 20% was noticed. High discharges were little affected (± 10%) while low discharges mainly decreased. In summer 2004 flows even ceased for two months compared to the control with only 10 days ceasing.

Water chemistry in the Porla wetland was characterised by high water colour, fairly low pH and base cation content, rather high ammonia concentration and ordinary phosphorus content (Table 1). Changes that were noted after rewetting were lower pH and lower concentrations of DOC, base cations, sulphate and organic nitrogen. Sulphate concentrations decreased because of reduced oxygen bottom conditions with initially released phosphorus. Organic nitrogen making up most of the total nitrogen content decreased due to sedimentation. Nitrate most likely decreased at first because of lower decomposition rate of the organic matter but increased in wetland condition due to nitrification of ammonia and organic nitrogen in free water, probably contributing to denitrification.

Water chemistry in the West fen was influenced by seeping groundwater. When it was still drained, the low water level facilitated groundwater discharge, which induced a fairly high pH of 6, a high Ca content, and stimulated a high sulphate and nitrate production (Fig. 3). After the rewetting, pH was lowered as well as the Ca, SO_4 and NO_3 content and DOC and phosphate increased the first years but later decreasing over time. Despite a lowered Ca content, pH increased probably because of the reduced sulphate production. Then, anaerobic conditions prevailed in the sediments and thereby releasing phosphate. After a few years P-release finished and PO_4 concentration dropped.

Decomposition of peat before rewetting, produced inorganic nitrogen with high nitrate content but also ammonia on a 0.5 mg L^{-1} level. After rewetting, nitrate concentrations turned lower (c. 1 mg L^{-1}) while ammonia and organic nitrogen remained on somewhat higher levels. Organic nitrogen

Water quality and limnic life were influenced by oxygen content in the water often being ordinary for small lakes and occasionally low at stagnation periods (Fig. 4). Close to the bottom and in the top sediments often low oxygen content occurred.

Figure 2. Porla before and seven years after rewetting. Porla (middle) vegetation transect indicated in central picture with Eriophorum tussocks found also in the south part of Porla.

Table 1. Water chemistry at the Porlan site before rewetting 1997-1999 (mean) with average changes after rewetting (Δ) for 2000-2003 (Δ1) and 2004-2006 (Δ2).

	pH	Colour mgPt/l	DOC mg/l	Ca mg/l	Mg mg/l	SO_4-S mg/l	NO3-N mg/l	NH4-N mg/l	Norg mg/l	Ptot, mg/l
mean	5.0	245	38	4.0	1.1	0.7	0.06	0.6	0.9	0.018
Δ1	-0.2	+20	-7	-2	-0.6	-0.2	-0.02	+0.3	-0.3	+0.01
Δ2	-0.1	-32	-7	-2.6	-0.3	-0,4	0,01	-0.02	-0,5	0

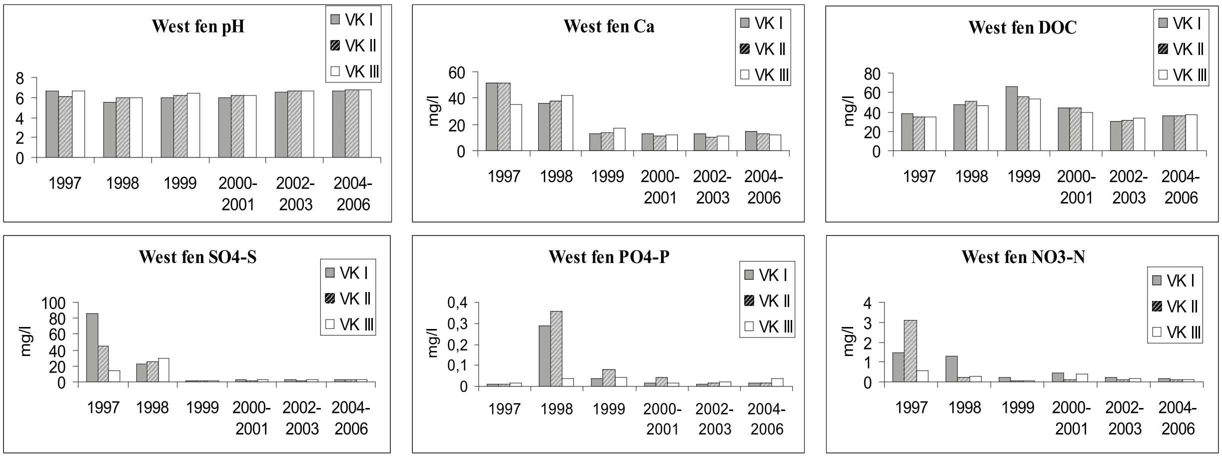


Figure 3. West fen water chemistry 1997 to 2006 with pH, Ca, DOC, SO_4-S, PO_4-P and NO_3-N.

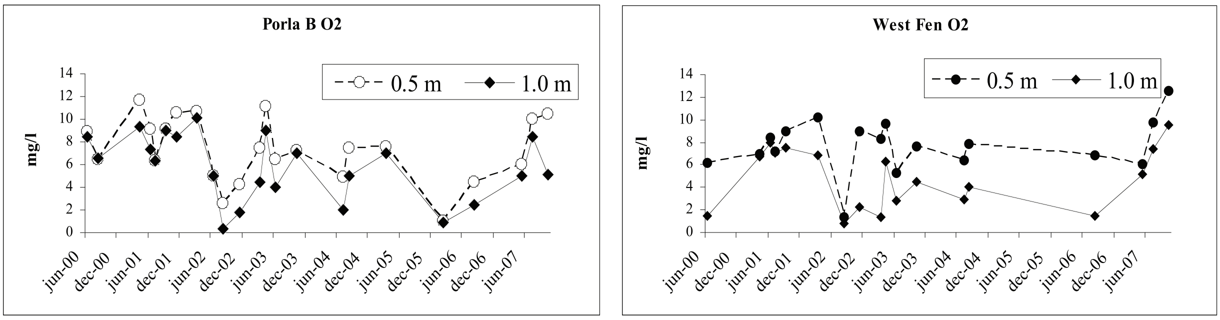


Figure 4. Oxygen content in the Porla and West fen wetlands during the years 2000 to 2007..

Limnic life indicated by bottom fauna

The benthic fauna in the Porla wetlands is species poor but tolerant to acidification and has increased up to 2007 (Fig. 5). In the bottom layers (2 m), the species indicate oxygen depletion. The number of the phatom midge *Chaoborus flavicans* was large indicating high zooplankton production. In the West fen, the number of species, individuals and biomass varied considerably and 4-5 years after rewetting, there occurred deteriorated water quality conditions with low values as consequence. Conditions improved later with increased numbers and biomass (Fig. 5).

Gas emissions

Wetland restoration by rewetting changes the CO_2 emissions that are supposed to decrease while methane emissions may increase. Poor wetlands turn to sinks but rich ones could still be emitters. These conditions were investigated in the poor Porla site using camber technique. Six 'vegetation types' were studied including a control sphagnum mire (*mire*). The other five types were drained peat without vegetation (*peat*), tussocks on drained peat (*tussock dry*), tussocks with surface water level (*tussock wet*), *carex* with high groundwater level (*carex wet*) and open water (*water*).

The CO_2 emissions from the vegetation types varied, with the lowest emissions measured on the pristine mire and the drained bare peat (Fig. 6). Variations were related to vegetation coverage and different amount of respiring biomass. The CH_4-fluxes showed a similar pattern as the CO_2 fluxes. The higher CO_2 emissions on tussocks on drained peat compared to the bare drained peat, can easily be explained by the respiration from living biomass. However, while the bare drained peat did not emit any CH_4, the tussock on drained peat did. This suggests that

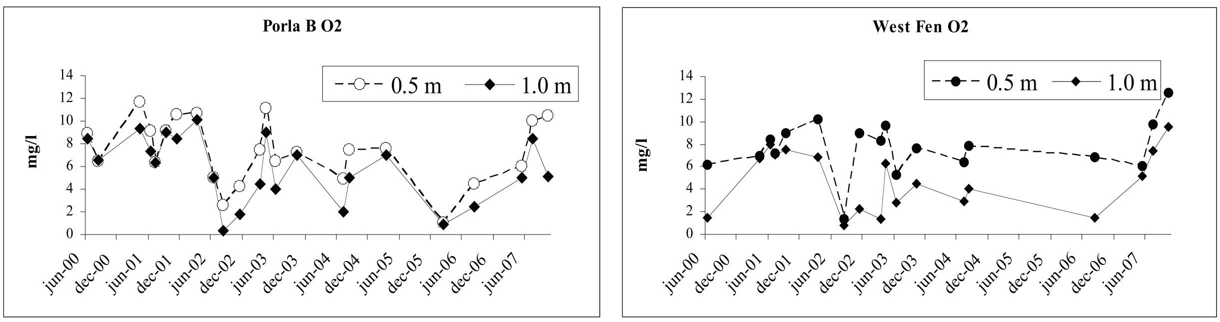
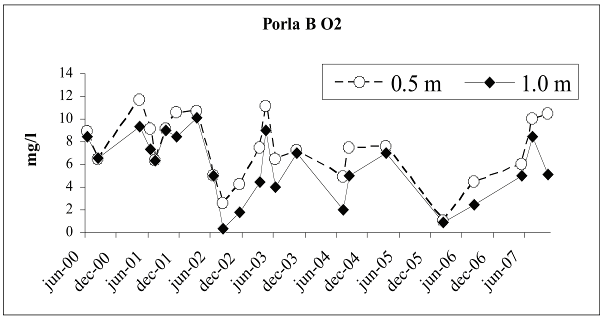


Figure 5. Number benthic fauna individuals and species and biomass content in Porla and West fen wetlands.



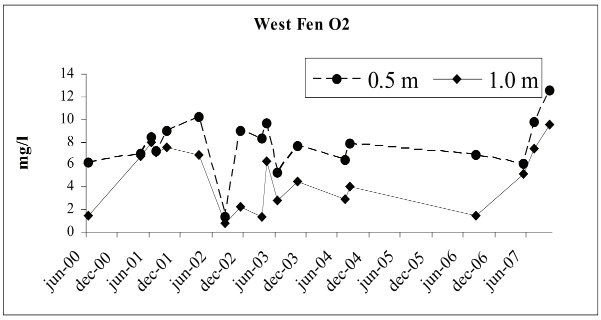


Figure 6. Emission of CO_2 and CH_4 from vegetation types in a rewetted area 20 June 2007. CH_4 emissions are converted to CO_2 equivalents.

the plants can (*i*) emit CH_4, (*ii*) promote the transport of CH_4 from the soil to the atmosphere and/or (*iii*) promote the formation of CH_4 in the soil.

First year measurements show lower emissions from the surface of the natural mire compared to the vegetation types on the rewetted area except the bare peat. Although, the emissions of CH_4 are smaller than CO_2 *per mole*, most vegetation types are dominated by CH_4 emissions when the much *higher radiative force* of CH_4 is taken into account (Fig. 6).

Conclusions

Rewetting, as wise-use after peat cutting, creates partly open water surfaces and with time vegetation colonisation. Water flows may change and during dry periods. There could be increasing risks for ceasing water flows. Water chemistry changes to lower element leaching for most major compounds. Vegetation and surface soil conditions, partly with floating rafts, contribute to a balance with new spontaneous *Sphagnum* colonisation. Water quality changed also with biological consequences where deteriorated water quality results in lower levels of limnic life but in the long run improvements were noticed. Emissions of greenhouse gases showed low values on bare peat but vegetation colonisation increased the emissions.

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