The influence of urban lawn mowing regimes on diversity of Heteroptera (Hemiptera)

PHILIPP ANDREAS UNTERWEGER, CHRISTIAN RIEGER & OLIVER BETZ

Abstract

In order to analyse the potential of an extensive mowing regime for influencing the biodiversity of insects on public urban grassland areas in a middle-sized town, we compared intensively mowed lawns (one mowing event per month) with meadows that were extensively mowed only twice a year. Over the entire field season, 335 true bug individuals of 49 species and 12 families were caught by using spoon nets and an insect aspirator. We established that the process of mowing on a regular monthly basis reduced heteropteran biodiversity about 50% per mowing event. Moreover, extensively mowed meadows showed significantly higher total species numbers and biodiversity indices. With respect to true bugs, lawns were characterised by the absence of typical meadow species that could be found on the extensively mowed study plots. Our research supports the initiative "Bunte Wiese (Colourful Meadow) – Species Diversity in Public Greenspaces" of the University of Tübingen, which is campaigning for the enhancement of species diversity in public urban greenland areas by reorganising the intensive mowing into a "twice a year"-programme.

Zusammenfassung

Die Häufigkeit der Mahd von Grünflächen hat einen großen Einfluss auf die Entwicklung von Pflanzen und Tieren. Insbesondere Insektenpopulationen können durch eine hohe Mahdfrequenz empfindlich geschädigt werden. In vorliegender Arbeit untersuchten wir daher die Auswirkung der Reduktion der Mahdfrequenz innerstädtischer Rasenflächen auf die Wanzenvielfalt. Die Umstellung von intensiver Rasenpflege zu extensiver Wiesenmahd ermöglichte es uns, während einer Vegetationsperiode 335 Wanzen aus 49 Arten und 12 Familien zu fangen. Der Vergleich mit weiterhin intensiv gepflegten Rasenflächen zeigte uns, dass die monatliche Mahd die Wanzenpopulation um etwa 50% pro Mahd reduziert. Extensiv gepflegte Stadtwiesen zeigten eine signifikant höhere Artenzahl und höhere Biodiversitätsindizes. In Bezug zur Wanzenzönose lassen sich intensiv gepflegte Rasenflächen durch die Abwesenheit von typischen Graslandwanzen charakterisieren. Unsere Ergebnisse unterstützen die Ziele und Argumente der Initiative „Bunte Wiese – Für mehr Artenvielfalt auf öffentlichem Grün" der Universität Tübingen, die einen Beitrag zur Verminderung des weltweiten Insektensterbens leisten möchte, indem sie für eine weitreichende Extensivierung der Mahd eintritt und dadurch flächendeckend artenreiche Grünflächen schaffen möchte, welche Lebensraum für Pflanzen und Tiere bieten.

Keywords

Baden-Württemberg, conservation, Heteroptera, Insecta, true bug, insect communities, meadow, mowing, public green areas, urban ecology, vegetation management

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Introduction

Approximately 25% of the world's terrestrial zone is open grassland (TSCHARNTKE & GREILER 1995). Grassland is characterised by a special composition of monocotyledonous grasses and dicotyledonous flowering plants (TSCHARNTKE 2003). In Central Europe, with the exception of natural grasslands such as alpine meadows, anthropogenic grasslands can only persist by the frequent use of grazing animals or by mowing (BUNZEL-DRÜKE & VIERHAUS 2001; HUMBERT et al. 2009). Therefore, meadows are a special type of an inner European habitat (ELLENBERG 1986) with strong linkage to anthropogenic use (UNTERWEGER & UNTERWEGER 1989). The regular disturbance of grasslands by grazers or non-industrialised farmers and the rich vertical and horizontal structure provide many species with the opportunity of settling in such habitats (BRIEMLE & FINK 1993).

The loss of plant and insect species in European grasslands has increased in the past 60 years as a result of the industrialisation and intensification of agriculture (THOMAS et al. 2004; SCHUCH et al. 2012). The change of agricultural land-use, the intensification of mowing (e.g. more than twice a year) connected with fertilisation since the 1960s have destroyed many of the original natural meadows and have often caused the extinction of grassland species (SCHUCH et al. 2012). Because of economic reasons, even grasslands in protected areas are at risk. These facts make inner European grasslands and agricultural meadows endangered ecosystems (MAYR 2013). Approximately 80% of German grassland is under intense use and is thus of only low significance for the protection of grassland biodiversity (SCHUCH et al. 2012). In contrast, extensively used agricultural grasslands (e.g. grazing land or sedge meadows) in areas without natural grassland significantly contribute to the total number of species in such areas (DI GIULIO et al. 2001; VENN & KOTZE 2014).

The biodiversity of urban areas has long been neglected (KLAUS 2013), although cities possess many open spaces and public grassland (usually cultivated in the form of lawns) that could help to enhance biodiversity (SATTLER et al. 2011; INEICHEN et al. 2012; SMITH et al. 2015). The protection of biodiversity in urban areas might thus contribute to fulfill ecosystem functions such as pollination, oxygen production, human well-being and pest regulation (ALBRECHT et al. 2010).

In 2010, the year of biodiversity, a group of students and academics of the University of Tübingen (Baden-Württemberg, Southwest Germany) founded an initiative called "Bunte Wiese" (i.e. "Colourful Meadow") (UNTERWEGER et al. 2013). Its primary concern was to improve the biodiversity in urban public areas such as meadows, lawns and forests (either in parks or surrounding public buildings that can be considered as places most naturally found in a city). The goal was to optimise the management of the grassland areas to improve their quality with respect to conservational and ecological services. Administrative authorities and cooperating scientists helped to develop and implement this concept to improve the biodiversity in the inner city. The involved scientists investigated plants and insects (orthopterans, wild bees, beetles and butterflies) on intensely cut lawns *versus* extensively cut meadows (ADE et al. 2012; HILLER & BETZ 2014; KRICKE et al. 2014; WASTIAN et al. 2016). These investigations established clear evidence that reduced mowing regimes (once to twice per year) significantly led to an increase of insect diversity, even already one year after the change to this extensive mowing programme. Furthermore, a correlation was found between the number of dicotyledonous plant species and the number of insect species. In the present contribution, we present the results obtained with regard to true bugs investigated within the green areas of a city.

We investigated true bugs (Hemiptera, Heteroptera) because of their relatively small vagility and their strong linkage to special plant species and habitat structures (BRÖRING et al. 1989). In previous studies, about six percent of all the insects captured on meadows were true bugs (TSCHARNTKE & GREILER 1995). Another factor explaining their high biodiversity is their wide range of feeding strategies, as they comprise phytophagous, zoophagous, saprophagous and mixed feeders (NIEDERER 1998). Furthermore, heteropteran diversity strongly correlates with the total insect diversity and can thus be used as a proxy for insect biodiversity in general (DI GIULIO et al. 2001). HUMBERT et al. (2009) and SCHÄFER et al. (1995) have established strong reactions of grassland heteropteran populations with respect to the mowing regime. Focusing on public urban grasslands in the medium-sized city of Tübingen, we have aimed at evaluating the potential of public urban meadows with regard to keeping and improving the diversity of heteropteran true bugs. We have hypothesized that (1) meadows that are mown only twice a year (extensively mown) contain more heteropteran species than monthly mowed lawns (intensively mown) and (2) that on urban grasslands of Tübingen, one can find rare and endangered true bug species. In this context, our study intends to evaluate the potential that the extensification of the mowing regime of public lawns has to enhance the biodiversity of insects. Other hypotheses we had were (3) that both the number of true bug individuals and true bug species raises with the distance to the city centre and (4) that mowing leads to a significant loss of the number of true bug individuals.

With this research we intended to evaluate the potential that a change of green space management towards a more extensive mowing regime has to enhance intra-urban biodiversity.

Materials and Methods

Sampling setup:

Eight inner urban grassland areas (Fig. 1: spots A-H) located within the city area of Tübingen (Baden-Württemberg, Germany, 48°32'15''N 9°2'28''O) were studied. Every grassland study plot was subdivided into a lawn area that was mowed frequently (about 8 times per year) *versus* an equal-sized meadow area that was extensively mowed (only twice a year). The size of these areas was between 100 - 1000 m². All these areas belonged to the presentation areas of the students initiative.

The insects were captured with spoon nets of 35 cm diameter, an especially modified aspirator (Stihl LS, Dieburg, Germany) vacuum foliage collector with a fine net inside the aspiration tube) and an exhauster (Trautner 1992). We used standardised methods that are normally used for beetles. We took 60 steps across the capturing areas with spoon nets. Each step was accompanied by a spoon net drive of about one meter. In addition, the modified aspirator was used to aspirate ten patches of 10 cm² in size per sampling site. The transects for the spoon nets and the plots for the aspirator were selected randomly.

This sampling program was repeated every four weeks, from May to October 2012. This spectrum of diverse collecting methods guaranteed the acquisition of a wide range of true bug species. After preparation, the species were identified according to Stichel (1955-1962), Wagner (1966; 1967) and Wachmann (1989; 2006).

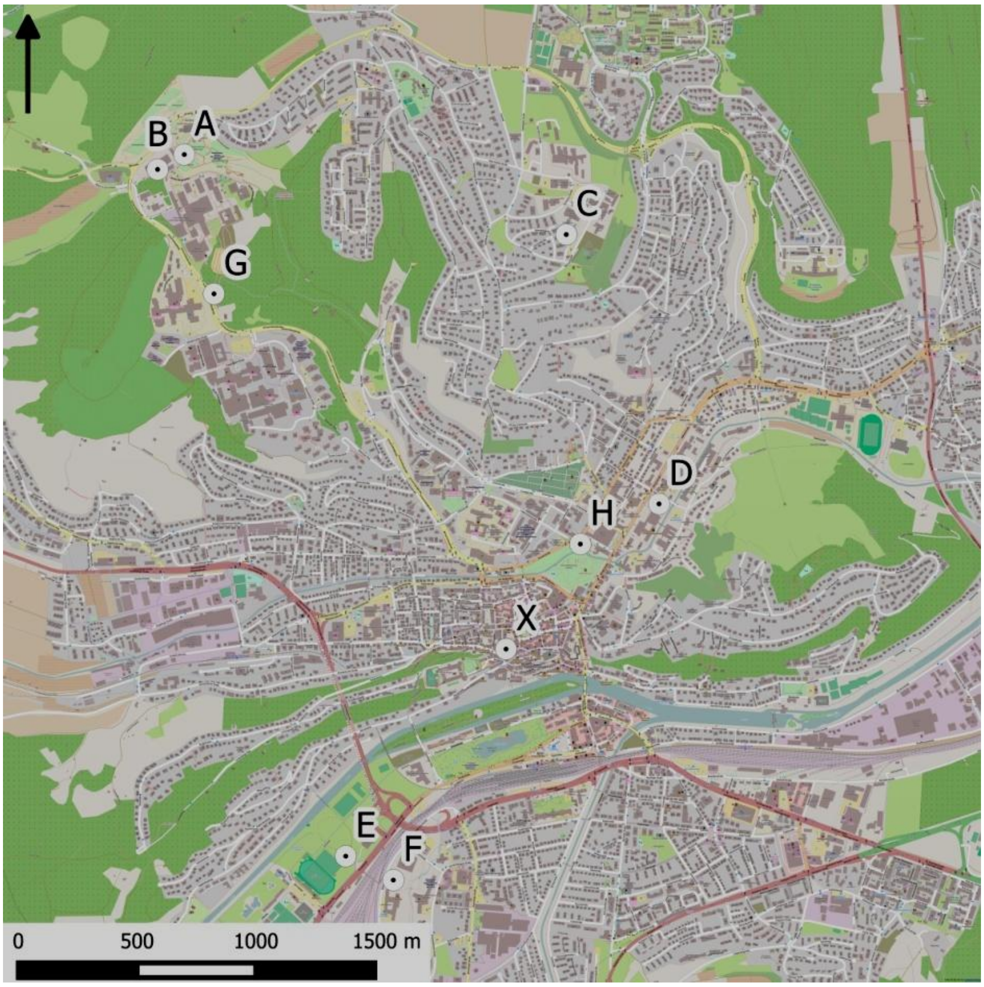

Figure 1: The map of all the sampling sites in Tübingen. A: Botanical garden; B: Botanical Institute; C: Observatory; D: Hegelbau; E: Europastraße; F: District Office; G: BG-Unfallklinik (Emergency Clinic); H: Old Botanical Garden; X: City Centre. © OpenStreetMap contributors

Our primary data were compiled into a list of all the captured individuals per species combined with the capturing date, place and type of area. We used Microsoft-Excel-2008 (© Microsoft, Office) and SPSS 21 (© IBM, SPSS) for further analysis of these data.

Biodiversity indices:

The number of species (species richness) was used as an important biodiversity index. The SÖRENSEN quotient was used to determine the similarity of two areas with respect to their species inventory (MÜHLENBERG 1993). Finally, the SHANNON index was used to quantify the species diversity (MÜHLENBERG 1993).

Statistical tests:

The SHANNON index, the total number of species and the total number of individuals were statistically compared on both extensively and intensely mowed plots by WILCOXON tests (RUDOLF & KUHLISCH 2008). According to our low sample size ($n = 6$), significance levels $0.5 < p < 0.1$ were accepted as "almost significant", since they always showed the same trend as our statistically significant comparisons. We also used a correlation analysis to evaluate the significances of the three biodiversity scales in relation to the distance to the town centre.

Multivariate analyses:

A Principal Component Analysis (PCA) with Varimax rotation and KAISER criterion (Eigenvalue > 1) was performed to explore the similarity of the study plots with respect to their species composition (mean of the numbers of individuals per species). A discriminant function analysis helped to determine those species that could be used to distinguish between the two mowing regimes.

Results

During the growing season in 2012, we captured 335 heteropteran individuals on the experimental areas in Tübingen; they belonged to 12 families and 49 species (Tab. 1). Approximately 80% of the individuals belonged to the family Miridae, 5% were Pentatomidae, 4% Nabidae, 2% Berytidae, 2% Coreidae, 2% Lygaeidae, 2 % Tingidae, 1% Pyrrochoridae, 1 % Scutelleridae, 0.5% Alydidae and 0.5% Anthocoridae. On meadows, 27% of these species were zoophagous, another 27% phytophagous, and 46% polyphagous (classification according to WACHMANN 2006). On lawns, 9% of these species were zoophagous, 27% polyphagous and 64% phytophagous (classification according to WACHMANN 2006). On the intensely mowed lawns, we found 45% accidental species (untypical grassland species, vagrants) and 55% typical grasslands inhabitants (WACHMANN 2006). In contrast, the extensively mowed meadows harboured only 20% accidental (untypical grassland species) species and 80% typical grassland heteropterans.

Table 1: List of all captured species with their presence (X) / absence (space) on each study plot (A-H (cf. Fig.1)). 1: intensely mowed lawns; 2: extensively cultivated meadows. vag = vagrant, typ = typical meadow species, phy = phytophagous, pol = polyphagous, zoo = zoophagous.

			A		B		C		D		E		F		G		H	
family	**scientific name**	**ecol**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Alydidae	*Alydus calcarartus* (Linnaeus, 1758)	typ, phy		1														
Anthocoridae	*Anthocoris confusus* (Reuter, 1884)	vag, zoo							1									
Berytidae	*Berytinus minor* (Herrich-Schaeffer, 1835)	typ, phy										4						
Coreidae	*Coreus marginatus* (Linnaeus, 1758)	typ, pol				1										1		
	Coriomeris denticulatus (Scopoli, 1763)	typ, phy				1												
Lygaeidae	*Kleidocerys resedae* (Panzer, 1797)	vag, pol						1										
	Rhyparochromus vulgaris (Schilling, 1829)	vag, phy		1		2					2							
Miridae	*Adelphocoris lineolatus* (Goeze, 1778)	typ, phy		1		3								1				
	Amblytylus nasutus (Kirschbaum, 1856)	typ, phy				5				1		7		5		1		
	Apolygus lucorum (Meyer-Dür, 1843)	typ, phy						2		1		6		1		1		
	Capsus ater (Linnaeus, 1758)	typ, phy		1		1		1		1		2				4		1
	Charagochilus gyllenhalii (Fallén, 1807)	typ, phy										1						
	Chlamydatus pulicarius (Fallén, 1807)	typ, pol				3												
	Closterotomus biclavatus (Herrich-Schaeffer, 1835)	typ, pol								1						1		1
	Criocoris crassicornis (Hahn, 1834)	typ, phy														1		
	Deraeocoris lutescens (Schilling, 1837)	vag, zoo															1	
	Dryophilocoris flavoquadrimaculatus (De Geer, 1773)	vag, pol														1	1	
	Globiceps fulvicollis (Jakovlev, 1877)	vag, pol				1						1						
	Leptopterna dolabrata (Linnaeus, 1758)	typ, phy		2								3		2		6		1
	Lygus pratensis (Linnaeus, 1758)	typ, phy		5		7		14		3	4	4						
	Lygus rugulipennis (Poppius, 1911)	typ, phy				1					1							
	Megaloceroea reticornis (Geoffroy, 1785)	typ, phy		1												8		
	Notostira spec. (Fieber, 1858)	typ, phy		20				3		1		2				1		1
	Orthocephalus coriaceus (Fabricus, 1777)	typ, phy						1				7						
	Plagiognathus chrysanthemi (Wolff, 1804)	typ, phy		6	1	4		10				14				2		
	Polymerus unifasciatus (Fabricus, 1794)	typ, phy		4		17				3		1						
	Psallus haematodes (Gmelin, 1790)	vag, pol														1		
	Psallus sp. (Fieber, 1858)	vag, pol															1	
	Rhabdomiris striatellus (Fabricius, 1794)	vag, pol														1		
	Stenodema calcarata (Fallén, 1807)	typ, phy								2								
	Stenodema laevigata (Linnaeus, 1758)	typ, phy		1								2		1		1		
	Stenotus binotatus (Fabricius, 1794)	typ, phy		10								3		3		5		1
	Trigonotylus caelestialium (Kirkaldy, 1902)	typ, phy		1		2			1	8				1		3		
Nabidae	*Himacerus mirmicoides* (O. Costa, 1834)	vag, zoo				1						1				2		
	Nabis flavomarginatus (Scholtz, 1847)	typ, zoo		1														
	Nabis limbatus (Dahlbom, 1851)	typ, zoo							1									
	Nabis rugosus (Linnaeus, 1758)	typ, zoo								1								
	Nabis sp. (Latreille, 1802)	typ, zoo		4				1										2
Pentatomidae	*Aelia acuminata* (Linnaeus, 1758)	typ, phy		1		1												
	Carpocoris fuscispinus (Boheman, 1851)	typ, phy		2														
	Carpocoris purpureipennis (De Geer, 1773)	typ, phy		1														
	Dolycoris baccarum (Linnaeus, 1758)	vag, pol		2		2		1		3		1		1				
Pyrrhocoridae	*Pyrrhocoris apterus* (Linnaeus, 1758)	vag, pol				2		1							5			
Rhopalidae	*Rhopalus* sp. (Stal, 1872)	typ, phy		1		1												
	Stictopleurus sp. (Stal, 1872)	typ, phy		1														
Scutelleridae	*Eurygaster maura* (Linnaeus, 1758)	typ, phy		1		1												
	Eurygaster testudinaria (Geoffroy, 1785)	typ, phy				1				1						1		
	Podops inunctus (Fabricius, 1775)	typ, pol														1		
Tingidae	*Kalama tricornis* (Schrank, 1801)	typ, pol				3	4											

Influence of mowing:

The differences of captured individuals on lawns *versus* meadows over the entire sampling time are presented in Figure 2. The absence of true bugs on lawns is remarkable. Figure 3 demonstrates that the occurrence of large numbers of individuals is not only a result of one or two species. The number of individuals on these areas is also based on a large number of species.

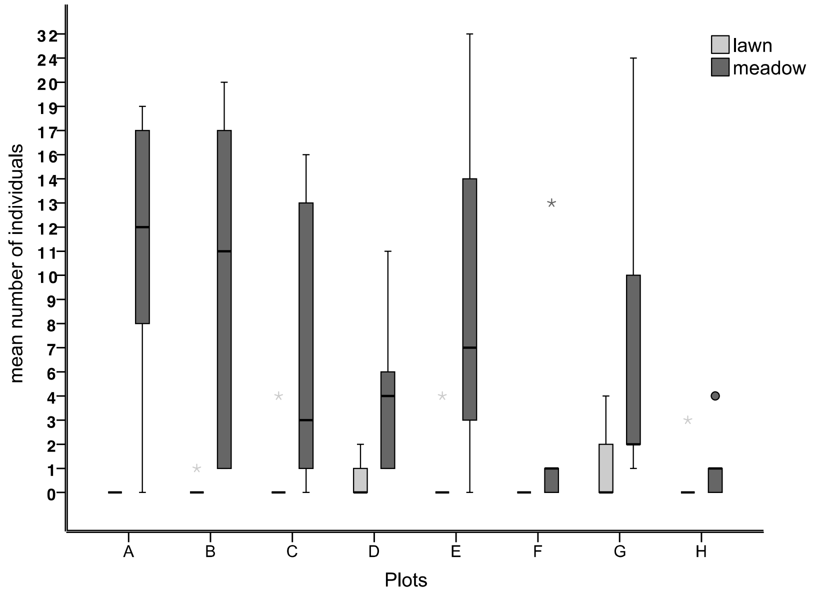

Figure 2: Comparison of the total number of individuals between intensely and extensively mowed areas (for an explanation of abbreviations, see Fig. 1). Black bars: extensively mowed meadow. Grey bars: intensely mowed lawn. WILCOXON-Test, n=6, A: p=0.04; B: p= 0.04; C: p=0.14; D: p=0.04; E: p=0.08; F: p= 0.10; G: p= 0.04; H: p=0.46. (A, B, D, G = significant; E, F = almost significant). * extreme values and ° statistical outliers are all included in the statistical tests.

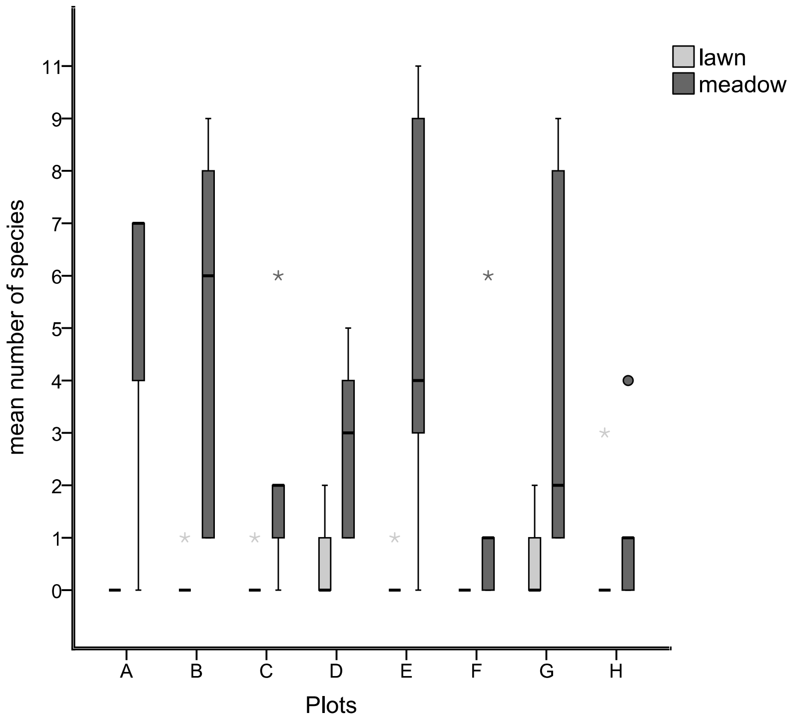

Figure 3: Comparison of the total number of species between intensely and extensively mowed areas (for an explanation of abbreviations, see Fig. 1). Black bars: extensively mowed meadow. Grey bars: intensely mowed lawn. WILCOXON-Test, n=6, A: p = 0.039; B: p = 0.027; C: p = 0.039; D: p = 0.042; E: p = 0.042; F: p = 0.102; G: p = 0.042; H: p = 0.336. (A, B, C, D, E and G = significant). * extreme values and ° outliers are all included in the statistical tests.

Mowing is one of the major impacts on insect life on meadows. Figure 4 shows the influence of mowing events on the total number of individuals and reveals a sharp decline of individuals even in a twice-yearly mowing regime.

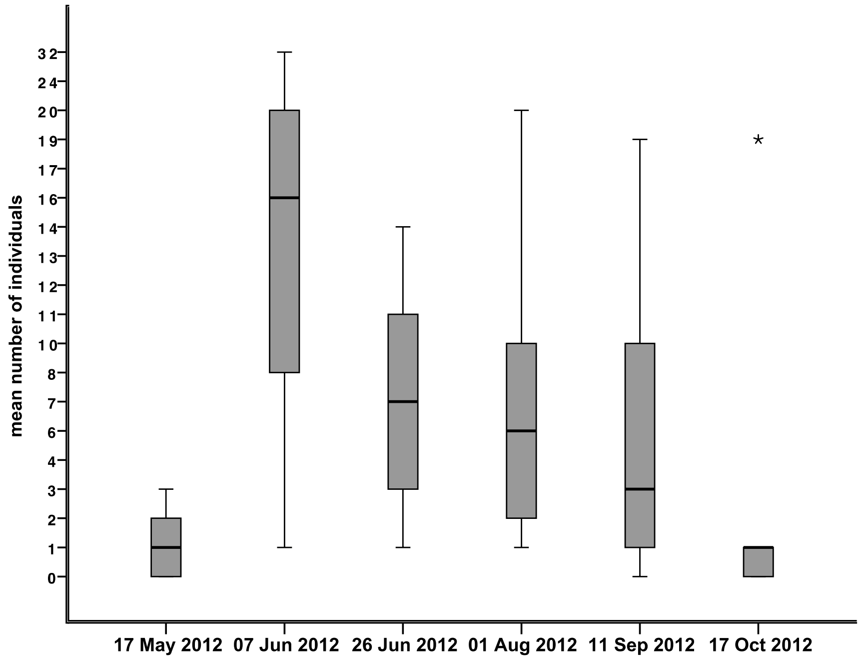

Figure 4: Boxplots of the total number of captured true bugs on extensively mowed meadows over the entire capturing season. Intensely mowed lawns are not included because of the almost complete absence of individuals (Fig 6). After every mowing event (June 7 - 26 and September 11 - October 17), the number of individuals sharply declined.

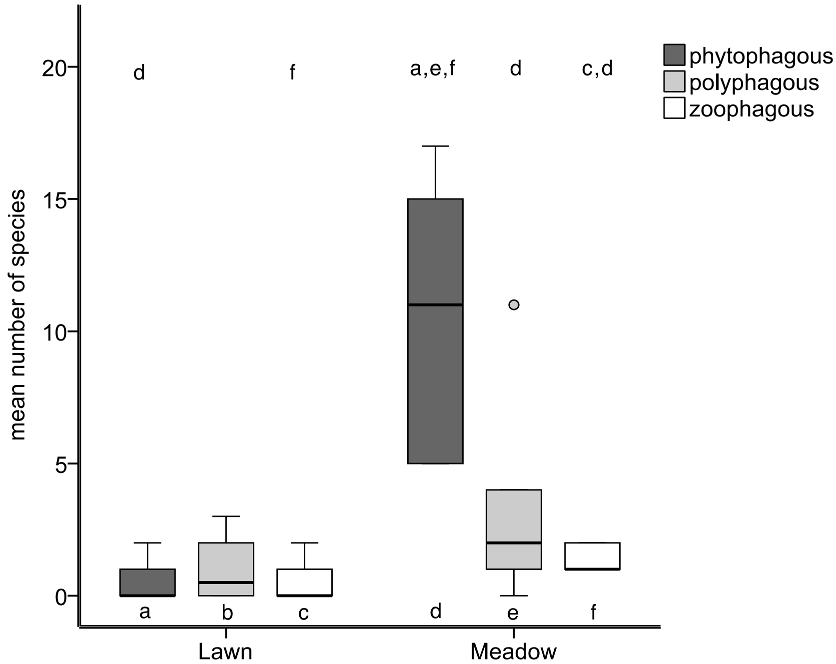

Figure 5: Distribution of all the captured species over the entire sampling time separated into the different feeding types. Different letters above the boxplots show significant differences of the respective boxplot towards the other boxplots indicated by these letters. (Significant differences between lawn and meadow: phytophagous species p = 0.027 (ad) almost significant differences between lawn and meadow: zoophagous species p = 0.096 (cf)); on meadows, significant differences are found between phytophagous – polyphagous species: p = 0.027 (de) and phytophagous – zoophagous species: p = 0.027 (df). WILCOXON-Test, N=6)

The comparison of zoophagous, phytophagous and polyphagous species between lawns and meadows showed an (almost) significantly higher number of phytophagous (*p = 0.027*) and zoophagous (*p = 0.096*) species on the extensively mowed meadows compared to the lawns (Fig.5). On meadows, we also found significantly more phytophagous species than polyphagous (p = 0.027) and zoophagous (p = 0.027) ones. The comparison of vagrant *versus* typical meadow species between the two mowing regimes revealed significantly more meadow-typical species on the extensively mowed meadows (Fig. 6).

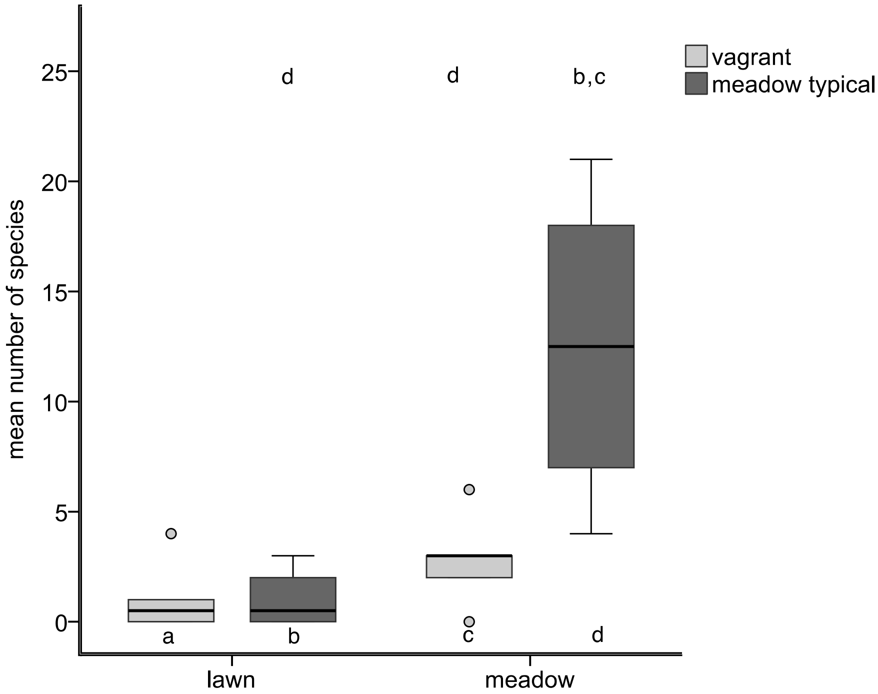

Figure 6: Distribution of the number of accidental (vagrant) and meadow-typical heteropteran species. Different letters above the boxplots show significant differences of the respective boxplot towards the other boxplots indicated by these letters. (Significances: vagrants p = 0.102; meadow-typical heteropterans p = 0.028 (bd). On meadows, a significant difference is seen between vagrants and meadow-typical heteropterans: P = 0.027 (cd). WILCOXON-Test. N=6).

Distance to the city centre:

The following analysis tested the correlation between (a) the number of families, (b) the number of species and (c) the SHANNON index with the distance of the extensively mowed sampling sites from the town centre (Fig. 7). We used only the results of the extensively mowed areas (mowed only twice a year), as intensely mowed lawns always showed a reduced number of species and individuals. The number of families (p = 0.004) and the number of species (p = 0.08) are (almost) significantly correlated with the distance to the city centre at least on the 10% significance level. The SHANNON index (p = 0.115) is not correlated with this distance.

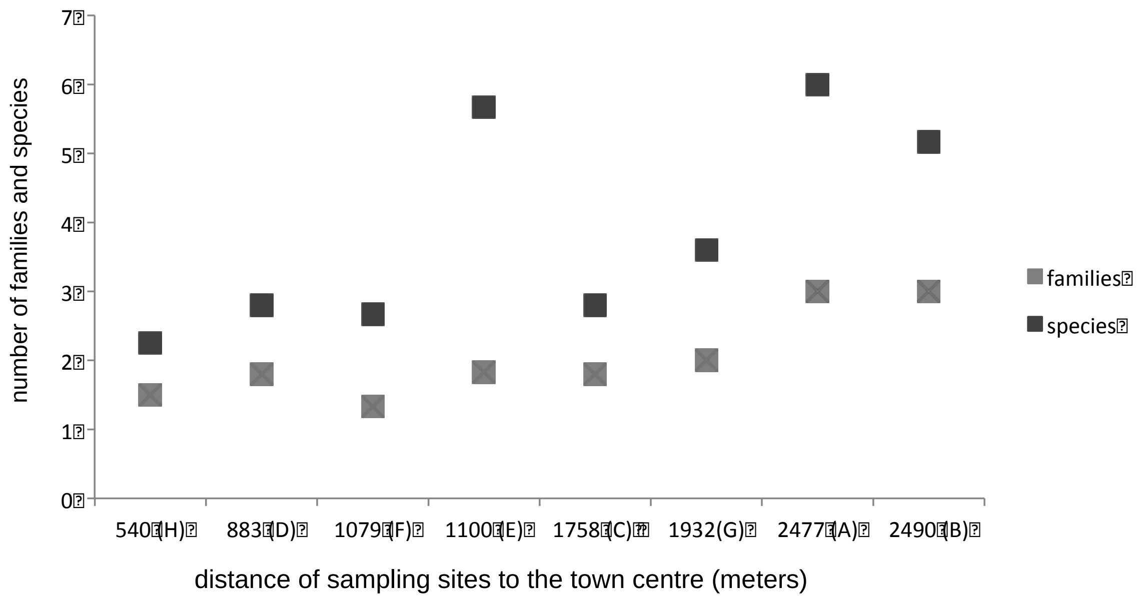

Figure 7: Correlation analysis between the number of families and the number of species of the extensively mowed sampling sites (for an explanation of abbreviations, see Fig. 1) and their distance [meters] to the town centre (X in fig.1.). Pearson correlation: families 0.875 (p = 0.004); species 0.639 (p = 0.08).

Principal component analysis (PCA)

The PCA extracted five principal components (KAISER criterion) that explained 88.9% of the total variance (Tab. 2). The loading of the species variables on each principal component can be seen in Table 3. The components are characterized by typical meadow species. Figure 8 shows PC1 plotted against PC2 and the characteristic species are given in the figure. The lawns occur densely near the origin of the axes, whereas the increasing numbers of individuals per species is reflected in the wider range of the meadow plots.

Table 2: Variances explained by the five extracted principal components (KAISER criterion) in the performed PCA.

Principal component	eigenvalues		
	total	explained variance (%)	cumulated explained variance (%)
1	6.6	41.3	41.3
2	2.8	17.5	58.8
3	2.2	14.0	72.8
4	1.5	9.4	82.2
5	1.1	6.7	88.9

Table 3: Interpretation of each PCA with respect to their correlation coefficients (loadings) showing the number of individuals per species. Only loadings > 0.5 and < -0.5 are considered for the interpretation of the meaning of the principal component.

	components				
	1	2	3	4	5
Leptoterna dolabrata	0.97				
Stenodema laevigata	0.92				
Stenotus binotatus	0.84				
Himacerus mirmicoides	0.75				
Capsus ater	0.69				
Amblytylus nasutus	0.60				
Lygus pratensis		0.89			
Plagiognathus chrysanthemi		0.79			
Apolygus lucorum	0.56	0.65			
Nabis spec.			0.94		
Notostira spec.			0.83		
Adelphocoris lineolatus				0.82	
Rhyparochromus vulgaris				0.81	
Polymerus unifasciatus				0.64	0.57
Trigonotylus caelestialium					0.95
Dolycoris baccarum		0.61			0.63

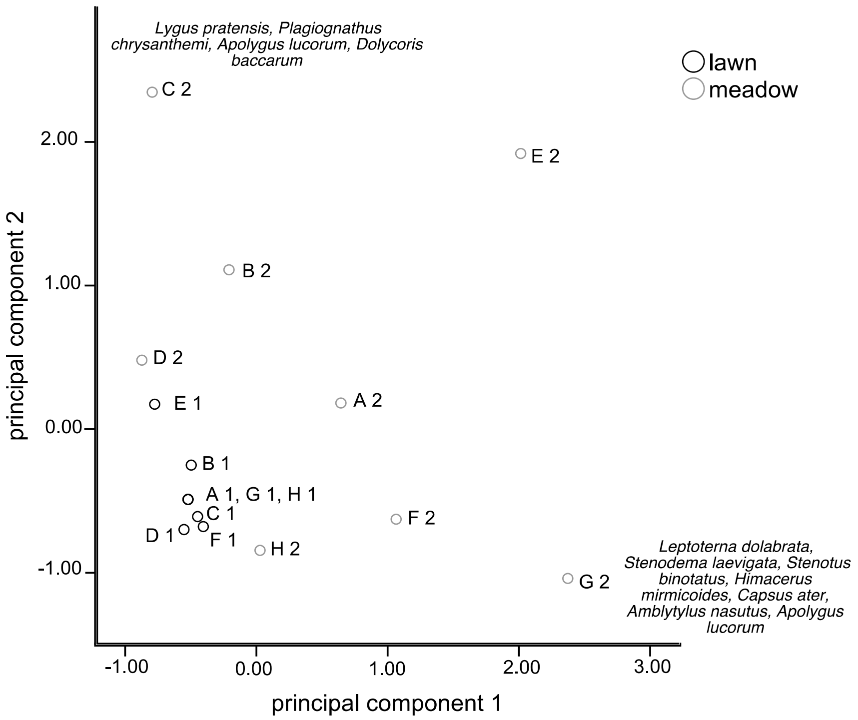

Figure 8: The graphical display of principal component 1 and 2 of our PCA (cf. Tab. 2-3). 1 means lawn, 2 means meadow. Higher PC values are indicative of an increase of the number of individuals of the listed species.

Discriminant function analysis

This analysis intended to verify the group membership (lawns *versus* meadows) of our study plots. Whereas almost all the study plots were correctly classified, the extensively mowed plot 16 (H2) was wrongly classified as an intensely cultivated lawn (Tab. 4). This can be explained on the basis that it is a site isolated by roads and covered by large trees leading to comparatively low vegetation.

Table 4: Results of the discriminate function analysis. All the eight lawns are correctly classified as lawns, whereas one of the eight meadows is wrongly classified as a lawn (Fig. 7). Eigenvalue = 4.36, Wilks-Lambda = 0.187 (significance: 0.002, canonic correlation: 0.902). The percentages are indicative of the number of intensely cut lawns / extensively cultivated meadows correctly characterized. Only one meadow (H 2) was wrongly characterized as a lawn; this can be attributed to its low heteropteran diversity.

type	predicted group		total
	lawn	meadow	
number of lawns	8	0	8
number of meadows	1	7	8
% of lawns	100	0	100
% of meadows	12.5	87.5	100

Discussion

The aim of our study has been to investigate the impact of two mowing regimes on the diversity of true bugs (Heteroptera) in order to demonstrate the potential that extensively mowed urban grasslands might have for the improvement of the (local) intra-urban biodiversity of a middle-sized town (KLAUS 2013; VENN & KOTZE 2014; GARBUZOV et al. 2015). SCHÄFER (1993) stresses the strong general linkage between insect species diversity (e.g. heteropterans), number of individuals and type of grassland management. BOCKWINKEL (1990) has proposed heteropterans as model species to evaluate grasslands according to their ecological value.

In our study, we expected that (1) we would find more heteropterans (both species and individuals) on meadows with an extensive twice-yearly cutting regime compared with lawns and that (2) there were more endangered true bug species found on our extensively mowed sampling sites. We also expected (3) that the number of species and individuals raises with the distance to the town center and (4) that the mowing incident itself drastically decreases the number of individuals.

General results

In the present study, we have investigated public grassland areas in the city of Tübingen (Baden-Württemberg, Germany) in order to establish the effect of regular monthly mowing compared with an extensive mowing regime of only twice a year on the faunal composition of grassland heteropterans. In total, we have established the presence of 49 species from 12 families (Tab. 1). Approximately 80% of the captured true bugs belong to the family Miridae, which is the largest heteropteran family worldwide (WACHMANN 2006) and typical for grasslands (KÜNZLE 2002).

SCHWOERBEL (1956) recorded 282 species for the countryside lying outside Tübingen. In our study, about 17% of this total amount was uncovered, which is a good rate considering the short time of collection. The data of SCHWOERBEL (1956) demonstrate the potential of species that might be establishable in the inner city following a reduction of grass maintenance, such as mowing intensity.

No especially endangered true bug species have occurred in our recordings, according to the proposed red list of true bugs of Baden-Württemberg (RIEGER 1979). However, using the same experimental design than ours on open grassland in the city of Tübingen, ADE et al. (2012); HILLER & BETZ (2014), WASTIAN et al. (2016) and KRICKE et al. (2014) have noted endangered (red list) species of locusts, wildbees, beetles and butterflies on the extensively mowed study plots only. Also, ALBRECHT et al. (2010) have found more rare heteropteran species on naturally managed grassland than on intensely mowed meadows.

Differences of the heteropteran fauna between meadows and lawns

In our study, areas with an extensive mowing regime always showed a significantly or almost significantly higher rate of both individuals and species compared with intensely mowed lawns (Fig. 2, Fig.3). Importantly, we should care not only about species numbers, but also about the numbers of individuals. As insects form a major part of terrestrial food webs, the number of individual insects is an important aspect for biodiversity conservation. According to MÜLLER (1989), mowing results in a drastic loss of both species and individuals. The mowing process itself reduces diversity along time (Fig. 4) (DIACON et al. 2011) and an intensive lawn-care concept can even cause the total loss of entire populations. In our study, a range of zero to six individuals per sampling area have been found over the entire vegetation period on the intensively mowed lawns. Even those lawns close to the meadows with the highest species numbers are poor in species. After a mowing incident, we ascertained a reduction of about 50% of the individuals (Fig. 4), and on several lawns, we could not find a single heteropteran within the entire investigation period. Similar results have been established by DIACON et al. (2011) and VAN DE POEL & ZEHM (2014) for agricultural grasslands and by HILLER & BETZ (2014) for grasshoppers on public green areas in Tübingen.

This clearly demonstrates the adverse impact of frequent mowing on urban grassland and, at the same time, shows the potential of the reduction of management intensity (GARCÍA 1992; PÖYRY et al. 2005; VENN & KOTZE 2014). DI GIULIO et al. (2001) and SCHWAB et al. (2002) obtained similar results by comparing different mowing regimes on agricultural grasslands and pastures, respectively. The same has been seen in previous investigations within our initiative "Bunte Wiese" ("Colourful meadow") with regard to grasshoppers (HILLER & BETZ 2014), beetles (ADE et al. 2012), wildbees (WASTIAN et al. 2016) and butterflies (KRICKE et al. 2014) also conducted on the urban grasslands of Tübingen.

Ecological characterisations

On lawns, feeding type abundances showed no statistically significant differences (Fig. 5), whereas on meadows, phytophagous heteropterans are significantly more abundant, as they probably find better (feeding) conditions due to the higher and longer-lasting potential of grasses, herbs and seeds.

The low abundance of meadow typical species in lawns (Fig. 6) supports the fact that lawns are heavily disturbed habitats. The typical grassland species (WACHMANN 2006) such as *Alydus calcarartus* (Alydidae), *Berytinus minor* (Berytidae), *Carpocoris purpureipennis* (Pentatomidae), *Charagochilus gyllenhalii* (Miridae), *Coriomeris denticulatus* (Coreidae), *Criocoris crassicornis* (Miridae), *Nabis limbatus* (Nabidae), *N. flavomarginatus* (Nabidae), *N. rugosus* (Nabidae) and *Podops inunctus* (Scutelleridae) have been caught in meadows only once during our investigation period. On the other hand, the often found meadow-typical species *Amblytylus nasutus* (Miridae), *Apolygus lucorum* (Miridae), *Capsus ater* (Miridae), *Himacerus mirmicoides* (Nabidae), *Leptopterna dolabrata* (Miridae), *Lygus pratensis* (Miridae), *Nabis* sp. (Nabidae), *Notostira* sp. (Miridae), *Plagiognathus chrysanthemi* (Miridae), *Stenotus binotatus* (Miridae) and *Stenodema laevigata* (Miridae) are absent on the intensely mowed lawns. These species might thus especially benefit from a change towards a more extensive mowing regime. Almost half of the species caught on lawns can be classified as vagrants, among which *Anthocoris confusus* (Anthocoridae), *Kleidocerys resedae* (Lygaeidae), *Rhabdomiris striatellus* (Miridae) and *Deraeocoris lutescens* (Miridae), as they live on broad-leafed trees (WACHMANN 2006) and thus are not typically linked to grassland.

On meadows, abundance of meadow-typical species is significantly higher than vagrant species (Figure 6). We have detected more than 20 individuals of the following typical meadow species with high affinities to grassland plants (WACHMANN 2006): *Lygus pratensis* (Miridae), *Plagiognathus chrysanthemi* (Miridae), *Polymerus unifasciatus* (Miridae) and *Stenotus binotatus* (Miridae). In contrast, only the typical non grassland true bug *Kleidocerys resedae* (WACHMANN 2006) has been found in meadows.

In the PCA (Tab. 3), all components consist of typical meadow species dominated by the family Miridae. Only four of sixteen true bugs do not belong to the family of Miridae.

Comparison of the sampling sites

Another result of our analysis is that the most diverse study plots are all located away from the city centre (Fig. 7). This might be caused by the grade of isolation by houses and streets in the city centre. The areas with a higher distance to the city centre have a higher degree of interaction with source populations in the suburban countryside. Similar results have previously been mentioned in other studies (KOWARIK 1992).

Conclusion

Using true bugs as an example, the present study shows the potential that a reduction of the management intensity of even public urban grasslands has for maintaining and improving biodiversity (SATTLER et al. 2011). Natural meadows inside urban areas have almost the same positive effects as natural meadows in rural regions even if the community composition and the dynamics are different (BANG & FAETH 2011; SMITH et al. 2015). They also have an important function in terms of educational issues, introducing citizens to the value of natural grassland ecosystems. Our study supports other faunistic and floristic studies showing that the extensivation of grassland maintenance results in a higher biodiversity, even in urban areas (KUTSCHBACH-BROHL et al. 2010; SATTLER et al. 2011; VENN & KOTZE 2014; GARBUZOV et al. 2015). This is immediately visible upon the conversion of the cutting regime from one year to the other. For this reason, extensive management concepts should be integrated into national plans for the protection of the biodiversity (MÜLLER 2005).

Although mowing can cause a huge loss of abundance and even the total loss of species (MÜLLER 1989), it is an essential process for stopping natural succession on grasslands (HUMBERT et al. 2009). The loss of individuals has to be balanced by newly immigrating individuals and by (shaded) hides that protect individuals during the mowing period on these areas. A good balance of source and sink habitats (which can be attained by tesselate mowing concepts) and the connection of (public) grasslands via stepping stones and corridors is extremely important for urban ecosystems (WEST & BÖTCHER 2012). This is the reason that the initiative “Bunte Wiese" ("Colourful Meadow - Improving species diversity on public green areas") positions its meadows in such a way that they can function as both portals and stepping stones. They thus form a wide meadow web inside the urban area of Tübingen with the aim of supporting their full ecosystem functions and of allowing animals to migrate from the countryside into the city.

The conflict of land use inside urban areas can be solved by a well-organised planning and dialogue between residents, policy makers and stakeholders.

Using true bugs as an example, the present study shows the potential that a reduction of the management intensity of even public urban grasslands has for maintaining and improving biodiversity. Natural meadows inside urban areas have almost the same positive effects as natural meadows in rural regions. They also have an important function in terms of educational issues, introducing citizens to the value of natural grassland ecosystems.

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Anschriften der Autoren:

Philipp Andreas Unterweger & Oliver Betz, Eberhard Karls Universität, Institut für Evolution und Ökologie, Evolutionsbiologie der Invertebraten, Auf der Morgenstelle 28; D-72076 TÜBINGEN, Germany

Christian Rieger, Lenbachstraße 11; D-72622 NÜRTINGEN, Germany,
e-mail: christian.rieger@kabelbw.de

Corresponding author / Kontakt: philipp.unterweger@uni-tuebingen.de