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Climate change and floodplain vegetation—future prospects for riparian habitat availability along the Rhine River

Eva Mosner[a,b,*], Arnd Weber[a], Maria Carambia[a], Enno Nilson[a], Ulf Schmitz[c], Bianka Zelle[d], Tobias Donath[d,e], Peter Horchler[a]

[a] German Federal Institute of Hydrology, Am Mainzer Tor 1, 56068 Koblenz, Germany
[b] Geisenheim University, Center of Applied Biology, Institute of Botany, Plant Ecology & Nature Conservation, Von-Lade-Str. 1, 65366 Geisenheim, Germany
[c] Landscape Analysis and Nature Conservation Planning, Lise-Meitner-Str. 71, 40591 Duesseldorf, Germany
[d] Justus-Liebig-University Giessen, Department of Landscape Ecology and Resource Management, Landscape Ecology and Landscape Planning, Heinrich-Buff-Ring 26-32, D-35392 Giessen, Germany
[e] Christian-Albrechts-University Kiel, Institute for Natural Resource Conservation, Department of Landscape Ecology, Olshausenstr. 75, 24118 Kiel, Germany

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ABSTRACT

Climate change is expected to alter temperature and precipitation patterns and thereby river discharges. As floodplain vegetation types in Central Europe are mainly structured by the local hydrologic conditions of the river, alterations in the flow regime should lead to changes in the structure of floodplain communities, too. However, much uncertainty about potential hydrologic changes exists due to the variability in modeled discharges by different global and regional climate models. Aim of our study was to assess potential changes and their uncertainty in the future habitat availability of plant species representing characteristic floodplain vegetation types along the Rhine River. Therefore, habitat distribution models for 29 different species were calculated relating species distribution to local hydrologic conditions. Habitat changes were assessed by comparing future habitat availability of five different climate change projections with reference state conditions for four stretches along the Rhine for two different future periods. Models revealed that besides different water level parameters also water level variability was decisive for habitat distribution patterns. Relative habitat changes showed large variation for the different species between and within vegetation types, as well as for the different river stretches and future periods. However, intersection of the five projections displayed large overlap regarding future habitat availability for many of the species. Moreover, a tendency of the different vegetation types to occur on higher elevated sites was found. Our study emphasizes the necessity to consider the variability of different climate change projections to reasonably assess potential changes in habitat availability of floodplain vegetation and provides a tool to identify species groups and river sections vulnerable to climate change induced hydrologic alterations.

1. Introduction

River floodplains belong to the most productive ecosystems worldwide and build important transition zones between aquatic and terrestrial habitats (Ward et al., 1999). They harbor great species diversity basically because of the large spatio-temporal heterogeneity originating from fluvial processes such as flooding and morphodynamics (Ward et al., 1999). Moreover, floodplains provide a variety of different ecosystem services such as flood and sediment retention, redistribution of nutrients, water purification and have high recreational value (Ward et al., 1999; Capon et al., 2013). Given their comparable small extent and their significance regarding biodiversity and ecosystem functions, floodplains are deemed highly valuable and have a high conservation status (Capon et al., 2013). However, due to anthropogenic impacts, they are highly endangered. The main threats for floodplain ecosystems are land use changes on the one hand and river engineering on the other (Ward et al., 2002; Capon et al., 2013). For example, in Germany most of the functional floodplain, i.e., the area directly inundated during high water, along the large rivers Rhine, Elbe, and

* Corresponding author at: Present address: Geisenheim University, Center of Applied Biology, Institute of Botany, Plant Ecology & Nature Conservation, Von-Lade-Str. 1, 65366 Geisenheim, Germany, Tel.: +49 6722 502 471.
E-mail address: evamosner@web.de (E. Mosner).

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Danube has become inactive due to the construction of dykes to foster agricultural use (Brunotte et al., 2009). These losses amount of up to 90% of the original floodplain area. Moreover, natural river flow and morphodynamics that are essential features structuring the floodplain and its communities, have been largely diminished by measures such as the construction of dams, embankments, and groynes, which aim at improving navigability, power production, or flood control. Nowadays, climate change is considered an additional threat floodplain ecosystems have to face (Erwin 2009; Palmer et al., 2009; Capon et al., 2013).

Generally, the vegetation of floodplains is described as azonal which means that local conditions, e.g., by flooding, are more decisive in structuring corresponding communities than overall climatic constraints (Ellenberg 2009). Hydrologic conditions, i.e., flooding and water availability, are described as the most prominent features structuring floodplain communities (Van Eck et al., 2006). In general, pioneer and marshland species occupy low elevation sites with longer inundation periods compared to the higher elevated sites where riparian softwood and hardwood forest species can be found (Blom, 1999). Therefore, changes of the local hydrologic conditions, both natural and manmade, are of particular concern regarding floodplain vegetation (Erwin 2009; Palmer et al., 2009; Ström et al., 2011; Capon et al., 2013). More specific, climate change is expected to change discharge regimes in Central Europe (IPCC, 2007a; Weiland et al., 2012) with projected increases in winter and decreases in summer for the Rhine River (Görgen et al., 2010). Hence differences in average annual discharge conditions might not be very different from what floodplain communities experience today but seasonality may change and low flow and high flow situations might be more extreme (IPCC, 2007a; Görgen et al., 2010). Thus, for the assessment of potential climate change effects on floodplain communities through altered river flow conditions, i.e., in different discharge parameters and the variability of river flows, the local scale as well as discharge conditions on a daily basis need to be considered.

Though climate modeling has much improved during the last decade assessing potential changes still results in large variability between different models, especially in precipitation and discharge. Variability between different models or model couplings is often much larger than differences between emission scenarios and therefore, the use of model ensembles is suggested (IPCC, 2007a; Krahe et al., 2009; Görgen et al., 2010; Weiland et al., 2012). In this context it has to be considered that not only different global circulation models produce variability in model outputs (Beaumont et al., 2008; Diniz-Filho et al., 2009). Also, regional climate models that enhance the simulation of atmospheric circulations and climatic variables at fine spatial scales and which are necessary to properly project alterations in discharge on the catchment scale (Dankers and Feyen, 2008), add to the uncertainty of climate change projections. Especially when considering conservation and restoration measures variability of climate change projections is of particular concern as it increases uncertainty of future habitat suitability (Kujala et al., 2013). However, if aiming at evaluating climate change effects on floodplain communities considering this variability is important.

In our study we focused on habitat distribution changes of characteristic riverine floodplain species in the course of climate change along the Rhine River. Our aim was to assess future habitat availability and the degree of uncertainty associated with the changes based on an ensemble of different global and regional

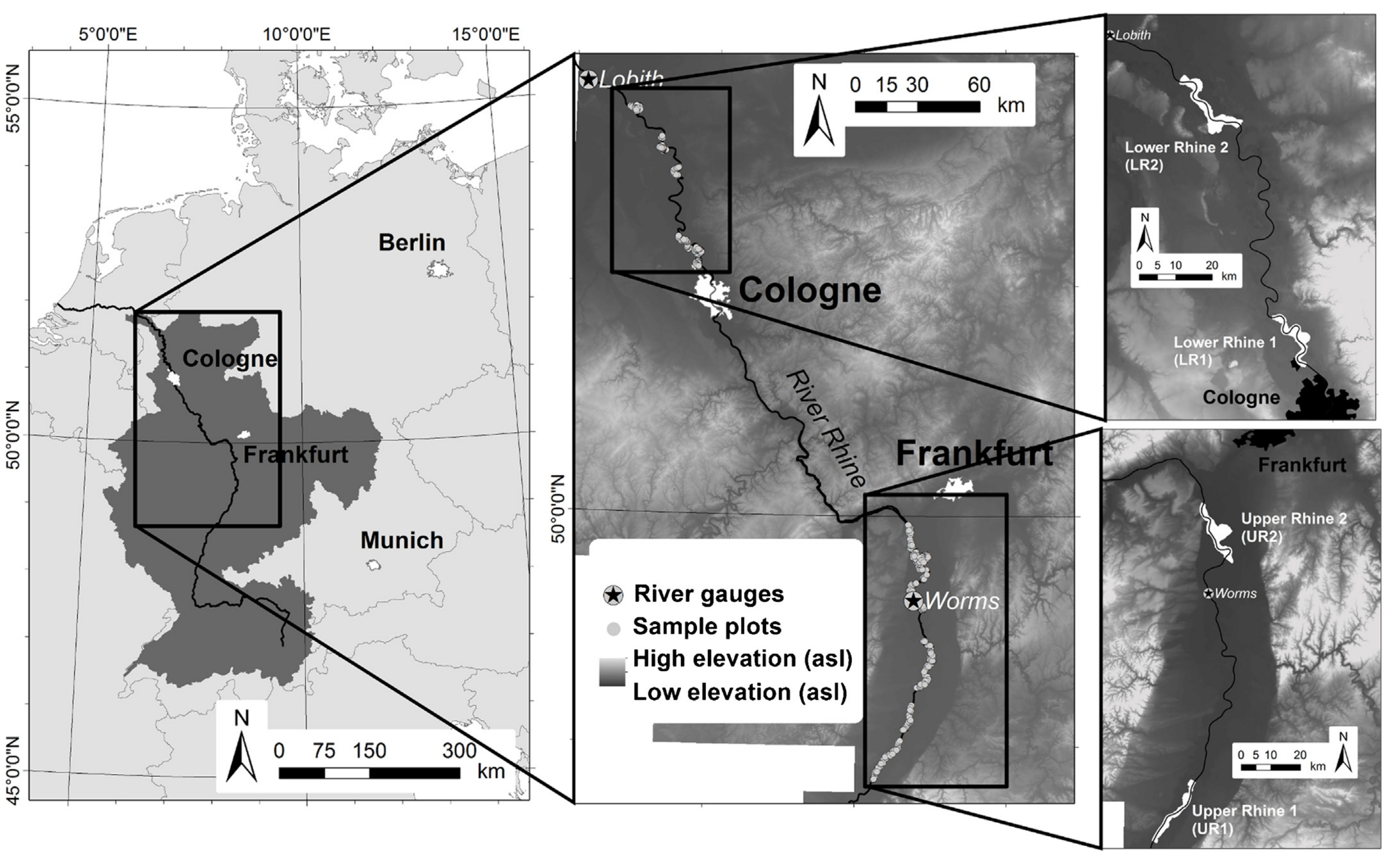

Fig. 1. Study area along the River Rhine. Left: catchment area of the River Rhine. Middle: sampling areas along the Upper Rhine (lower rectangle) and the Lower Rhine (upper rectangle) with the location of the two river gauges Worms and Lobith. Right: projection areas for the evaluation of climate change effects along the Upper Rhine (lower rectangle) with projection sites Upper Rhine 1 (UR1) and Upper Rhine 2 (UR2) and along the Lower Rhine (upper rectangle) with sites Lower Rhine 1 (LR1) and Lower Rhine 2 (LR2).