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Effect of beaver dams on the hydrology of small mountain streams: Example from the Chevral in the Ourthe Orientale basin, Ardennes, Belgium

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SUMMARY

The European beaver (*Castor fiber*) was recently reintroduced to Belgium, after an absence of more than 150 years; around 120 beaver dam systems have been established. In Europe, few studies consider the hydrological effects of those dams, and the spatial scale larger than that of one beaver pond system has not been addressed at all. This research focuses on the hydrological effects of a series of six beaver dams on the Chevral R., a second order tributary of the Ourthe Orientale R. in a forested area of the Ardennes. Thereby, also the Ourthe Orientale sub-basin itself was taken into account, being the area with probably the highest density of beaver dams in Belgium. The main research questions regarded: (1) the extent to which discharge peaks are reduced at the very location and well downstream of beaver dams and (2) the impact of the beaver dams on low flows. The first approach consisted of a temporal analysis of the Ourthe Orientale discharge and precipitation data for the periods 1978–2003 (before) and 2004–2009 (after the establishment of beaver dams in the sub-basin). The second study determined the *in situ* impact of the beaver dams: discharges were measured (September 2009–March 2010) upstream as well as downstream of the 0.52 ha beaver dam system on the Chevral river, and changes in water level within the system of six dams were monitored. Our findings indicate that there is a significant lowering of discharge peaks in the downstream river reaches due to the effect of the beaver dams. The temporal analysis of the Ourthe Orientale sub-basin shows an increase in the recurrence interval for major floods; for instance, the recurrence interval of a reference flood of 60 $m^3\ s^{-1}$ increased from 3.4 years to 5.6 years since the establishment of the beaver dams. At the scale of the Chevral beaver dams' site, we measured that the dams top off the peak flows, in addition delaying them by approximately 1 day. There are also increased low flows: Q_{355} (i.e. the discharge exceeded 355 days in a year) of the Ourthe Orientale was 0.6 (±0.15) $m^3\ s^{-1}$ before beaver dam installation and 0.88 (±0.52) $m^3\ s^{-1}$ thereafter. These findings agree with studies that suggest natural measures for flood control at the level of small mountain streams instead or in complement of building large anthropogenic constructions. Nevertheless, more studies are needed to assess the effectiveness of beaver dams in flood mitigation at the scale of sub-basins.

1. Introduction

The genus Castor comprises two species: the European beaver *Castor fiber* and the North American beaver *Castor canadensis*. Beavers (*C. canadensis*) have particularly been part of the riparian ecosystem of Northern America for centuries (Naiman et al., 1988). Ives (1942) described how beavers create an extensive artificial environment, and until major human impact took place, the changes to valley bottoms induced by beavers exceeded in magnitude those produced by humans. Though the two species cannot interbreed, they have very similar habitats, behaviour and impacts on the ecosystem (Djoshkin and Safonov, 1972; Macdonald et al., 1995).

Formerly widespread throughout much of the Palaearctic region, European beaver populations were reduced through overhunting to ca. 1200 animals, in eight isolated populations, by the end of the 19th century (Halley and Rosell, 2003). Since the 1920s, effective protection of the *C. fiber* remnant populations, the resultant natural spread, and widespread reintroductions have led to a powerful recovery both in range and in population (Halley and Rosell, 2003).

Increases in the populations and distributions of species that are able to modify ecosystems have generated much scientific interest (Rosell et al., 2005). Further, the period of rapid beaver population growth often coincides with a peak in conflicts with human land-use interests, as the colonisation of marginal habitats

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is more likely to require extensive modification by beavers (Halley and Rosell, 2003).

Since the early paper by Ruedemann and Schoonmaker (1938) in Science, it has been agreed that the most typical beaver habitat, the beaver dams, has not only nature or ecological value, but has also impact on runoff response and geomorphology. Beavers are among the few species besides humans that can significantly change river geomorphology, and consequently the hydrological characteristics (Butler and Malanson, 1995; Rosell et al., 2005). In the early Holocene, Coles (2009) argues that beavers had a greater influence on the environment than did humans, but at some point the balance shifted to humans having the greater impact. The ability of beaver ponds to effectively trap sediment, regulate the hydrology and reduce stream erosion has been demonstrated (Butler, 1995; Green and Westbrook, 2009). However, Butler (1995) estimated that "an enormous amount of work remains to be done before the effects of beavers on the landscape can be quantified".

The major local impact of beaver dams is that flow velocity is reduced and peak and low flows are regulated by beaver dams to a varying extent (Woo and Waddington, 1990). At wider scale, the beaver is considered a keystone species for water management (Angelstam et al., 2006). Although in Northern America beavers were more prevalent than today, their current induced alterations to drainage networks are not localised or unusual (Naiman et al., 1988). For instance, Woo and Waddington (1990) compared the water balance of basins with and without beaver dams and found that basins with dams lost more water to evaporation, suppressed the outflow and increased the basin water storage.

Beaver dams control the water table position in the river bed and in the adjacent alluvial plain (Westbrook et al., 2004) and create hydrologic regimes suitable for the formation and persistence of wetlands (Westbrook et al., 2006). As observed in many places, beaver activity in the Spessart (West-Germany) enhances the total water flow length by diverting water onto the floodplain, hence creating on it a multi-channelled (anastomosing) drainage network (John and Klein, 2004). Depending on the state of preservation, river flow can overtop or funnel through gaps in beaver dams, leak from the bottom of the dams or seep through the entire structure (Woo and Waddington, 1990). Beaver dams attenuate the expected water table decline in the drier summer months (Westbrook et al., 2006). The retention of event water in beaver ponds is favoured by relatively low pre-event storage (Burns and McDonnell, 1998). However, beaver dams are deemed to provide less retention during large runoff events such as snowmelt (Beedle, 1991; Burns and McDonnell, 1998). In contrast, the removal of beaver dams and subsequent change in channel structure in Sandown Creek (BC, Canada) resulted in an estimated fivefold increase in mean flow velocity (Green and Westbrook, 2009).

Most investigations on beaver impact on hydrology are dealing with impact at the local scale, and only few at the landscape or even regional scale (Ulevičius, 2009); none is known for *C. fiber*. Empirical evidence has been provided that beaver dams can influence hydrologic processes during peak- and low-flow periods on streams (Parker et al., 1985; Westbrook et al., 2004, 2006). If a single beaver dam system may only have a limited impact on discharge, a series of dams may induce a significant impact (Grasse, 1951), which will be especially pronounced in high- and low-flow periods (Duncan, 1984). Reductions in peak flows have been shown to increase as the number of ponds in a series increased (Beedle, 1991). In dry periods, the discharge of low flows is increased (Parker, 1986), what may even result in turning temporary rivers into permanent ones (Collen and Gibson, 2000; Rutherford, 1955; Yeager and Hill, 1954).

C. fiber was recently reintroduced to Belgium, after an absence of more than 150 years. Rosell et al. (2005) have suggested that beavers can create important hydrological management opportunities and the re-establishment of the beaver is deemed to be a

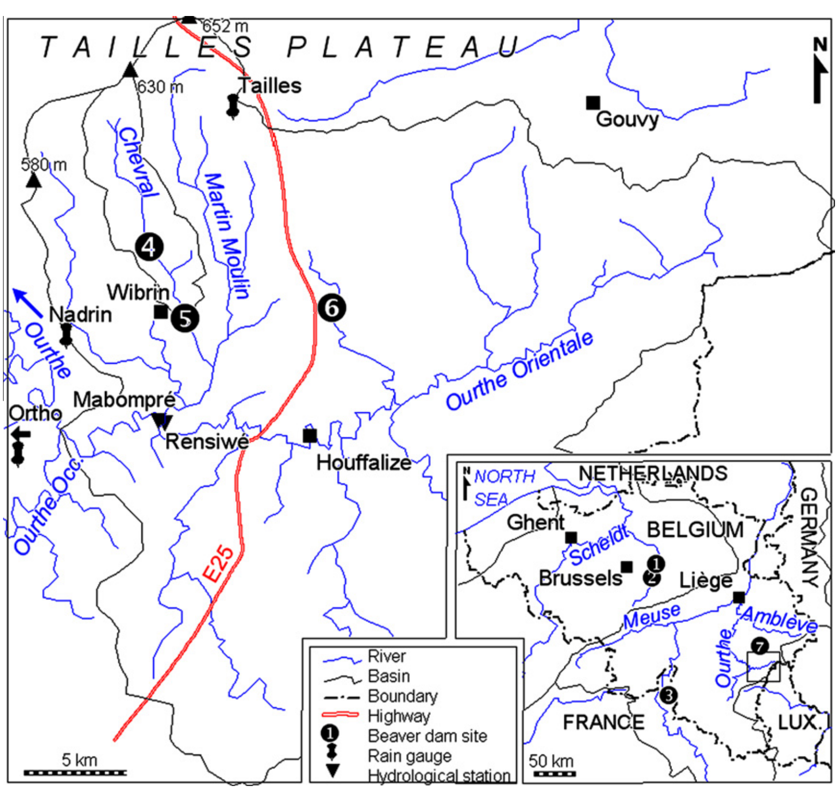

Fig. 1. The Ourthe Orientale sub-basin, hydrological and meteorological monitoring stations, and location of surveyed beaver dam systems.