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Impact of flooding on true bug communities (Heteroptera) on meadows of the Morava River floodplains, Eastern Austria

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Abstract

Annual flood dynamics represent a determining factor in shaping habitats of lowland floodplains. Terrestrial arthropods of the soil and herb layer are particularly exposed to flooding events. We quantified the impact of flooding duration on abundance, species richness and composition of terrestrial true bug assemblages (Heteroptera) on floodplain meadows in the nature reserve "Untere Marchauen" (Lower Austria) and its close proximity. Heteroptera were sampled by sweep netting on meadows with different flooding regimes ranging from meadows only occasionally flooded by a rising ground-water level to meadows usually flooded for several weeks per year. A total of 11,950 individuals, 5,312 of them adults belonging to 118 species, were collected. Species richness and abundance of true bugs were negatively affected by flooding duration and species composition differed between meadows of different flooding regimes. Our study proved that anthropogenically induced changes in hydrological dynamics of floodplains can have a tremendous effect on richness and structure of terrestrial true bug communities.

Keywords

terrestrial arthropods, species composition, species richness, flooding duration, floodplain ecosystem

Introduction

In floodplains, flood events play a key role in shaping and maintaining the complex mosaic of riparian and associated aquatic and semi-aquatic habitats (TOCKNER et al. 1998; HUGHES & ROOD 2003). However, recurrent flooding represents a serious challenge for terrestrial invertebrates and special survival strategies have to be developed to adapt to such conditions. Many species are not able to survive flooding for a longer period of time. Particularly flooded meadows hardly provide any refuge for non-aquatic arthropods. Therefore, the ability to fly, in order to escape from inundation and to re-colonize drying-out areas after the flood, seems to be crucial. Additionally, reproduction strategies or life cycles, synchronized to the likely appearance of flooding events, have been evolved in certain groups of arthropods (ZULKA 1999a; ROTHENBÜCHER & SCHAEFER 2005).

In this study, we investigated effects of flooding events on true bugs (Heteroptera). In Central Europe about 1,100 species are known (GÜNTHER & SCHUSTER 2000). True bugs inhabit most terrestrial and aquatic habitats and due to their sensitive response to environmental changes, they have a great potential as indicator organisms in evaluating the quality of habitats (ACHTZIGER et al. 2007; DOLLING 1991; MORRIS 1979; OTTO 1996; ZURBRÜGG & FRANK 2006).

In Austria about 12,000 animal and plant species live in floodplain areas (GEPP 1985). Today, about half of the European human population lives on former floodplains and the remaining wetlands have been highly modified through construction of locks, levees and dams, through the impacts of farming, gravel mining, timber harvesting, species extinctions, the invasion of alien species and other direct or indirect anthropogenic disturbances (BRINSON & MALVAREZ 2002; TOCKNER et al. 2009).

Only few studies tried to investigate the impact of flooding events on communities of terrestrial arthropods in floodplain landscapes of the temperate zone (e.g. NICKEL & HILDEBRANDT 2003; ROTHENBÜCHER & SCHAEFER 2005; TRUXA & FIEDLER 2012). We studied effects of flooding duration on richness and composition of true bug assemblages in meadows of the floodplain of the Morava River in Eastern Austria. Heteroptera were sampled on meadows with different flooding regimes ranging from meadows only occasionally flooded by a rising ground-water level during strong flooding events to meadows usually flooded for several weeks per year. In particular, we tested the following hypotheses:

(1) Abundance and species richness of terrestrial true bug assemblages are declining with flooding duration due to a resulting high mortality of many species not adequately adapted to this disturbance. Furthermore, flooding causes a reduction of plant biomass production (PEZESHKI 2001). This can correspond to a decline in vegetation height and structural diversity (MORRIS 2000). Hence, flooding is expected to diminish food supply and microhabitat diversity for true bugs (e.g. ZURBRÜGG & FRANK 2006; RABITSCH 2007). Both should additionally decrease richness and abundance of true bug assemblages.

(2) We expect that flooding events represent a selective force with the potential to structure true bug assemblages by promoting species which are better adapted to this disturbance. Consequently, species composition is expected to differ distinctly between meadows with a different flooding regime.

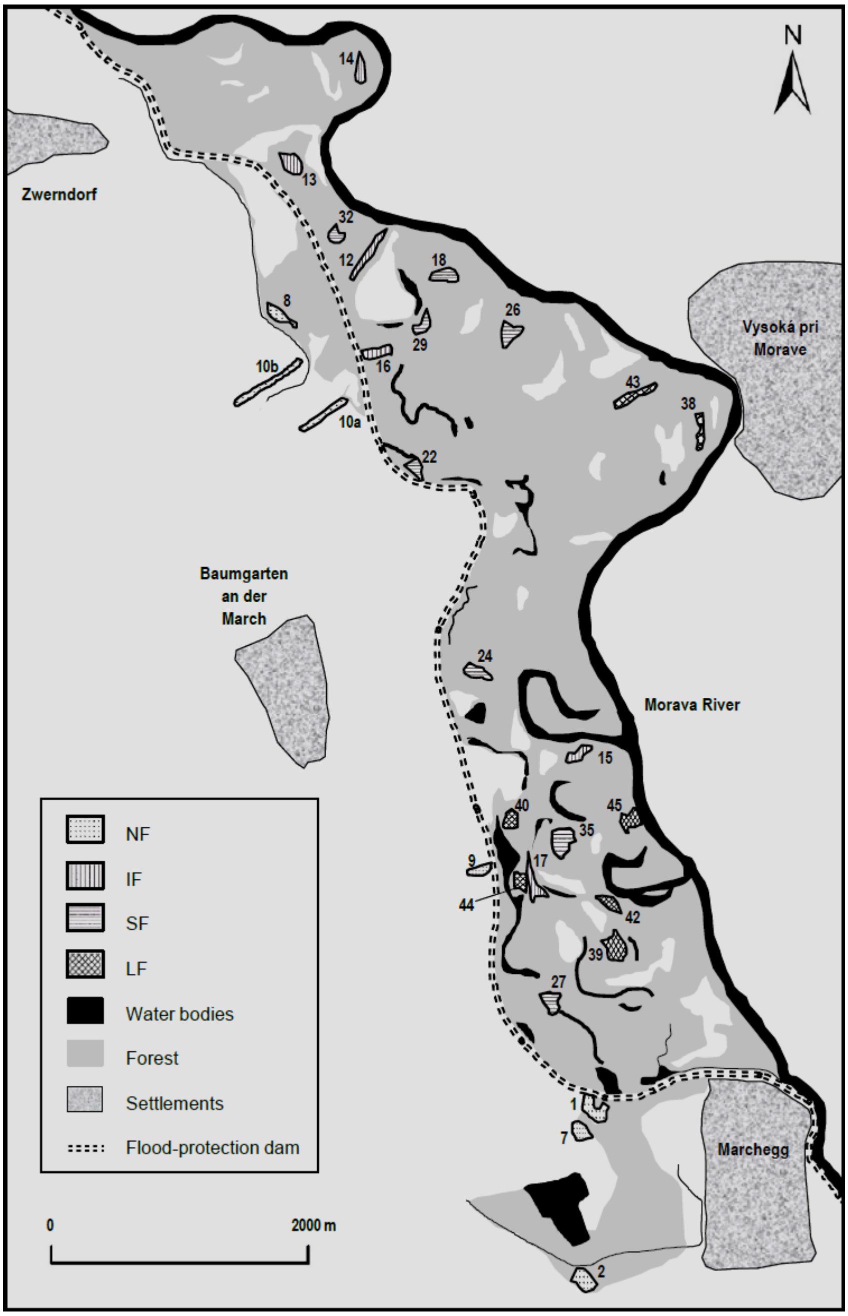

Figure 1: Study area and sampled meadows. Meadow types: NF – non-flooded meadows, IF – infrequently (not annually) flooded meadows, SF – meadows annually flooded for a short period of some days, LF – meadows annually flooded for a longer period of some weeks. Sampled meadows are indicated by code numbers.

Methods

Study area and study sites

Fieldwork was conducted in summer 2010 and spring 2011 in Lower Austria on meadows located in the nature reserve "Untere Marchauen" (48°18′31″N, 16°53′34″E) and its close proximity (Fig. 1). The reserve along the Morava River covers an area of 1,166 hectares (WWF Österreich 2012). Meadows account for 160 hectares of the total area (WWF Österreich 2012). The area west and south of the nature reserve is dominated by cropland. The lowland river Morava is characterized by a simple flow regime with a maximum runoff in April (Zulka & Lazowski 1999). Despite several river engineering measures, especially in the mid of the 20th century, the dynamics of annual flooding events are still a determining factor for the different habitats along the Morava (Zulka 1999b).

Selected study sites were hay meadows (size: 1-3 ha) inside or just outside the nature reserve. Meadows inside the nature reserve are periodically flooded. The selected meadows outside the dam are not directly influenced by flooding but can be affected by rising groundwater level during strong flooding events. According to their annual duration of flooding, the studied meadows were classified as non-flooded (NF) meadows, infrequently (not annually) flooded (IF) meadows, meadows with annual flooding for a short period of some days (SF) and meadows annually flooded for a longer period of some weeks (LF). Six to eight meadows were selected per meadow type resulting in a total of 28 study sites (Fig. 1).

Sampling of true bugs

On each meadow true bugs were sampled once in July 2010, August 2010, May 2011 and June 2011, respectively. A sampling unit consisted of 300 sweep net samples, roughly evenly distributed over the meadow area, per sampling date. The sweep net method is commonly used to assess true bug communities of meadows (ZURBRÜGG & FRANK 2006; TORMA & CSÁSZÁR 2012).

Table 1: Results of one-way ANOVAs testing for differences of number of individuals (log (x) transformed), and recorded species between meadows with different flooding regime. Results remained significant after controlled for false discovery rate (FDR) (Benjamini & Hochberg 1995).

Dependent variable	**One-way ANOVA**	**FDR-adjusted *p***
Individuals	$\boldsymbol{F_{3,24} = 14.04, p = 0.001}$	**0.003**
Recorded species[1]	$\boldsymbol{F_{3,24} = 13.24, p = 0.001}$	**0.003**

[1] only adult specimens considered

Data analysis

Because our study had a focus on effects of flooding on true bugs occurring on meadows, we excluded all exclusively arboreal species from our analyses. For all calculations on species richness only adult true bugs which could be identified at the species level were considered.

One-way ANOVAs were calculated to test for effects of flooding regime on total abundance and species richness. To approach a normal distribution of data, log (x) transformations were used. Least significance difference (LSD) tests were calculated to test for significant differences of variables between meadow types. All results of one-way ANOVAs listed in Tables 1 were controlled for false discovery rate (FDR) (BENJAMINI & HOCHBERG 1995). FDR-adjusted *p*-values were calculated by a spreadsheet program of Pike (2011). Species accumulation curves were calculated using the program PAST (HAMMER et al. 2001).

Analyses of similarity (ANOSIM; number of permutations: 999) were calculated with Primer v5 (CLARKE & GORLEY 2001) to test for differences in true bug species composition between meadow types. Similarity of species composition was quantified by Bray-Curtis similarities (calculated using square-root transformed abundances). Similarity relationships between true bug assemblages of the sampled meadows were visualized in a two-dimensional plot using non-metric multidimensional scaling (NMDS). A stress value of <0.20 was considered as appropriate for displaying similarity relationships (CLARKE 1993).

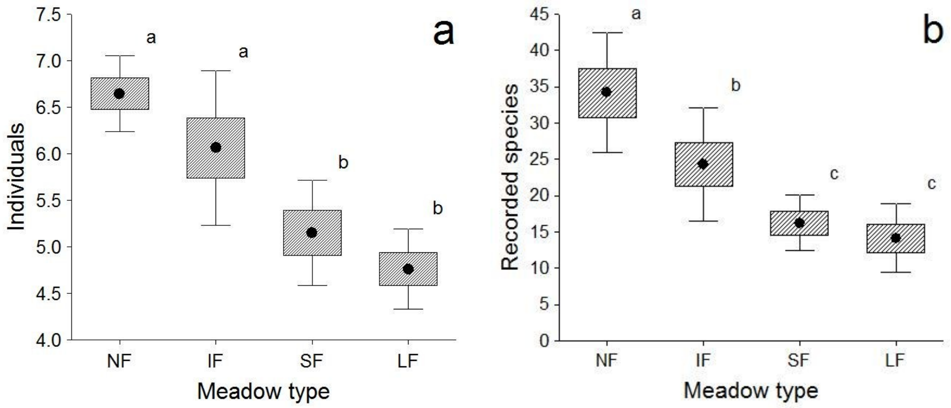

Figure 2: (a) Mean number of individuals (log (x) transformed) and (b) species ± SE (box) and 95% CI (whiskers) sampled on meadows with different flooding regime. Different letters indicate significant differences (LSD tests). Meadow types: NF – non-flooded meadows, IF – infrequently (not annually) flooded meadows, SF – meadows annually flooded for a short period of some days, LF – meadows annually flooded for a longer period of some weeks.

Results

A total of 11,950 individuals, of that 5,312 adults belonging to 118 species, were sampled. Only 15 individuals of 9 arboreal species, which were excluded from all subsequent analyses, occurred in our samples. True bug abundance was significantly affected by meadow type (Table 1). NF and IF meadows showed higher abundances than meadows characterized by longer flooding durations (Fig. 2a). The mean number of species recorded per study site decreased from NF sites to IF sites and, further, to meadows flooded for longer durations (Fig. 2b).

Species accumulation curves for samples pooled on the level of meadow types indicate significant higher species richness for non-flooded meadows compared to all other three meadow types, which apparently were characterized by relative similar species richness as indicated by similar shapes of their species accumulation curves and a strong overlap of the associated 95% confidence intervals (Fig. 3).

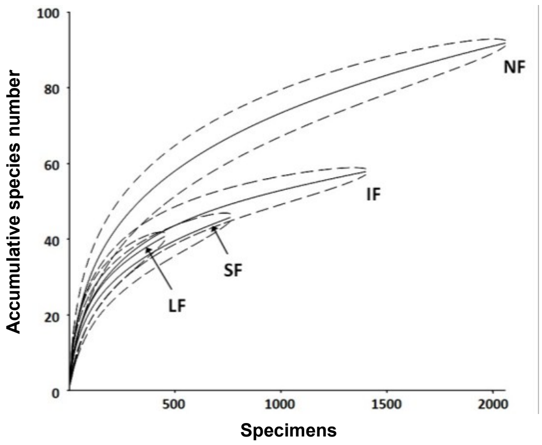

Figure 3: Species accumulation curves ± 95 % CI (dashed lines) for four different meadow types: NF – non-flooded meadows, IF – infrequently (not annually) flooded meadows, SF – meadows annually flooded for a short period of some days, LF – meadows annually flooded for a longer period of some weeks.

The similarity relationships (quantified by Bray-Curtis similarities) between species assemblages of the sampled meadows are visualized in a NMDS plot (Fig. 4). Dimension 1 can be interpreted as the flooding duration. NF meadows (predominantly plotted in the right part of the graph) are clearly separated from LF meadows (segregating in the left half of the graph), while the two other meadow types IF and SF are plotted in-between these two extremes (Fig. 4). A significant effect of flooding regime on true bug species composition was indicated by a one-way ANOSIM (global r = 0.32, p = 0.001). Pairwise tests to detect differences between meadow types achieved a significant level for the comparisons between NF and SF as well as LF sites and between LF and IF sites (Table 2).

Discussion

Disturbance caused by flood immediately reduces diversity, abundance, and biomass of the soil macrofauna. The effect becomes stronger with the duration of flooding (Plum 2005). The survival rate of species without special physiological adaptations, like certain annelids or insect larvae, is very low. For other groups the only way to respond to flooding is by active or passive movement, by re-colonization or reproduction from resistant stages (Plum 2005). Accordingly, our study showed a negative impact of flooding events on true bug communities. Both abundance and species richness on meadows decreased with increasing flooding intensity. The species accumulation curves calculated for the four meadow types indicate that on a larger spatial scale non-flooded meadows were characterized by a higher species richness. In addition, a reduced structural heterogeneity and diversity of the herb layer may have been contributed to this pattern (Morris 2000; Schwab et al. 2002). Although we did not conduct a vegetation mapping on the sampled meadows, we noticed, that NF and IF sites were characterized by a higher herb layer density and plant species richness, which should correspond to a higher plant biomass and a higher structural heterogeneity. Higher richness at non-flooded compared to flooded sites was also found for grasshoppers and spiders (Rothenbücher & Schaefer 2005; Katušić 2008). The latter group also showed a higher abundance in non-flooded grasslands (Katušić 2008). However, it appears that these patterns cannot be generalized. Remarkably, terrestrial beetles studied in a floodplain forest in south-eastern Australia showed an opposite response. Abundance, species richness and biomass were greatest at sites flooded for the longest period of about four months. Spiders maintained a similar abundance, species richness and biomass at flooded sites (Ballinger et al. 2005).

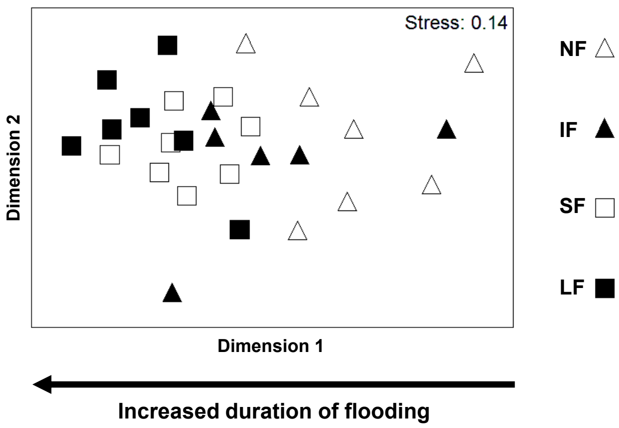

Figure 4: Similarity relationships between species assemblages of meadows with different flooding regime visualized in a NMDS-plot based on Bray-Curtis similarities. Meadow types: NF – non-flooded meadows, IF – infrequently (not annually) flooded meadows, SF – meadows annually flooded for a short period of some days, LF – meadows annually flooded for a longer period of some weeks.

Our data show that the composition of true bug species assemblages was significantly affected by flooding duration. Similarly, differences in the inundation duration of riparian habitats are affecting species composition of spider and ground beetle assemblages (BONN et al. 2002; GERISCH et al. 2006). In contrast, a high similarity of species composition between flooded and non-flooded sites was found in grasshoppers on floodplain meadows along the river Elbe (Germany), possibly because most of the species survived the flooding period in the egg phase (FISCHER & WITSACK 2009). Also many planthopper and leafhopper species can tolerate flooding in the egg stage during winter (ROTHENBÜCHER & SCHAEFER 2006). A follow-up study has to identify which factors are responsible for the high sensitivity of true bug assemblages against flooding in the Morava floodplains. Perhaps, the phenology of hydrological conditions plays an important role.

Table 2: ANOSIMs testing for differences in species composition between meadow types (NF – non-flooded meadows, IF – infrequently (not annually) flooded meadows, SF – meadows annually flooded for a short period of some days, LF – meadows annually flooded for a longer period of some weeks). Significant differences printed bold.

Pairwise comparisons of meadow types	*R*	*p*
NF vs. IF	0.124	0.090
NF vs. SF	**0.625**	**0.001**
NF vs. LF	**0.705**	**0.003**
IF vs. SF	0.109	0.112
IF vs. LF	**0.250**	**0.024**
SF vs. LF	0.077	0.204

Conclusion

Our study proved that flooding does not only affect abundance and richness, but also has an impact on species composition of true bug assemblages. Therefore, river restoration measures changing the hydrological dynamics of adjacent floodplains do not only affect diversity of terrestrial arthropods but also have a significant impact on species composition. Hence, a declined hydrological dynamic of floodplains causing a loss of habitat heterogeneity on a landscape level will most likely result in a decrease of beta diversity and consequently a decline of regional true bug species richness.

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