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Collembolan communities show distinct edge-effects in a fragmented hardwood floodplain ecotone

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Abstract. Investigations on edge-effects in collembolan communities are quite rare. For this reason from October 2007 until May 2008 pitfall traps were used to determine possible edge-effects on epedaphic springtail communities on a small fragmented hardwood floodplain, the peripheral area of the hardwood floodplain and two adjacent softwood floodplains. The hardwood floodplain was additionally divided into three sections each at a different distance from the river Rhine. Altogether 10148 individuals belonging to 15 families and 51 species were caught. Different dominance-based, species-based and combined similarity indices were used to measure differences between the collembolan communities in neighbouring areas. There were very high species-based and dominance-based similarities between the three sections on the hardwood floodplain. In contrast, the similarity between the three hardwood floodplain sections and the adjacent softwood floodplains was very low, due to the high incidence of flood in softwood floodplains. The dominance-based and combined similarity indices showed strong differences between the forest edge and the hardwood floodplain sections, although the species-based indices indicate a high similarity. In the peripheral area *Lepidocyrtus cyaneus* Tullberg, 1871, which prefers open habitats, was eudominant. In the hardwood floodplain this species showed only sporadic to recedent dominance values.

Key words. Edge effects, floodplain forests, forest fragments, springtails, pitfall trapping.

INTRODUCTION

Edge effects have been studied for decades because they reveal how landscape structure influences habitat quality (Ries et al. 2004). Some authors have quantified edge effects, identified possible spatial frontiers and formulated general definitions (Laurance 2000, Ries et al. 2004, Ewers & Didham 2006, 2008). Arthropod communities (e.g. carabid beetles) are often used to describe edge effects in urban-rural gradients or forest-grassland habitats (Davies & Margules 1998, Magura 2002, Magura et al. 2001, Niemelä & Kotze 2009). Only a few studies deal with the edge-effects on epedaphic springtail communities (Querner 2003, Freiner & Duarte 2009, Östmann et al. 2009). Slawski & Slawska (2000), however, reveal positive effects of forest edges on the diversity of hemi- and euedaphic collembolan communities in Northwest Poland. However, Shaw et al. (2007) did not detect an edge effect on the distribution of arboreal collembolan communities in coniferous plantations in Northern England.

The current investigation focused on possible edge effects in a fragmented softwood and hardwood floodplain forest in the Northern Upper Rhine Valley. The forest fragmentation in this area has resulted in a marked increase in habitat edges. Some invertebrate taxa avoid forest edges because of changes in microclimate and the increased risk of desiccation and thus are especially vulnerable to habitat fragmentation (Didham 1997, Laurance 2000). Springtails are expected to show dominance and species based differences at different sites, because they are not a very

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mobile group of arthropods and therefore likely to be strong affected by changes in microclimate and hydrology associated with flooding intensity and habitat structure.

MATERIAL AND METHODS

From October 2007 until May 2008 a total of 24 pitfall traps (Ø funnel: 8 cm; Ø inner hole: 3 cm) were used to determine possible effects of edges between habitats on epedaphic springtail communities in a small fragmented hardwood floodplain (FT1-12), forest edge of a hardwood floodplain (ET1-6) and two adjacent softwood floodplains (ST1-6) in the Northern Upper Rhine Valley in Germany (see Fig. 1). The hardwood floodplain was additionally divided into three sections based on their distance from the river Rhine. The sections were called the riverine section (FT1-4), middle section (FT5-8) and dam section (FT9-12), respectively. The six pitfall traps set on the softwood floodplains were modified to prevent them being flooded. The funnel was enclosed in a ring of polystyrene, which caused it to float when the area was flooded (Fig. 3). Each trap was additionally secured by three poles which prevented it from drifting away on the current of the river Rhine. The killing agent was saturated saline solution (~30%). Pitfall traps were replaced every two weeks and after returning to the laboratory the catches of arthropods were sorted under a stereo-microscope at a maximum magnification of 40× and stored in ethanol (70%). Subsequently the Collembola were determined to species level using a phase-contrast microscope (Leica Microscope DML) at up to 1000× magnification.

The sites studied are located in the nature reserve "Inselrhein" near Mainz (for details see Marx et al. 2010). The softwood floodplains are covered with willow and poplar (*Salicetum albae* and *Salicetum albae cornetosum* with *Populus*

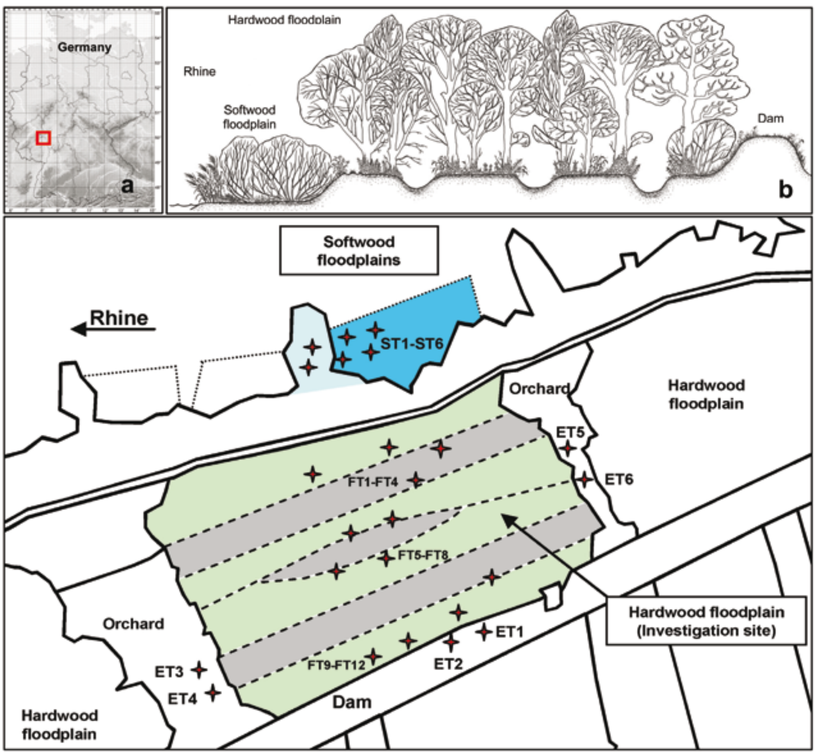

Fig. 1. (a) Location and (b) sketch of the site studied in Germany and (c) positions of the pitfall traps (FT1-12 = traps on the hardwood floodplain; ET1-6 = traps at the edge of the forest; ST1-6 = swim (=floating) traps on the adjacent softwood floodplains).

Fig. 2. Peripheral area of the hardwood floodplain.

× *canadensis*). The hardwood floodplain with forest (*Querco Ulmetum* and *Carici Tilietum*) typical for the fragmented floodplain forests in this area. The periphery of the hardwood floodplain is covered with shrubs grading rapidly into open grassland (Fig. 2).

For detecting edge effects different species-based (Jaccard, Sørensen), dominance based (Renkonen) and combined (Wainstein) similarity indices were used (Sørensen 1948, Jaccard 1902, Renkonen 1938, Wainstein 1967).

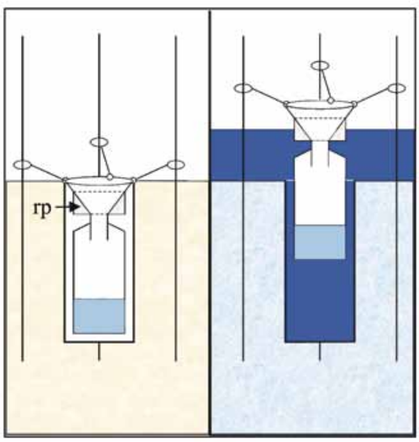

Fig. 3. Pitfall-traps that were modified by placing a ring of polystyrene (rp) around them so that they floated during flooding events and were set in the softwood floodplains.

Table 1. Total number of individuals caught at the different investigation sites over the whole sampling period (October 2007 – May 2008). Dominance classification follows Engelmann (1978) and refers to the specific sites studied: ***eu-dominant; **dominant; *subdominant

	riverine section	middle section	dam section	forest edge	softwood floodplains
Lepidocyrtus lignorum (Fabricius, 1793)	441 ***	496 ***	628 ***	223 *	108 **
Sminthurinus aureus (Lubbock, 1862)	150 **	100 *	37	47	81 **
Orchesella villosa (Geoffroy, 1762)	145 **	86 *	95 *	745 **	4
Ceratophysella denticulata (Bagnall, 1941)	79 *	250 **	49 *		
Dicyrtomina ornata (Nicolet, 1842)	68 *	96 *	30	6	
Pogonognathellus flavescens (Tullberg, 1871)	68 *	74 *	38	12	
Entomobrya muscorum (Nicolet, 1842)	52 *	43	8	13	
Isotoma viridis Bourlet, 1839	28	47 *	24	754 **	57 *
Entomobrya nivalis (Linnaeus, 1758)	19	5	9	17	13
Isotomurus palustris (Müller, 1776)	16	8	3	717 **	83 **
Lepidocyrtus lanuginosus (Gmelin, 1788)	15	22	11	16	
Pseudachorutes subcrassus Tullberg, 1871	15	19	6	15	1
Xenyllodes armatus Axelson, 1903	14	24	16	30	
Dicyrtoma fusca (Lubbock, 1873)	11	16	4		
Lepidocyrtus cyaneus Tullberg, 1871	11	10	11	2040 ***	8
Allacma fusca (Linnaeus, 1758)	9	6	8	10	
Lepidocyrtus curvicollis Bourlet, 1839	8	59 *	348 **	9	
Tomocerus vulgaris (Tullberg, 1871)	5	22	3	195 *	
Heteromurus nitidus (Templeton, 1835)	5	2	3		
Orchesella cincta (Linnaeus, 1758)	3	11	7	18	2
Superodontella lamellifera (Axelson, 1903)	3	8	4		
Orchesella flavescens (Bourlet, 1839)	2	3		9	8
Folsomia quadrioculata (Tullberg, 1871)	2	1	1	3	
Lepidocyrtus violaceus (Geoffroy, 1762)	2	1		112	1
Neanura muscorum (Templeton, 1835)	2				
Sminthurinus elegans (Fitch, 1863)	1	5	1	9	4
Lepidocyrtus paradoxus Uzel, 1890	1	3	7	57	
Willowsia nigromaculata (Lubbock, 1873)	1	1	1		2
Lathriopyga longiseta Caroli, 1910	1				
Pseudosinella alba (Packard, 1873)	1				
Ceratophysella bengtssoni (Ågren, 1904)		3		48	
Vertagopus arboreus (Linnaeus, 1758)		2			7
Sminthurides aquaticus (Bourlet, 1843)		1			138 **
Folsomia candida Willem, 1902		1	1		
Ptenothrix atra (Linnaeus, 1758)		1			
Deuterosminthurus bicinctus (Koch, 1840)		1			
Isotomurus maculatus (Schaeffer, 1896)				276 *	9
Isotomurus plumosus Bagnall, 1940				91	1
Entomobrya lanuginosa (Nicolet, 1842)				40	14
Isotomurus unifasciatus (Börner, 1901)				8	
Sminthurus nigromaculatus Tullberg, 1871				7	
Isotomurus antennalis Bagnall, 1940				4	1
Micranurida pygmaea Börner, 1901				3	
Sminthurus viridis Linnaeus, 1758				3	
Sminthurides malmgreni (Tullberg, 1876)					92 **
Podura aquatica Linnaeus, 1758					9
Protaphorura campata (Gisin, 1952)					4
Sminthurides signatus (Krausbauer, 1898)					3
Folsomia inoculata Stach, 1947					1
Proisotoma minuta (Tullberg, 1871)					1
Arrhopalites principalis Stach, 1945					1
total	1178	1427	1353	5537	653

RESULTS

Altogether 10148 individuals belonging to 15 families and 51 species were caught (Table 1). Very high species-based (Jaccard: 75–81%; Sørensen: 85–90%) and dominance-based (Renkonen: 64–80%) similarities were calculated for the three sections of the hardwood floodplain (Table 2). The values (51–60%) of the combined Wainstein-index for these sections were also very high. In all sections *Lepidocyrtus lignorum* (Fabricius, 1793) was the eudominant species making up almost 40% of the total number of individuals caught in the hardwood floodplain forest. Other important dominant and subdominant species in the hardwood floodplain sections were *Orchesella villosa* (Geoffroy, 1762) and *Ceratophysella denticulata* (Bagnall, 1941). In contrast, the similarity between the softwood floodplains and the three sections of the hardwood floodplain was very low. The softwood floodplains were dominated by different epineustic and hygrophilic species like *Isotomurus palustris* (Müller, 1776), *Sminthurides aquaticus* (Bourlet, 1843) and *Sminthurides malmgreni* (Tullberg, 1876). High numbers of *Lepidocyrtus lignorum*, *Sminthurinus aureus* (Lubbock, 1862) and *Isotoma viridis* Bourlet, 1839 were caught in both areas and 32 species in

Table 2. Similarity-values [%] of the different species-based, dominance-based and combined indices (bold: highly similar; red: very highly similar)

	Jaccard [%]						Sørensen [%]				
	Forest edge	Softwood floodplains	Riverine section	Middle section	Dam section		Forest edge	Softwood floodplains	Riverine section	Middle section	Dam section
Forest edge		35,71	**56,41**	**56,10**	**54,05**			52,63	**72,13**	**71,88**	**70,18**
Softwood floodplains			30,23	37,21	30,00				46,43	54,24	46,15
Riverine section				**75,00**	**80,65**					**85,71**	**89,29**
Middle section					**78,79**						**88,14**
Dam section											

	Renkonen [%]						Wainstein [%]				
	Forest edge	Softwood floodplains	Riverine section	Middle section	Dam section		Forest edge	Softwood floodplains	Riverine section	Middle section	Dam section
Forest edge		31,14	25,40	20,51	18,21			11,12	14,33	11,51	9,84
Softwood floodplains			37,86	31,98	24,78				11,45	11,90	7,43
Riverine section				**79,85**	**65,17**					**59,89**	**52,36**
Middle section					**64,77**						**51,03**
Dam section											

only one floodplain forest area. The lowest similarity (e.g. Wainstein: 7.43%) was recorded for the dam section and the softwood floodplain forest. The low values for these areas, which are distant from one another, is due to the low activity of *Sminthurinus aureus* and very high activity of *Lepidocyrtus curvicollis* Bourlet, 1839 in the dam section of the hardwood floodplain.

The species composition of the collembolan communities in the peripheral area and the hardwood floodplain sections were very similar (Jaccard: 54–57%; Sørensen: 70–73%). But the dominance-based and combined similarity indices of these sites are very different. In the peripheral area *Lepidocyrtus cyaneus* Tullberg, 1871 was eudominant. In the hardwood floodplain this species occurred sporadically to recedent dominance values. Similar results were obtained for different *Isotomurus*-species (*Isotomurus maculatus* (Schaeffer, 1896), *Isotomurus palustris* and *Isotomurus plumosus* Bagnall, 1940), *Tomocerus vulgaris* (Tullberg, 1871) and *Isotoma viridis* Bourlet, 1839.

DISCUSSION

The main reason for the homogeneity of the three hardwood floodplain sections is the strong eudominance of *Lepidocyrtus lignorum* and dominance of *Orchesella villosa* and *Ceratophysella denticulata*. For several years these three species have had high dominance values in the hardwood floodplain forest (Marx 2005, Marx et al. 2009). *Lepidocyrtus lignorum* and *Ceratophysella denticulata* seem to be especially restricted to the riverbank of the river Rhine. Marx et al. (2010) caught only a few specimens of these species in pitfall traps over a period of six years in softwood floodplains and on islands in the Northern Upper Rhine Valley. Both species are absent from areas that experience long-lasting but infrequent flooding events. These findings are in accordance with the results of the long-term study of Russell (2007), who classified *Lepidocyrtus lignorum* as a wetness-avoiding species. *Orchesella villosa* is recorded as highly active in almost all of the studies carried out in the Northern Upper Rhine Valley. It avoids areas that are infrequently flooded. Therefore, this species is classified as xerotolerant and mesophilic and is frequently recorded in open habitats and floodplain forests (Marx et al. 2010, Lessel et al. 2011). In contrast to their homogeneity the three hardwood floodplain sections are not similar to the adjacent softwood floodplains, which are frequently flooded. Thus, the greater activity of different epineustic and hygrophilic species in the softwood floodplains can be accounted for. The dominant occurrence of *Lepidocyrtus lignorum* in the softwood floodplain traps could be due to the long periods of drought during which this species migrates into this area. After a prolonged flooding event the activity of *Lepidocyrtus lignorum* decreased dramatically, which accounts for why this species is classified as a wetness-avoiding species. The difference between the softwood and hardwood floodplain forests accords with what is indicated by the results of other studies on eu-, hemi- and epedaphic springtail communities in similar habitats (Russell et al. 2004, Russell & Griegel 2006, Sterzyńska 2009, Marx et al. 2010).

The species composition at the edge of the forest and the hardwood floodplain sections is very similar. Many species occurred in both areas, but the dominance-based and combined similarity indices revealed strong differences between these sites. At the edge of the forest *Lepidocyrtus cyaneus*, a typical species of open habitats, was eudominant. The 2040 individuals of this species caught in the peripheral area indicates their activity there was very high and accounts for more than 50% of all the springtails caught in pitfall traps on the hardwood floodplain edge. Other species like *Lepidocyrtus violaceus* (Geoffroy, 1762), *Lepidocyrtus paradoxus* Uzel, 1890, *Tomocerus vulgaris*, *Isotoma viridis* and different *Isotomurus*-species, which prefer open habitats, showed similar differences in their activity-patterns. The increase of activity can be explained with the fewer spatial space resistivity of the grassland area in comparison to the hardwood floodplain forest, but the distribution of these species indicates distinct edge effects in this ecotone.

This investigation has revealed the niche characteristics and ecological value of the typical small fragmented hardwood and softwood floodplain forests in the Northern Upper Rhine Valley for epedaphic collembolan communities.

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