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Minor effect of beaver dams on stream dissolved organic carbon in the catchment of a German drinking water reservoir

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ABSTRACT

Rising concentrations of dissolved organic carbon (DOC) are negatively affecting the water quality in several drinking water reservoirs. The presence of beaver dams can influence surface water quality on a catchment scale. In recent years, beavers have been re-introduced in numerous locations in Central Europe. We investigated whether the presence of beaver dams in the catchment of a German drinking water reservoir impacts DOC quantity and quality in the streams entering the Wehebach reservoir in Germany.

By comparing water quality upstream and downstream of beaver dams during three low discharge situations we did not find a significant effect of dams both on DOC quantity and quality. The analysis of long term monitoring data at the gauges showed that beaver dams had a negligible effect on the DOC load to the reservoir. DOC quantity was closely linked to iron concentration in the streams. Co-precipitation with iron minerals was an effective process removing DOC from the stream-water. By analyzing fluorescence excitation emission indices we show that beaver dams did not have a clear effect on DOC quality. We conclude that the presence of beaver dams has only small effects on water quality and is not a problem for water quality in the downstream drinking water reservoir.

1. Introduction

Concentrations of dissolved organic carbon are currently rising in many regions of the world (Evans et al., 2004). In particular, rising DOC in the catchment of drinking water reservoirs pose problems for drinking water production (Matilainen et al., 2011). The reasons for DOC increase as well as the mechanisms of DOC transformation in the streams are not yet completely understood. It has been hypothesized that pH increase in catchment soils due to decreased acid deposition has been mobilizing DOC (Monteith et al., 2007). Recent evidence suggests that reduced atmospheric nitrate deposition might have caused redox shifts in soils (Musolff et al., 2016) which mobilizes DOC adsorbed to ferric minerals (Knorr, 2013). Especially near stream soils and riparian areas have been identified as main sources for stream DOC (Marwick et al., 2014).

Beavers have the potential to affect these potential drivers of stream DOC (Naiman et al., 1986) and biogeochemical cycles on a landscape scale (Naiman et al., 1994). Beavers are abundant in boreal landscapes and can increase the wetted surface to several hundredfold, enlarging the area of waterlogged and reduced soils (Naiman et al., 1986). Beaver dams increase the contact zone between soils and stream, probably enabling more DOC input from riparian soils. Beavers are eco-engineers with diverse effects on ecosystems (Vehkaoja et al., 2015). They change catchment hydrology (Nyssen et al., 2011), increase the greenhouse gas emissions (Ford and Naiman, 1988; Roulet et al., 1997; Weyhenmeyer, 1999; Whitfield et al., 2015) and retain nitrogen in the catchment (Naiman and Melillo, 1984).

Regarding the effect of beavers on DOC export from catchments there exists contrasting evidence. Beaver dams trap particulate organic carbon (POC) (Johnston, 2014; Naiman et al., 1986; Wohl, 2013). This organic material is a potential source both of greenhouse gases (Roulet et al., 1997) and DOC. Beaver dams may also

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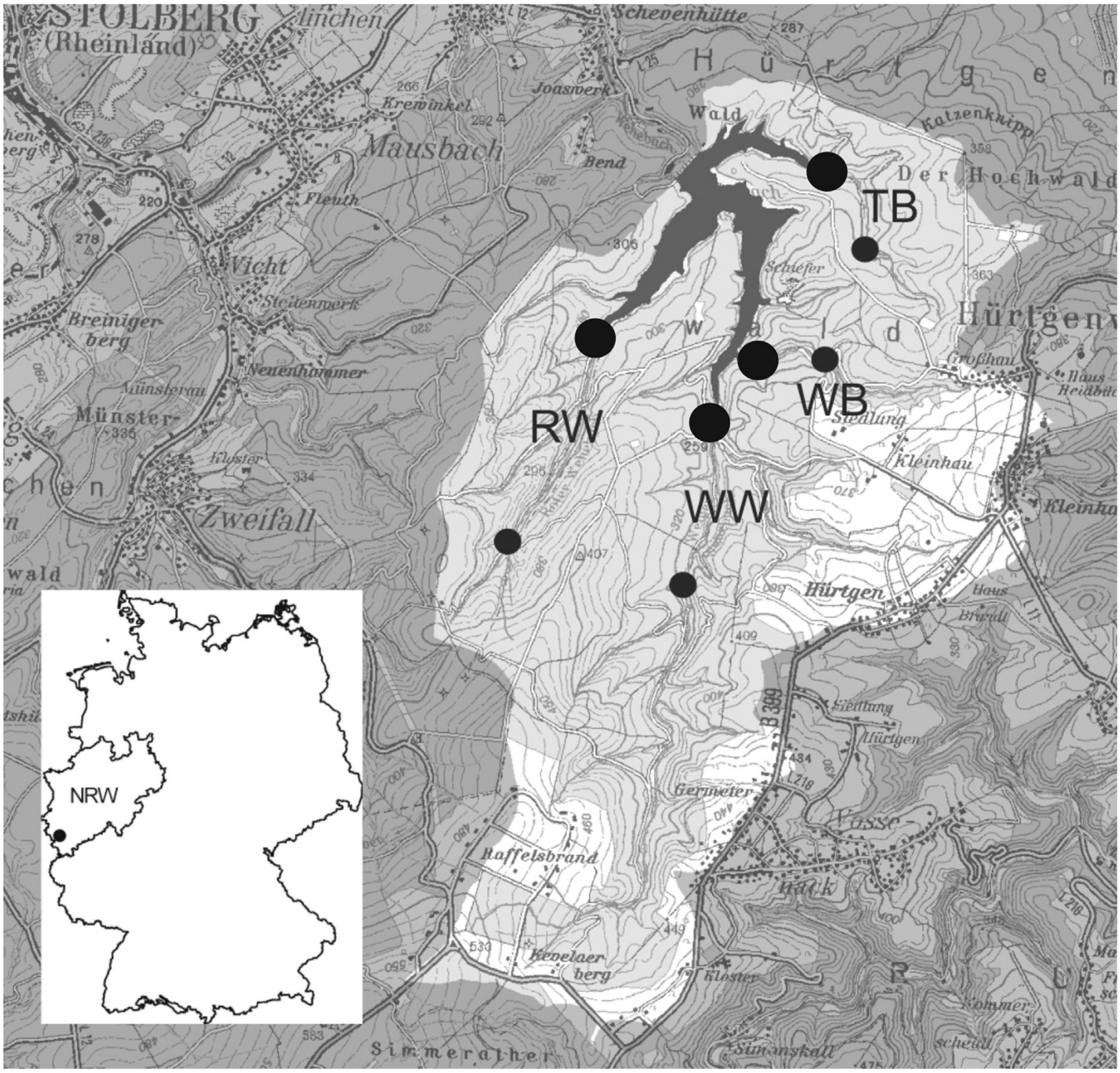

Fig. 1. Catchment of the Wehebach reservoir and sampling sites (black dots, large dots indicate gauging stations). The insert shows the location of the catchment in the state of Nordrhein Westfalen (NRW) in Germany.

increase DOC export from catchments by stimulating aquatic primary production (Cirmo and Driscoll, 1996). Mass balances of two Canadian beaver ponds revealed seasonal differences with DOC retention during summer and DOC emission during the rest of the year (Devito et al., 1989). Concentration increase in DOC was higher in summer, but because of higher discharge the total DOC load was more increased in the non-summer months (Cirmo and Driscoll, 1993). The effects of beaver ponds seem to depend on the age of the pond. In a coastal plain catchment a newly formed beaver pond reduced annual discharge of TOC by 28% (Correll et al., 2000). The DOC concentrations in boreal lakes increased in the first years of beaver colonization, but after 4–6 years returned to background concentrations (Vehkaoja et al., 2015). These diverse studies make clear that the effects of beaver dams on DOC export from catchments are complex and not fully understood.

Existing studies focus on North America and the boreal zone of Europe. Nothing is known about the effect of beavers on DOC export from central European catchments. It is not clear, whether results obtained in boreal catchments can be transferred to central Europe, where streams are more affected by human activity and geochemical conditions are different. After nearly being extinct in Central Europe, since a few decades beavers have been re-introduced into numerous areas in Germany (Dalbeck, 2012) and are now present in all 16 federal states of Germany. In the Hürtgenwald area in Western Germany in 2013, 149 beaver dams were counted in a 24.3 km^2 area, 6.1 dams per km of stream (Dalbeck et al., 2014). This recent increase in beaver population raises the question, whether the creation of beaver dams in the catchment of drinking water reservoirs could be a problem for water quality in the reservoirs.

Our objective was to clarify whether the presence of beaver dams may increase the DOC load in a German drinking water reservoir catchment. We hypothesize that the formation of beaver dams should increase DOC export from the catchment because they increase the area of potentially DOC releasing riparian wetlands (Marwick et al., 2014). To test this hypothesis we compared the water chemistry upstream and downstream of the dams in three streams with different abundance of beavers and a control stream which was not influenced by beaver dams. An analysis of long term monitoring data should answer the question, whether the presence of beaver dams change the DOC concentration in streams especially during low discharge.

By studying optical properties of the water we aimed to find out whether beaver dams have an effect not only on DOC quantity but also on DOC quality. We hypothesize that due to the extended ripar-