Changes of plant diversity in riparian grassland after extreme hydrologic events in the Elbe floodplain

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1 Introduction

Floods are an essential component of active floodplain ecosystems. They play an important part in maintaining biodiversity by creating a successional landscape mosaic with high spatial and temporal habitat heterogeneity (Ward & Tockner 2001; Robinson et al. 2002). Floodplain organisms are well adapted to the different flood frequencies and groundwater levels encountered in these habitat types. In temperate regions, most of the adaptations aim to survive the ‘‘usual’’ winter and spring floods (Adis & Junk 2002). Theses floods, occurring in periods of low physiological activity, have little effect on most plant and animal species. Moreover, the alternating wet-dry cycle is of crucial importance for floodplain organisms (Crawford 1996). In contrast, summer flood events, such as the extreme flood of 2002 at the Elbe, may severely disturb both vegetation and faunal communities (Vervuren et al. 2003; Ilg et al. 2008). So far, the effects of unusual and extreme floods on floodplain ecosystems and their communities were little known because precise data describing the pre-flood situation were lacking.

The Elbe is one of the largest rivers in Europe with a length of 1,091 km and a catchment area comprising 148,268 km^2. The floodplain of the Middle Elbe in central Germany has a hydrological regime close to the natural state (Scholz et al. 2005), characterised by a higher discharge and some heavy floods during the winter and early spring and a lower discharge from June to November (Scholten et al. 2005). Therefore, the flood of August 2002 with a statistical recurrence interval of 168 years (Schiermeier 2003) can be considered as extreme both in terms of its timing and height, and led to the inundation of the whole active floodplain area.

Alluvial grasslands dominate the floodplains along the middle reach of the River Elbe. The study area is located within the UNESCO Biosphere Reserve ‘‘Riverine Landscape Elbe’ and under the direct influence of the River Elbe hydrodynamics (Henle et al. 2006; Scholz et al. 2009). In a monitoring project, vegetation data of a riparian grassland site were collected over twelve years. In the study presented here, the effects of two extreme hydrologic events, the summer flood of 2002 and the extreme low water of 2003 on plant diversity, were analysed. In August 2002, all sampling plots were inundated for at least two weeks. Water level ranged from 1.6 to 4.4 m above soil level.

2 Methods

The study site near Steckby (51°54’ N, 11°58’ E) in the active floodplain of the Elbe shows typical, extensively managed grassland communities (fig. 1). 36 sampling plots of a size of 100 m^2 each were established based on a stratified random sampling design (Henle et al. 2006; Scholz et al. 2009). The plots were measured with D-GPS so that they could be relocated exactly (Henle et al. 2006).

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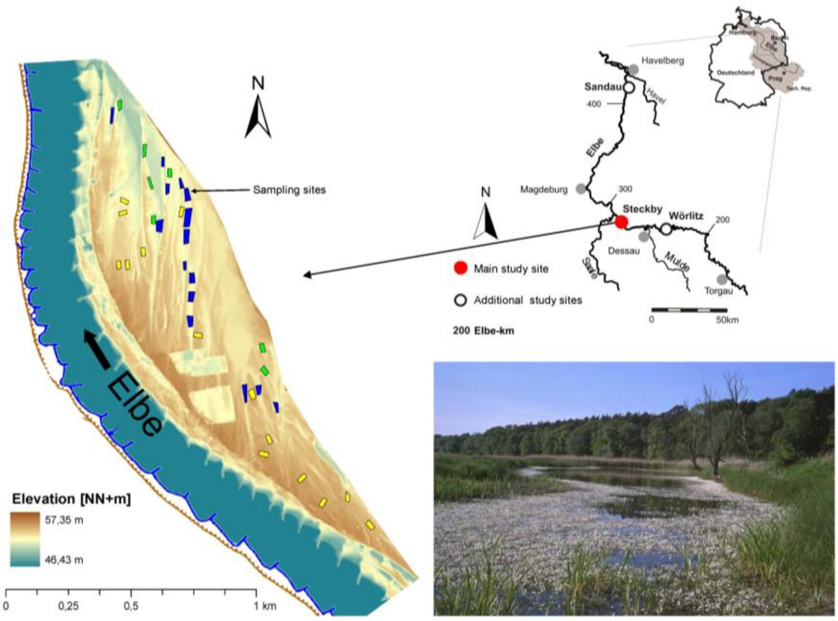

Figure 1. *Overview and detailed map of the study area. The photo shows a representative section of the study area. The coloured rectangles on the left show the sampling plots: blue: flooded depressions with amphibian vegetation, green: wet grassland and yellow: moist grassland.*

The study site is characterised by a high variation in the relief. Therefore, the plots were classified into three groups according to their hydrology: flooded depressions with amphibian vegetation (n = 15), wet (n = 7) and moist grassland (n = 14). Vegetation in these plots was recorded twice a year using the classical Braun-Blanquet scale (Braun-Blanquet 1964). The sampling periods were 1998 and 1999, 2003 to 2006 and 2009. For the description of plant diversity, species richness, Shannon's diversity index (Shannon & Weaver 1994) and Simpson's dominance index (Simpson 1949) were calculated.

3 Results

The study showed that between 1999 and 2003, species richness and Shannon's diversity index declined in all classes while Simpson's dominance increased (fig. 2). In the following years until 2009, species richness increased and reached even higher levels than before 2002 in wet and moist grassland. In these classes Shannon's diversity and Simpson's dominance indices reached values similar to those of 1998 and 1999. For the vegetation of the flooded depressions, these indices did not recover.

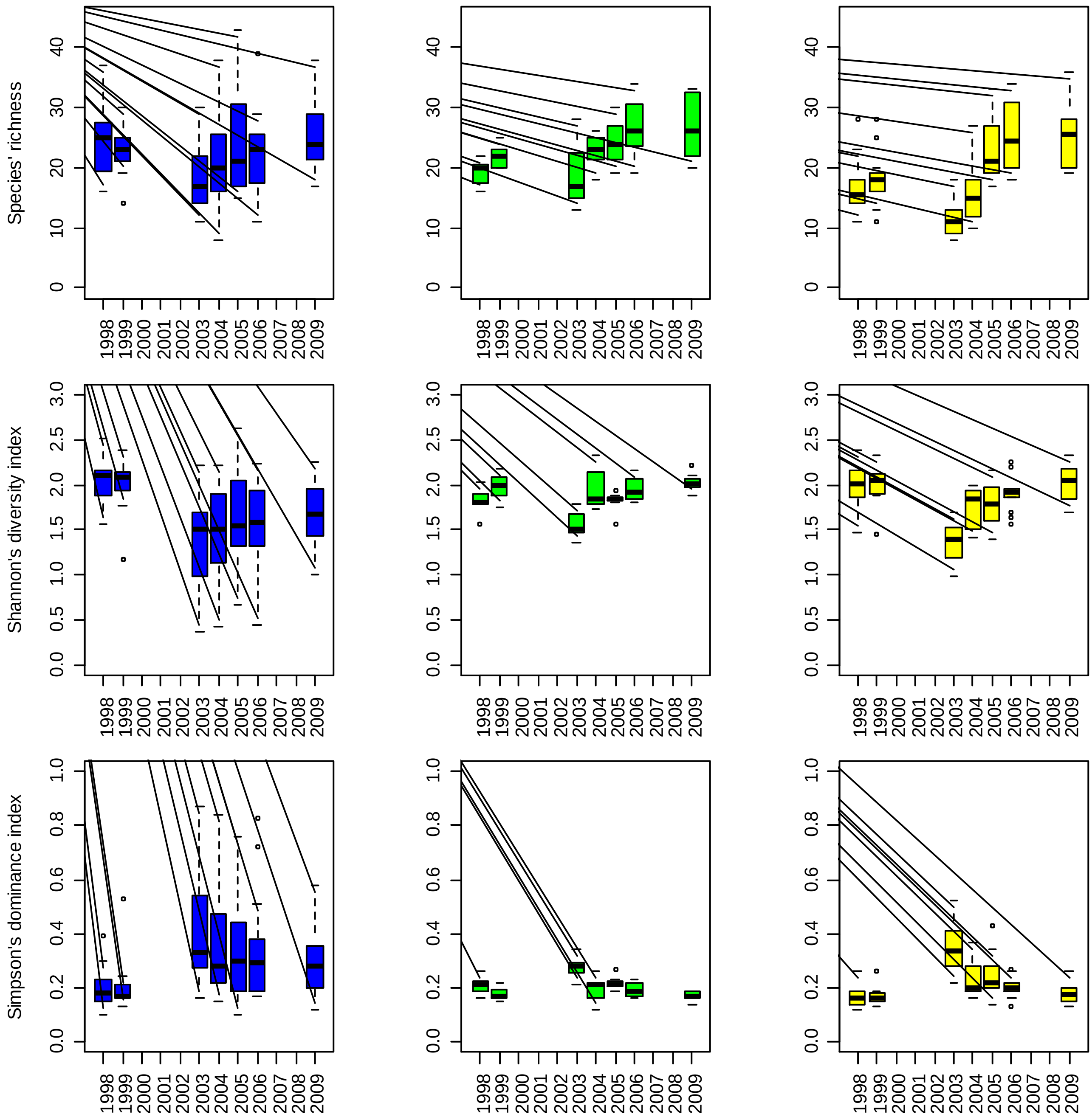

Figure 2. *Box-and-Whisker diagrams of a seven-year record of species' richness, diversity (Shannon's diversity index) and dominance (Simpson's dominance index) of three types of riparian grassland vegetation on the Middle Elbe floodplain. The black horizontal lines in the boxes represent median values. Blue, left column: flooded depressions with amphibian vegetation (n = 15). Green, central column: wet grassland (n = 7). Yellow, right column: moist grassland (n = 14).*

The observed extreme hydrologic events had a clear effect on species composition of the study site. While areas on higher elevations that are less frequently flooded gained species after few years, Shannon's diversity index reflecting the evenness of species' cover in the assemblage needed a few more years to reach the level before 2002. The shift of cover values towards a stronger dominance of certain species after 2002 is reflected by Simpson's dominance index. For example the cover value of *Lycopus europaeus, Stachys palustris* and *Xanthium albinum* declined in flooded depressions between 1998 and 2003. Whereas in moist grassland the cover value of *Alopecurus pratensis, Euphorbia esula, Plantago major* subsp. *major, and Ranunculus ficaria* increased, those of

Arrhenatherum elatius, Galium album and *Ornithogalum umbellatum* decreased. Details will be presented in Glaeser et al. (2009).

Diversity was most strongly affected in the vegetation of flooded depressions. Due to the higher disturbance regime, even after six years, species composition remained less balanced and more dominated by single species as compared to 1998 or 1999. However, it remains uncertain if the flood event of 2002 or the drought of 2003 or both led to the observed changes in vegetation.

4 Discussion and conclusions

This case study shows that changes in hydrology such as extremely high or low water levels can affect floodplain vegetation in a way that biodiversity declines and needs some years to recover. Similar effects have also been shown for other organisms such as ground beetles and molluscs (Ilg et al. 2009). If the hydrology of a site (habitat) would change to a new state, this would clearly lead also to a new habitat with a different species composition. If this shift would take place slowly, it is likely that plants or other organisms will be able to follow, i.e. the species composition of a given site will change to a new assemblage that is adapted to the new environmental situation (van Eck et al. 2006). Non-adapted species may move to sites that are better suited. The open question is what a slow shift means in this context. This cannot be answered by the results of the case study because the hydrologic situation after the extreme events of 2002 and 2003 returned to a similar average than before. Historical case studies such as the decline of groundwater along the Upper River Rhine due to Tullas's correction work resulted in a complete and drastical change of the former floodplain vegetation, leading to a completely different habitat (Huegin & Henrichfreise 1992). A yearly monitoring (KLIWAS project 5.06, BMVBS 2008) of these sites at least until 2013 may provide further understanding of the effect of extreme hydrologic events.

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