Mires as buffer areas for high water quality in forest land

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Summary

Mires and wetlands exert crucial functions for aquatic ecosystems in forest landscapes. Forest land is extensive in the Nordic-Baltic region with forestry operations adding to element outflows exerting enhanced pressures on water courses. The importance of retention areas such as buffer zones attracts interests in water turnover and chemical element balances. Investigations on mires as protection areas were carried out with special attention on the Bälgsjön lake catchment. The conclusion regarding changed water quality related to forestry measures showed the importance of the mire mitigation for water quality providing results on fen functions as buffer area.

Key index words: buffer area, element leaching, forestry, mire, water quality

Introduction

High water quality is a burning issue in many countries, including those with excessive water assets. Activities in rural areas have impacts on the water quality and the catchment composition would be of significant importance. Wetlands are one such area making up only small fractions of the landscape but because of location in the transition zone from uplands to surface waters, furnish the final water composition at surface water formation. Such conditions provide influences on chemical transformations, biodiversity and ecosystem functions.

A considerable part of the wetlands are peatlands and these have been claimed for agriculture, forestry and peat mining. In many European countries only few areas remain in natural state. Restoration by rewetting is a priority task (Kuntze, 1994). However, this means influences on the hydrochemistry of the area and downstream watercourses. Drainage and peatland utilisation means increased leaching of many nutrients (Lundin, 1988) while natural wetlands are considered as retention areas for most elements apart from hydrogen and organic substances (Sallantaus, 1989). Nutrient leaching from natural forest areas is mainly low but the extensive areas furnish anyhow considerable total amounts. Added to this should be elevated leaching from forestry measures on managed forest areas.

Forestry and agriculture practices in recharge areas to peatlands mean leaching of nutrients and elements to the peatland (Grip, 1982; Ahtiainen, 1992; Lundin, 1999) where hydrochemical processes alter the contents and the outflows depend on the transformations occurring. This is especially important to phosphorus and nitrogen (Lundin, 1998). Other changes could be smoothened discharge, nitrogen and phosphorus trapped and organic compounds added.

Forestry activities concern clear-felling, drainage, scarification and afforestation. Effects of such measures could be elevated water levels and higher discharge, increased leaching of base cations, nitrogen, phosphorus and organic compounds. Other measures, such as drainage and afforestation partly could have opposite effects. Superimposed effects on this might come from climate change. Long-lasting effects of both forest management and peatland conditions, as investigated in the Bälgsjön area, seemed to be decreased runoff from the forest catchments and ongoing retention of several nutrients in the wetland.

In the Bälgsjön catchment one of the major subcatchments, the Bohyttan mire catchment, was of main focus in this study. Investigations were carried with monitoring of inflow from forested uplands under silvicultural impacts and outflow to a lake being a municipality fresh water supply. Problems with high water colour have been evident in periods during the last 20 years. Important in leaching is then especially dissolved organic carbon (DOC) and iron (Fe) but also nitrogen and phosphorus. Long-lasting effects of both forest management and peatland conditions on leaching from forest land showed nutrient transformations at transition of the mire buffer zone.

Materials and methods

The Bohyttan catchment, located in central south Sweden (Fig. 1), being a joint upland 218 ha catchment, with subcatchments (31-81 ha) under various forest management, was monitored for discharge and water chemistry for over fourteen years. Water from the forest uplands was transferred through the mire before entering the freshwater supply lake. The catchment area includes forested upland mineral soils drained through the mire to the outlet in a lake. The mire, being an open poor sedge fen, had a peat thickness of 0.5-2.0 m with water levels commonly between 0.1-0.4 m below ground surface. Characteristic plants were *Carex lasiocarpa* and cottongrass (*Eriophorum vaginatum*) with a wide spread coverage of Sphagnum mosses (*S. palustre* and *S. fallax*).

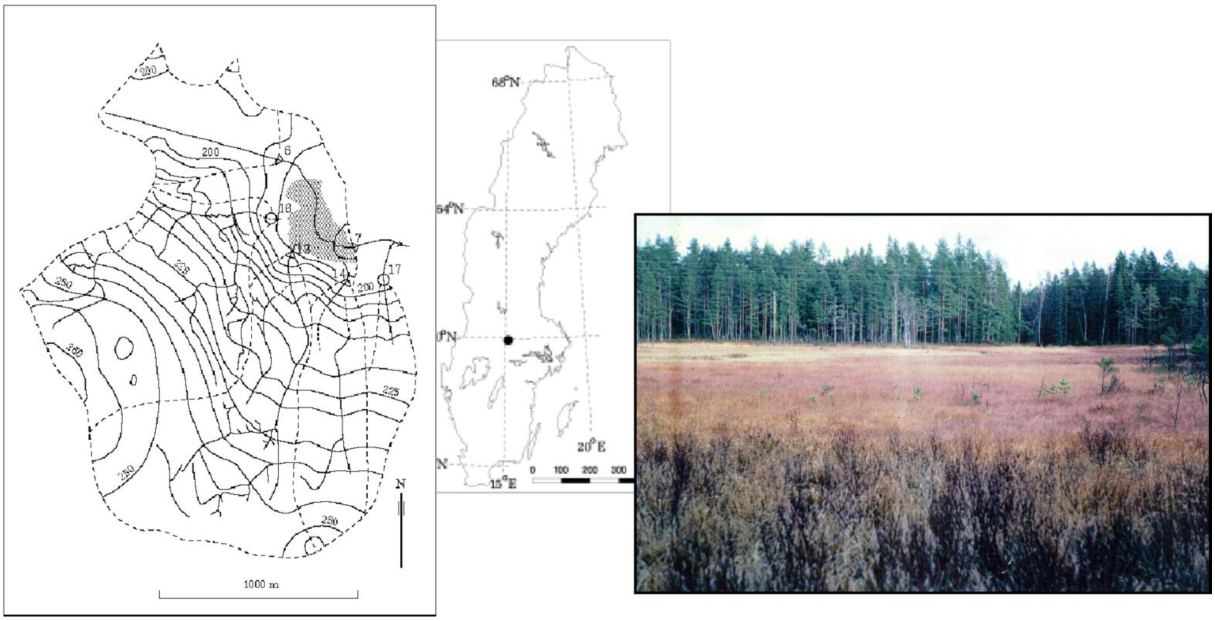

Figure 1. Geographical location of the Bohyttan fen catchment in central south Sweden with upland catchments to the fen (grey polygon) and a photo illustration of the sedge fen.

Hydrochemical budgets have been established for the leaching through the fen. The total catchment was 243 ha and the fen 7 ha. Forest stands in the uplands were mature coniferous stands on 60% of the area and c. 30% being young or clear-cut areas. The remaining area included peatlands, lakes etc. The exposition of the area is on the south-west side of a regional highland, which at current climatic conditions means relatively high precipitation and chemical deposition. Climate is fairly cold with a snow-covered period from December to March and a vegetation period (Temp. > 5°C) from mid-April to end of October (Table 1). Inflow was measured continuously at discharge weirs at three inflows and one outflow location. Water was sampled monthly for chemical analysis (analysis according to Swedish standards).

Results

Transformation of inflow chemical composition to outflow would be dependent on the chemical conditions in the mire retention area. For the Bohyttan fen the composition was characterised by fairly acid water with pH below 5 and high water colour (c. 150 mgPt L^{-1}). Also content of dissolved organic carbon (DOC), Fe, P_{tot} and N_{tot} were relatively high with inorganic nitrogen making up c. 15% of the total nitrogen (Table 2). Base cations were at low concentrations and dominated by Na and Ca with a total BC content at c. 250 meq L^{-1}. The ion balance resulted in an anion deficit of 20-50 meq L^{-1}, i.e. charge density of 5-10 meq mg^{-1} DOC, which agrees fairly well with the c. 10 meq mg^{-1} DOC given by Thurman (1985).

Table 1. Climate and hydrology at the Bohyttan fen (Raab and Vedin, 1995).

Annual mean temperature, °C	+5	Precipitation, mm	850
Length of vegetation period, days	190	Runoff, mm	400
Snow-covered period, days	125	Evapotranspiration, mm	450

Table 2. Water chemistry characteristics at the Bohyttan fen with inflow and outflow values together with conditions in two groundwater levels (depth in peat below ground surface level) (Gw) for the years 1992-1995.

	Inflow	Gw 0.2 m	Gw 1.0 m	Outflow
pH	4.9	4.3	4.9	4.7
DOC, mg L^{-1}	16	22	31	16
Fe, mg L^{-1}	0.8	1.1	3.1	0.9
Ca, mg L^{-1}	2.2	1.1	3.1	0.9
P_{tot}, mg L^{-1}	0.016	0.016	0.020	0.012
NH_4-N, mg L^{-1}	0.06	0.03	0.07	0.05
NO_3-N, mg L^{-1}	0.05	0.03	0.01	0.03
N_{tot}, mg L^{-1}	0.65	0.65	1.02	0.66

Table 3. Chemical composition of streamwater before and after forestry measures.

Element	Clear-cut Before (3 years)	Clear-cut 1-5 years after	Cut and drained Before (9 years)	Cut and drained 1-5 years after
pH	4,35	4,30	5,05	5,64
K, mg L^{-1}	0,30	0,51	0,57	8,86
Fe, mg L^{-1}	4,0	6,2	0,60	0,40
Ptot, mg L^{-1}	0,025	0,025	0,009	0,030
NO3-N, mg L^{-1}	0,028	0,053	0,016	0,070
DOC, mg L^{-1}	38,5	42,0	13,7	9,6

Additional to the ordinary chemical content in inflow from forested land were effects of the forestry measures in the uplands such as clear-felling, scarification and ditching. Common effects could include increased leaching of many elements (Grip, 1982; Ahtiainen, 1992; Lundin, 1999) and especially enhanced could be nitrogen, phosphorus, base cations and metals. In the Bohyttan catchment case, increased leaching concerns potassium, nitrate and phosphorus while hydrogen decreased (Table 3).

DOC and Fe were dependent on hydrological conditions and with drainage giving lowered groundwater tables lower concentrations occurred. After harvesting water levels rise with through flow in organic soil layers providing flow of organic material. Such conditions would also influence pH with lower values at high water levels.

The inflow of elements from the uplands to the fen was changed before outflow to surface waters. The Bohyttan fen acted as a retention area for several elements such as most base cations, silica, sulphate, nitrogen and phosphorus. Especially, nitrate and phosphate were retained (Fig. 2) while hydrogen, organic carbon, iron and manganese were released, meaning an excess outflow compared to the inflow (Table 4).

Organic compounds emanating from the fen carry metals and many other elements from the fen. Higher outflow of organic carbon and nitrogen indicate the release of organic substances in the fen. Water colour would be influenced from this, where metals such as iron contribute.

Conclusion

In countries with extensive areas of forest land, leaching of nutrients even at fairly low concentrations could add up to considerable total amounts and exert deteriorating effects on surface waters. Locally, forestry measures could add to this given hazardous conditions for surface freshwaters. To mitigate leaching, wetlands may contribute as nutrient traps (Devito et al., 1989). Such impacts are fairly well known in agriculture areas but less clarified in ordinary rather nutrient poor forest land with adherent mires. In relation to a surface water supply lake in central Sweden investigations of a fen were carried out with results for many elements showing mainly retention, especially for the eutrophication compounds nitrate (34%) and phosphate (5%). However, organically bound elements, such as metals, had a tendency to be released as well as organic carbon and hydrogen furnishing slightly acid water with high water colour. An increase of the colour from 144 mgPt L^{-1} to 158 mgPt L^{-1} was observed. In the forest land use, considerations on preserving riparian sites in the near stream zone for surface water formation are important and should be considered in a careful way. Water pathways, though would be crucial to retention or release. Often such areas are peatlands forming transition areas in the landscape but also being complex and should need more research to clarify the fen hydrochemical ecosystem functions.

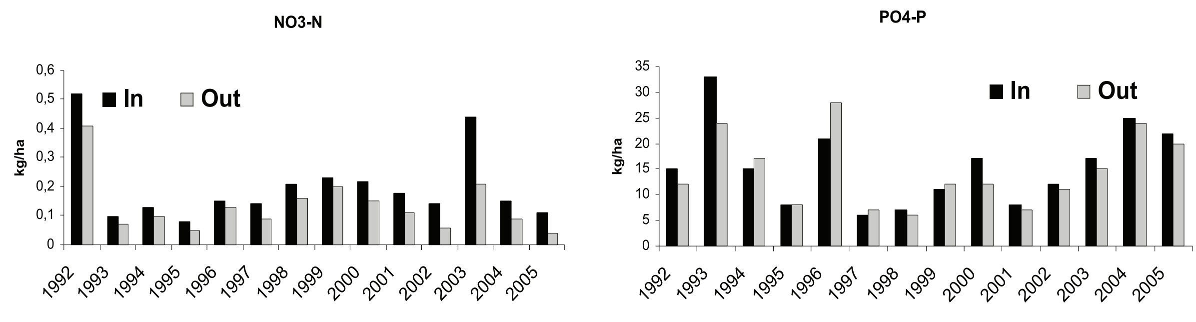

Figure 2. In and out flow of nitrate (NO_3-N) and phosphate (PO_4-P) to the Bohyttan fen during fourteen years.

Table 4. Element balances for the Bohyttan fen during the years 1992-2005. Positive changes In-Out means retention. Values in kg ha^{-1} but discharge, Q in mm.

Element	IN	OUT	Element	IN	OUT	Element	IN	OUT
Q, mm	542	535	Fe	5.8	6.3	NO_3-N	0.20	0.13
Na	12.9	12.4	Si	21.3	20.7	NH_4-N	0.24	0.22
K	2.6	2.4	SO_4-S	26.6	24.8	N_{tot}	2.83	2.90
Ca	11.2	10.8	Mn	0.05	0.09	PO_4-P	0.02	0.01
Mg	3.5	3.6	DOC	106	108	P_{tot}	0.05	0.05

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