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RESTORATION OF WATER QUALITY AND BIOLOGY IN TWO REWETTED CUT-OVER PEATLANDS

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Summary
Restoration of wetlands is of high priority in Europe. After-use of peat excavation areas, including rewetting, is one such measure and has been investigated at two sites in Sweden. Water quality changed after rewetting with fairly stable or higher pH and concentrations of base cations. Nutrient concentrations were initially high but decreased after a number of years. Oxygen contents in water were similar to ordinary small lakes, also with occasional depletion in bottom layers at stagnation periods. The colonization of vegetation was rapid at Västkärr site but slower at Porla site, also with start of *Sphagnum* colonization. The bottom fauna consisted of high numbers of species and individuals the very first years after rewetting. After a few years the bottom fauna decreased to lower levels but is now slowly rising.

Keywords: After-use, bottom fauna, hydrochemistry, vegetation, wetland

Introduction
Peatlands cover vast areas of several North-European countries. The resource has been considered a societal asset and utilization concerns agriculture, forestry, horticulture and energy. These activities have resulted in various remnants of the mires and restoration or better expressed after-use is of high concern (Vasander et al., 2003). Regarding peat excavation, it has been carried out in many countries for at least 200 years. For a number of recent decades it has been mandatory to find suitable use of the remaining land. Forest production has been one main option but with increasing biodiversity interest rewetting reaches increasing attention (Maltby, 1986).

There are multiple possibilities for wise after-use of terminated peat extraction areas (Joosten and Clarke, 2002). Wetland restoration is one and relates to restoration of the hydrology to achieve a functioning wetland ecosystem. Indicators of success are water quality, vegetation development and freshwater biology such as bottom fauna.

Large mire areas have been affected by drainage and on sites with low success in crop or forest production, rehabilitation activities are taken to improve especially biodiversity values. In modern peat industrial utilization often the total peat resource is extracted with only thin remnants of peat remaining on top of the mineral soil. This furnishes conditions strongly deviating from areas where rather thick (> 1 m) peat still remains. Probably, there is a benefit to totally extract one site instead of affecting many sites but only extracting the top peat. This latter situation would probably keep conditions resembling the natural undisturbed mire but still, excavation impacts the mire. In cases with extraction of the total peat storage, the new, actually very old, bottom peat layers and mineral soil, for long time being covered by peat and preserved from surface water and atmosphere interface processes, now turns into influences from new environmental properties. Such situations provide new hydro-chemical and biological conditions and were studied in this investigation.

Site description

Two peat cut-over areas rewetted to wetlands after peat excavation termination were investigated before and after rewetting. The sites, the rich Västkärr fen and the poor Porla wetland, were located in south-west Sweden and had different nutrient status. In Västkärr, at excavation termination, c. 0.2 m fen peat covered a flat post-glacial clay mineral soil. In Porla, the mineral soil underlying the peat is an uneven moraine formation that led to a remaining peat thickness in a range from two metres depth to no peat layer, i.e. where only the bare mineral soil remained. Partly *Sphagnum* peat was left and later formed floating rafts. In Västkärr fen, pH in peat was 6.5 and CN-ratio 21 and in Porla peat values 4.5 and 45, respectively (Lundin and Lode, 2004).

Water chemistry

Water chemistry at the two rewetted sites show initially after rewetting a lowered pH but later increased and even reached values higher than before rewetting. Dissolved organic carbon (DOC) shows initially increased DOC at Västkärr fen after rewetting but later lower DOC concentration. This later pattern coincides with changes at Porla site where lower concentrations were experienced after rewetting (Fig. 1). Regarding phosphorus (P), there were increased contents after rewetting at both sites. However, at Västkärr fen, initially new probably reduced conditions in the bottom water released large amounts of P but after a few years, P decreased to low concentrations, probably due to planktonic and higher vegetation uptake (Fig. 2).

Base cations, especially calcium (Ca), showed lower contents after rewetting as well as total nitrogen (N) at the Porla site. Nitrate increased initially at Porla wetland but turned lower with time as was also observed at Västkärr fen. Ammonium (NH_4) also increased short after rewetting at Porla wetland but mainly decreased at Västkärr fen. After ten years, NH_4 turned lower also at site Porla. In Västkärr fen, the sub-basin VK III received leaching water from the nearby ongoing peat excavating area up to 2001 when the outlet was changed to sub-basin VK I and NH_4 content decreased at VK III but instead increased in VK I (Fig. 2). In conclusion, however, rewetting seems to lead to a decreased nutrient content in the wetlands.

Insert Figure 1

Insert Figure 2

Wetland water quality

Water quality was to a large extent controlled by the oxygen (O_2) content and in the shallow wetland lakes, water turnover could be fast and sensitive to wind. This furnishes often fairly good conditions with existing O_2 content. However, in stagnation periods and especially in the deep bottom water, depletion of O_2 content could appear. This occurred a number of times in the two wetlands (Fig. 3).

Insert figure 3

Limnic life indicated by bottom fauna

The benthic fauna in the Porla wetland is species poor but tolerant to acidification and the number of species has increased (Fig. 4). The groups dominating in the early wetland period were collectors, scrapers, and shredders but most of these decreased over time and after ten years predators dominate. In the bottom layers (1-2 m), the species indicate O_2 depletion. This was especially evident in the year 2002.

The number of the phantom midge *Chaoborus flavicans* was large and indicated high invertebrate production. In the Västkärr 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. One of the sites (VK III) was considered rich in individuals in 2001 but this decreased. Bottom fauna conditions improved later with increased numbers and biomass but have again, in the last three years, slightly decreased (Fig. 4).

Insert figure 4

Water levels and vegetation

In the nutrient rich Västkärr Fen, the low-lying location in the landscape allowed good rewetting conditions due to inflowing groundwater 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 effusus och Juncus stygius* (1-15%), *Potamogeton natans (*locally also *gramineous)* (1-5%), *Phragmites australis* (5-40%), *Phalaris arundinacea* (10-30%), *Carex rostrata* and *Carex* spp. (5-20%) and occurrence of *Equisetum limosum*, *Alisma plantago-aquatica*, and *Bidens tripartita* (Fig. 5). Ten years after rewetting fewer species dominated with 20-30% *Phalaris arundinacea*, 30-60% *Carex spp*., 10-30% *Typha angustifolia* and 0-30% *Phragmites australis. Phragmites* dominated totally close to open and deeper water. Open water and bare peat occurred between the plants with coverage of 10-50% each. Observed, but with smaller coverage, were *Alisma plantago-aquatica*, *Juncus sp.*, *Sparganium emersum* and *Butomus umbellatus.*

Insert Figure 5

At the Porla site, maybe as a result of the fairly poor nutrient conditions, the spontaneous plant re-colonization within the first 3-5 years was dominated by *Eriophorum vaginatum* (5-40%) tussocks with a good presence of *Eriophorum angustifolium* (2-30%) at many locations (Fig. 5). Other occurring species were *Drosera rotundifolia*, *Scirpus caespitosus*, *Betula pubescens* and *Polytrichum commune*. About ten years after rewetting *Eriophorum vaginatum* still dominated with coverage of 20-90%. Also *Eriophorum angustifolium* was common with 5 to 50% and *Drosera spp*, *Betula spp.*, *Utricularia minor*, *Juncus sp.* and *Rhynchospora alba* were found in many places. In a few places *Sphagnum* colonization started in 2006 and increased after that with patch sizes in 2010 ranging from 0.1 to 1 m^2.

Conclusions

Wetland restoration after terminated peat excavation turned the peat cut-over area from a source of elements to a retention area for several chemical compounds. Initial colonization of bottom fauna and vegetation showed high species number but turned more trivial after some years and the new wetland conditions resembles ordinary small shallow lakes in the Swedish landscape.

Acknowledgement
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Captions to figures

Figure 1. Water chemistry at Porla rewetting with measured values for four periods and changes after rewetting during the three later periods.

Figure 2. Water chemistry at the three basins at Västkärr fen during 1997 – 2010. VK I solid bar, VK II hatched bar and VK III open bar.

Figure 3. Oxygen content in the two rewetted sites.

Figure 4. Number benthic fauna individuals and species and biomass content in Porla and Västkärr fen wetlands.

Figure 5. The peatlands before and after rewetting. The middle figure shows Porla site eight years after rewetting and the right figure Västkärr fen after the same time.

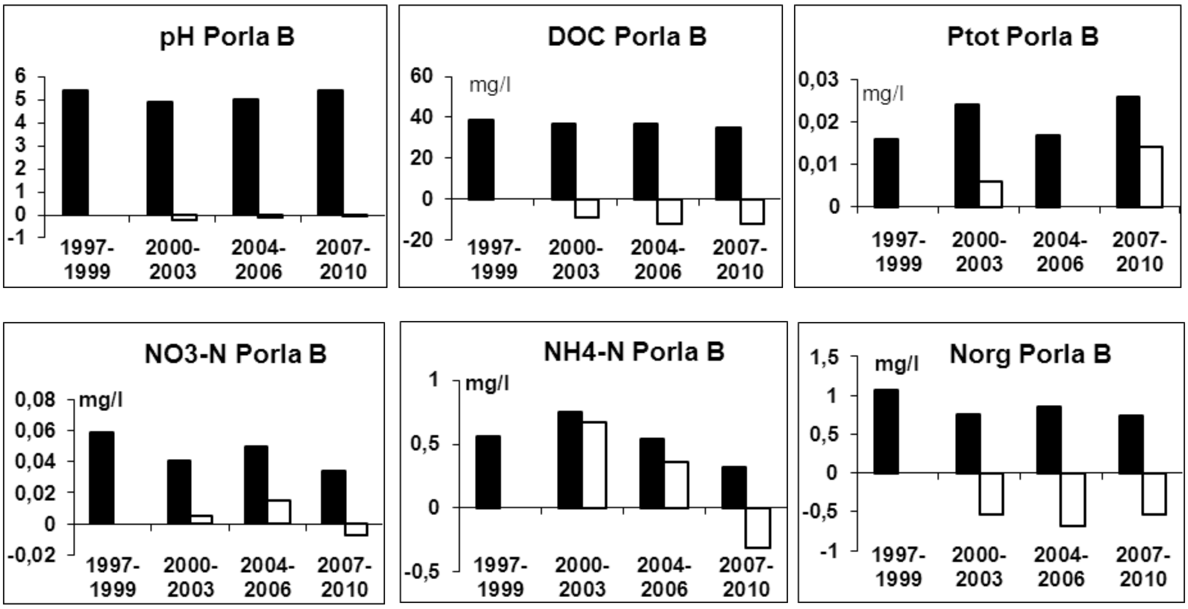

Figure 1.

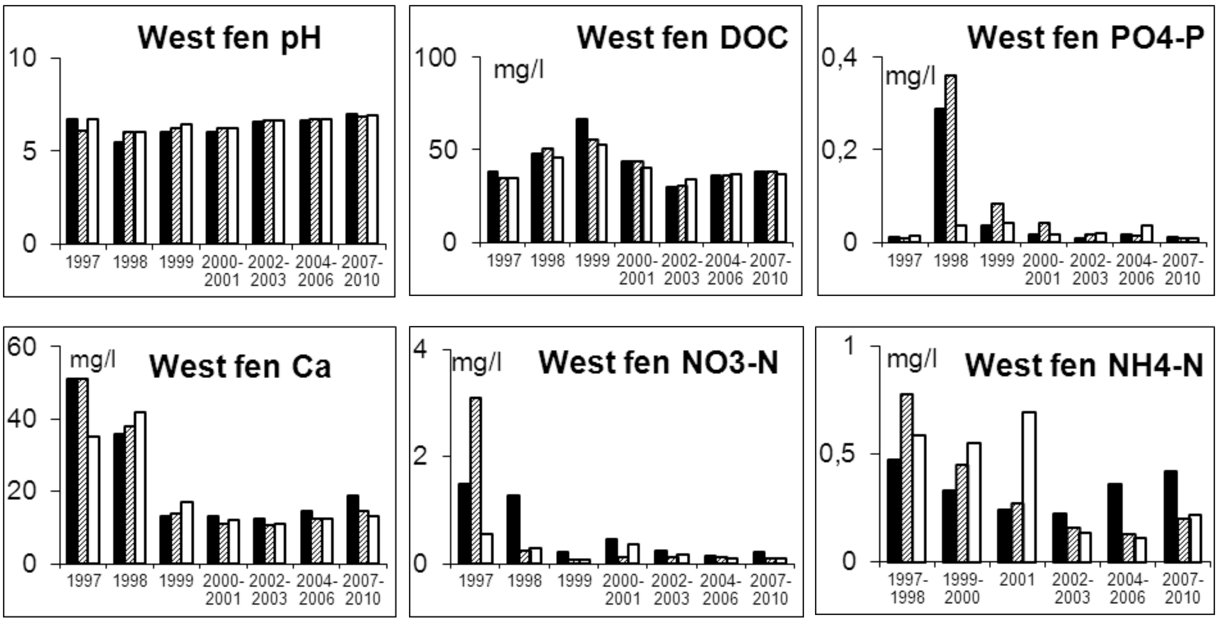

Figure 2.

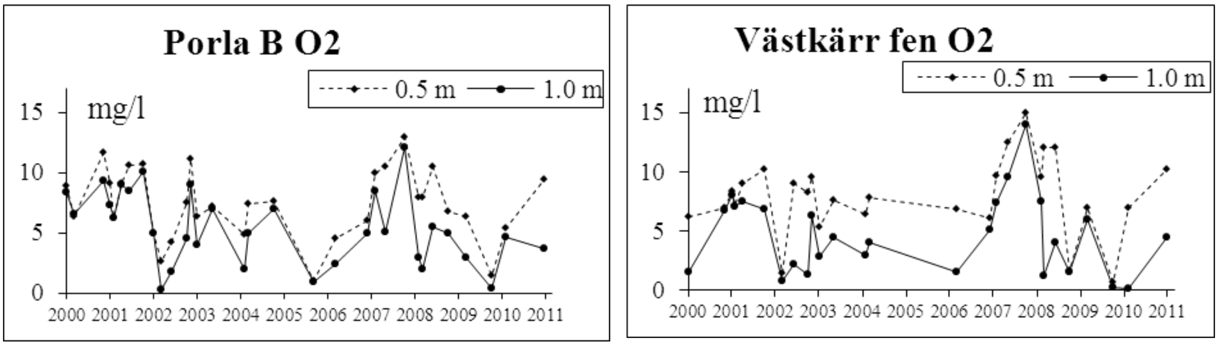

Figure 3.

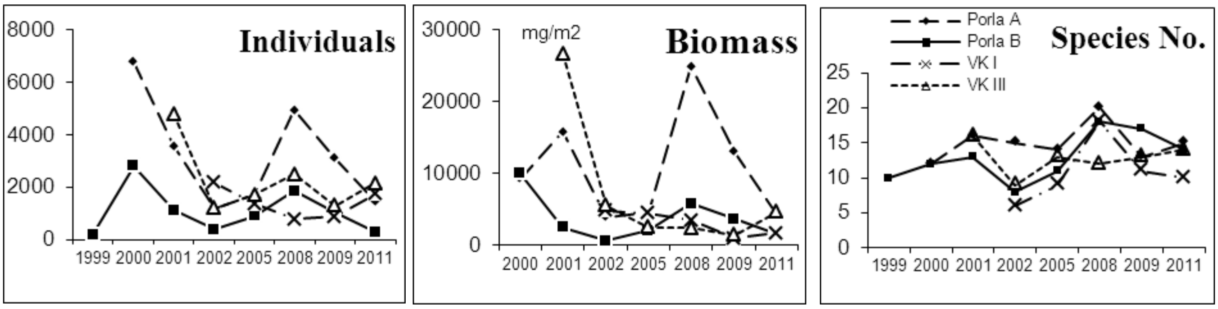

Figure 4.

Figure 5.