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Impact of inundation regime and meadow management on wild bee communities and bee-flower networks in the Donau-Auen National Park

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Abstract

Wild bee communities on flood-prone meadows were compared with those on rarely inundated sites in the National Park Donau-Auen. Flower-visiting bees were sampled on 32 meadows between April and August 2016. Counter to expectation, flooding regime had no significant impact on observed individual numbers. Rather, bee species richness was higher on regularly flooded meadows. As a potential driver of this pattern, an increased beta diversity among annually flooded meadows was identified. Additionally, three network metrics derived from a bipartite plant-bee interaction matrix were analyzed. None of the network indices was affected by flooding regime. We conclude that extreme floods may have a devastating effect on wild bee populations, but communities quickly recover. This resilience surely depends on recolonization from the surrounding landscape. Hence it is important to consider biodiversity on a landscape scale beyond the limits of the nature reserve.

Keywords

Wild bees, community recovery, species richness, floodplain, bipartite networks

Introduction

Intensity of meadow management is well known to alter species composition and structure of grassland vegetation and its inhabiting fauna (STEFFAN-DEWENTER & LESCHKE 2003). Close to running waters severe pulse disturbance can also be caused by flooding episodes (GERISCH et al. 2012). Population declines caused by floods have been described for wild bees (FELLENDORF et al. 2004) and other insect groups (GERISCH et al. 2012). Nevertheless, strong resilience to flooding was reported for ground beetles by GERISCH et al. (2012), and TRUXA AND FIEDLER (2012) even found a richer moth fauna in annually inundated floodplain forests than in neighboring non-flooded forest habitats.

While responses of bee assemblages to environmental gradients have been documented in some cases (FELLENDORF et al. 2004), less is known about the biotic networks and associated dependencies that result from interactions between flowers and bees.

The aim of this study was to analyze how flooding and mowing regime shape local bee communities and bee-flower networks on meadows interspersed in floodplain forest.

Methods

Thirty-two meadows were sampled four times each, between April and August 2016. Sixteen of the meadows were situated on the flood-prone and another 16 on the flood-protected side of a levee which stretches through the reserve. Sampling units lasted 30 minutes on 30 x 60 m plots in a central position on the meadow. Plant species on which bees had been collected were recorded and assigned to their observed flower visitors.
Interaction webs of individual meadows were characterized by three network metrics using the package "bipartite" (DORMANN et al. 2016), viz.:

1. H2′: A network-level measure of specialization (DORMANN et al. 2009);
2. Vulnerability: Weighted mean number of bee visitor taxa per plant species (TIEDEKEN et al. 2015); and
3. Niche overlap: Mean similarity in interaction pattern between bee species (DORMANN et al. 2009).

To quantify bee species richness, randomized species accumulation curves were calculated for samples aggregated within either flooding regime using the package 'iNEXT' (CHAO & HSIEH 2016). To test for relationships between site descriptors and response variables (bee activity density, bee species richness, network metrics), Generalized Linear Mixed Models were calculated using the package 'lme4' (BATES et al. 2016).
To determine if the position of meadows relative to the dam affected wild bee differentiation diversity, a permutation-based multivariate analogue of Levene's test for homogeneity of variances was performed (OKSANEN et al. 2017).

Results

In total, 92 wild bee species interacting with flowers of 62 plant species were recorded. A significantly higher activity density (z=-8.901, p<0.001; mR^2=0.563; cR^2=0.563) and species richness (z=-6.575, p<0.001; mR^2=0.501; cR^2=0.519) was found on meadows which had not been mown since the preceding survey (Fig. 1). Flood regime had no significant impact on species numbers or activity density per site and survey (Fig. 1). Species accumulation curves indicate an even higher species richness aggregated over all meadows south of the dam (Fig. 2). Additionally, bee differentiation diversity was significantly higher on regularly flooded meadows (F1;30=7.556, p=0.011). None of the tested network metrics was significantly affected by flood or mowing regime.

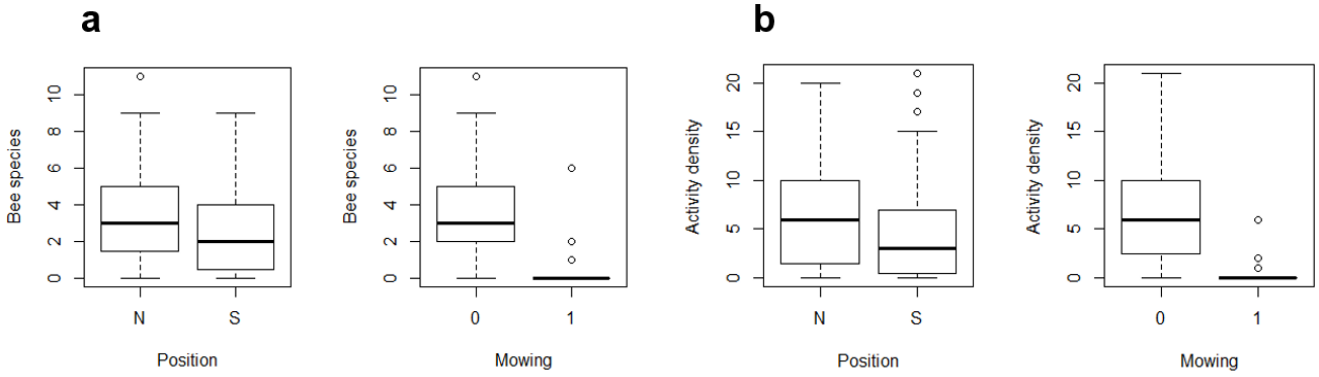

Figure 1: Number of observed bee species (a) and activity density (b) relative to the position of the levee and mowing status. Box-and-whisker-plot, range = 1.5 * IQR. N = North of the dam, S = South of the dam, 0 = not mown since last survey, 1 = mown since last survey.

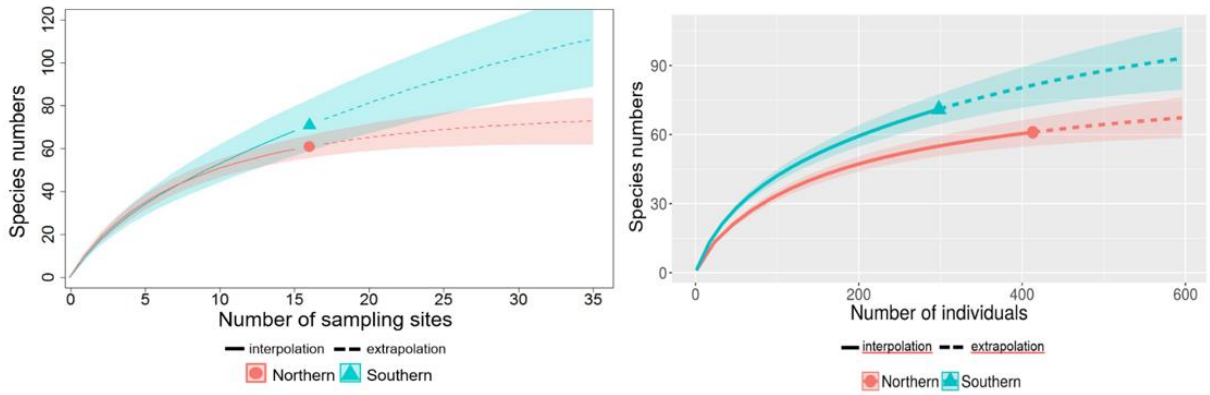

Figure 2: Sample site based (left) and individual based (right) randomized species accumulation curves of wild bee species numbers north and south of the levee. The shaded areas represent 95% confidence intervals.

Discussion

TRUXA AND FIEDLER (2012) investigated forest moth communities in relation to flood regime in eastern Austria. They also found a slightly richer moth fauna in flooded forest stretches of the National Park Donau-Auen. Similarly, bee species richness was higher in the flood-prone part of the national park if aggregated across sites. Increased species turnover that we observed between meadows south of the levee represents a likely explanation for this pattern, as turnover between local patches is closely linked to species richness on a wider scale (WHITTAKER 1972).

GERISCH et al. (2012) found that species richness and abundance of ground beetles decreased strongly after a flood but pre-flood values were restored only two years later. Diversity patterns of wild bees relative to the levee suggest that these insects are likewise quite resilient and communities were able to recover since the last extreme flood event that had hit our study sites in 2013, just three years earlier. Also the lack of differences in the network metrics related to the flood regime indicate that local bee communities in the National Park Donau-Auen are well able to cope with regular inundation events.

As expected, mowing had a disastrous effect in the short run. However, the characteristic meadow vegetation and its associated insect communities of semi-natural grassland habitats on the long run depend on continuation of extensive mowing or grazing (STEFFAN-DEWENTER & LESCHKE 2003).

Conclusion

The meadows in the near annually flooded part of the national park house unexpectedly species-rich and resilient bee communities. These would vanish from the reserve if meadow management were totally abandoned. The non-flooded parts of the reserve likely act as an important source for recolonization processes after extreme floods that largely wipe out bee populations on a local scale. Hence, it is extraordinarily important for this conservation area to consider biodiversity not only locally, but on a wider landscape scale. Since mowing almost completely eliminates food sources of bees at a short term, it is advisable to maintain the custom of unsynchronized mowing of the meadows as conservation management practice.

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