1. Introduction

European countries are dominated by agricultural landscapes. The increased farming intensity in the last decades caused a decrease of species richness due to the destruction and fragmentation of the natural habitats.

Considering the differential habitat use of arthropods only a mosaic of different habitats can provide high species richness. Therefore the natural remnants of heterogeneous grasslands and the patterns and processes taking place in these remnants have an important role in the conservation of arthropod diversity in an agricultural landscape.

Mosaic pattern of grasslands derives from changes of several environmental factors e.g. microrelief, exposure, soil moisture, soil organic carbon content. Human land use practices (grazing, moving, fertilizing, burning) also affects the rate of heterogeneity of grasslands.

Heterogeneity can influence the species richness, because a heterogeneous environment can provide various source for more species. Moreover, heterogeneity creates borders and edge-zones between different patches which can creates new patterns and processes and new properties for e.g. edge related species.

The term edge effect was introduced to describe the increase in the abundance and species diversity in the transition zone between two habitats. At present, the changes in both biotic and abiotic conditions, occurring at the transition zones between adjacent habitats, are referred to as edge effects. The edges may influence the distribution and abundance of the species, the interactions between populations, and the structure of communities.

Central and Eastern European grasslands still harbour a diverse and unique arthropod community. However, during the last decades these grasslands have also become endangered as a consequence of changes in agricultural practices. Therefore, studies of the spatial patterns and processes in these remnants are necessary to obtain information on the actual state of the fauna and the ecological communities.

True bugs represent an ecologically very divers group including both predaceous and herbivorous species with different degree of food specialization and both adults and nymphs live at the same habitat. Furthermore, the true bug diversity correlates with the total insect diversity and they respond sensitively to habitat changes. True bugs are an ideal group to study the patterns and processes in heterogeneous grasslands.

2. Aims

In my thesis I tried to answer two main questions and several sub-questions as follows:

1 Does spatial scale affect the composition of Heteroptera assemblages in heterogeneous grasslands?

1.1. Do Heteroptera assemblages of heterogeneous grasslands differ in their structure, species richness and composition between habitat and landscape scale?

1.2. Which components of control affect the structure, the species composition and diversity of true bug assemblages in heterogeneous grasslands at habitat and landscape scale?

2. How the fine scale patterns of epigeic Heteroptera assemblages change across transition zones between natural habitats?

2.1. Do spatial patterns of Heteroptera assemblages denote smooth transitions or sharp boundaries?

2.2. How the species richness and composition of epigeic true bug assemblages change across grassland–grassland and forest–grassland transitions?

2.3. Is there any correspondence between the habitat properties of grasslands and Heteroptera assemblage patterns?

3. Material and Methods

3.1. Study sites

The study sites are situated in the Kiskunság Region and all sites but one were in the territory of the Kiskunság National Park. The Kiskunság is the central part of the Danube-Tisza interfluve, which is situated at a higher elevation than the rest of the lowland, as a result, of a large Quaternary alluvial fan of the Danube, composed of sand, sandy loess and loess in restricted areas. The area lies in the warm temperate zone with an annual mean temperature between 10.2 and 10.8 °C; the mean annual precipitation is approximately 550 mm. The remnants of the various natural vegetation (e.g. open sand grasslands, fen meadows, salt marshes, juniper-poplar forests) are embedded in agricultural fields.

Kisbugac:

Kisbugac is a pasture near Bugacpusztaháza village in the Kiskunság National Park. The study plot is an approximately 2.4 hectare area and it was earlier a sandy pasture. The site was fenced in 1976 and no management (grazing or cutting) has been applied since fencing. Plant associations of the higher sand hills are *Festucetum vaginatae* and *Potentillo-Festucetum pseudovinae*, and *Brometum tectorum* in the very dry patches. The 1.5-2 m deep wind grooves are covered with *Molino-Salicetum rosmarinifoliae*. By this time, the *Molinia* swards are in a transitional state towards the dry grasslands due to the drop of the water table

Fülöpháza:

Sand dune area of Fülöpháza is a part of the Kiskunság National Park with an area of 1992 hectares. The study site consists of sand dunes and wind grooves: the average of the relative elevation difference is approximately 8 m. Plant community structure of the open habitats is mainly open perennial sand grassland (*Festucetum vaginatae*) community on the top and the upper slopes of the dunes, and dense dry *Molinia* sward (*Molinio-Salicetum rosmarinifoliae*) in the dune valleys

Kisasszonyerdő:

Kisasszonyerdő is not a reserve. The natural vegetation remnants are embedded in agricultural fields and forest plantations and consist of open sandy grasslands (*Festucetum vaginatae*) and juniper-poplar forests (*Junipero-Populetum albae*). The composition of juniper-poplar forests varies widely: some patches consist almost exclusively of juniper composing a dense scrubland, whereas juniper is missing from other patches.

Körös-ér Landscape Protected Area:

In the southern Kiskunság the natural vegetation (sand steppe, fen meadow, fen or marsh and alkali vegetation) survived in the dune slack meadows. The vegetation of these meadows is species rich, and has high natural value. Körös-ér Landscape Protected Area contains 13 remnants of dune slack meadows with a total area of 2800 hectares. Csipak-semlyék is one of the grasslands belonged to the Körös-ér Landscape Protected Area. Csipak- semlyék is situated near town Mórahalom. The area of this meadow is approximately 8.5 hectares. Csipak-semlyék contains a mosaic of sand steppe, fen, marsh, and alkali vegetation patches.

3.2. Sampling methods

As true bugs are an ecologically very divers group thereby various collecting techniques may be applied to sample Heteroptera communities. Choice of sampling methods depends on the purpose and location of the study. D-vac is an optimal technique for sampling , because it collects species from both the vegetation and ground surface. However, it is difficult to use both in the case of loose sand soil, because of the great amount of sand sucked during the collecting and in the case of dune slack meadows because of the high water level in spring and early summer. Therefore, epigeic true bugs were collected with pitfall traps, and plant-dwelling true bugs were sampled by sweep-netting.

Altogether 25 patches of 13 grasslands were studied at landscape scale in the Körös-ér Landscape Protected Area and 18 patches of Csipak-semlyék were studied at habitat scale. To sample the Heteroptera assemblages 5 x 50 sweeps were applied three times in a year in each patch.

Two transect of SW-NE direction – running from a sand-dune top through the wind groove to the adjacent sand-dune top – of pitfall traps were applied to show the effect of the grassland heteromorphy on the Heteroptera assemblages. In Kisbugac, the transect was 55 m long with an elevation of 2.8 m between the highest and lowest points of the transect. The other transect situated near Fülöpháza village and was 120 m long with a maximum elevation of 11.66 m.

The spatial pattern of epigeic true bug assemblages was studied across forest–grassland edges at forest steppe remnants in Kisasszonyerő. Two edges were investigated: a poplar forest−open sand grassland (site one) and a juniper forest−open sand grassland (site two). The abundance and variety of true bugs was sampled by pitfall traps.

3.3. Data analyses

Moving split window technique (MSW) with squared Euclidean distance and the complement of Renkonen similarity index as dissimilarity functions was used to detect discontinuities in Heteroptera assemblages and vegetation along two SW-NE running transects through wind grooves and dune-tops.

To detect the width and the position of the transition zones between the true bug assemblages of forest and grassland habitats, I computed the Chao's Jaccard and Morisita-Horn indices between the adjacent samples.

Canonical correspondence analysis (CCA) and Redundancy Analysis (RDA) were used to reveal the effects of the environmental variables and factors on true bug assemblages. Marginal and partial effects were calculated.

Permutational Multivariate Analysis of Variance (PerManova) based on Bray-Curtis dissimilarities was used to test the differences between the species composition of true bug assemblages in different habitat types.

The effects of the environmental variables and factors on the species richness of true bug assemblages were tested with generalized linear mixed models (GLMM).

Simple linear regression was used to test the influence of the distant from the forest edge on the abundance of frequent Heteroptera species.

Pearson's correlation coefficient was used to reveal the relationships between the abundance of specialist species and the density of their host plants.

Spermann's rank correlation was used to seek correspondences between the distance from the edge, the environmental variables and the specie richness of true bug assemblages.

4. Main results

4.1. Effects influenced true bug assemblages in heterogenic habitats at two spatial scales

The distribution of organisms is influenced by numerous factors and presumably the complex relationships among these factors. Two groups of components of the environmental control i.e.

the vegetation and landscape structure played an important role in shaping the distribution of Heteroptera species, structure and species composition of assemblages.

The analyses based on the data set of 67585 adult individuals of 155 species at habitat scale and 6326 adult individuals of 126 species at landscape scale.

4.1.1. Impacts of vegetation

According to the CCA the vegetation components – i.e. coverage of vegetation, plant species richness and diversity, vegetation type of a patch – had a significant influence in shaping the distribution of Heteroptera species, structure and species composition of assemblages at both habitat and landscape scales. The vegetation components had a significant joint effect, but variance partitioning revealed that only the vegetation types of patches had significant partial effect.

The vegetation types of patches influenced the species richness and diversity of true bug assemblages, too. Both habitat and landscape scales the species richness of sand steppe patches were higher than fen and marsh meadow patches.

There was little impact of vegetation properties on the species richness of true bug assemblages in the same type of vegetation patches, according to mixed models.

4.1.2. Impacts of landscape components

Contrary to the vegetation components, landscape variables – i.e. isolation, diversity of surrounding patches, area and shape of a patch – had no important role in shaping the structure and species composition of Heteroptera assemblages at habitat and landscape scales.

According to the mixed models, landscape components influenced the species richness of assemblages in the same type of vegetation patches at both two scales. Isolation, shape-index and patch area were the main components affected the species richness. However, their effects differed between the true bug assemblages of sand steppe and wet meadow patches. The species richness of true bugs in sand steppe patches decreased with increasing isolation and shape-index and increased with increasing patch area. Sand steppe patches seemed to be terrestrial habitat-islands, in the matrix of fen and marsh meadow patches.

Differences in the effects of both vegetation and landscape components between scales were observed, however the differences in their effects were more relevant between the various types of patches.

4.2. Patterns of epigeic Heteroptera assemblages across transition zones

4.2.1. Transitions between grassland habitats

The analyses based on the data set of 911 adult individuals of 41 species collected in Kisbugac and 1584 adult individuals of 54 species in Fülöpháza.

According to both MSW and ordination techniques distinct true bug assemblages were found at the top of the sand dune, South-facing sand-dune slope, the wind groove and the North-facing slope in Fülöpháza. However, consequent species composition was found only in the samples of sand-dune habitats in Kisbugac. In the wind groove habitat a distinct true bug assemblage was not observed. The indicator species analyses showed which the characteristic species of the different assemblages were.

Results of CCA revealed that microrelief and vegetation properties had a significant joint effect on true bug assemblages.

Abrupt changes of assemblage structure were mostly detected between different habitat types. However, between the assemblages of South-facing sand-dune slope and the wind groove smooth transitions were observed. The transition zone was characterised by high species turnover in Fülöpháza, but in Kisbugac it was characterised by the dissolution of the sand-dune assemblage and high species turnover was not observed, because of the lack of a distinct wind groove assemblage. The lack of the distinct assemblage was presumably due to the relatively small size of wind groove. However, bug assemblage in wind grooves depended stronger on climatic conditions then the bug assemblage at dune tops and a dry period could cause a decline in species richness and abundance in wind grooves. The long-term dry period observed in the Kiskunság may cause intrinsic changes in assemblage structure of true bugs in this manner, but further studies are needed to reveal the real impact of the dry period.

In Fülöpháza there was strong relationship between the microrelief, vegetation and Heteroptera patterns. We did not find clear congruence between the patterns of vegetation and true bugs along the transect in Kisbugac, contrarily to Fülöpháza. However, the abundance of numerous species correlated with the density of their host plants along both two transects.

4.2.2. Transitions between grassland and forest habitats

Altogether 1396 adult individuals belonging to 49 species were collected with pitfall traps.. Some species occurred exclusively at forest habitats however, distinct Heteroptera assemblages were found only at grasslands.

The response of the grassland Heteroptera assemblages to the proximity of the edge differed between the two sites. At site one, an approximately seven-meter wide transition zone could be observed from the grassland into the forest, which was characterized by the dissolution of the grassland true bug assemblage. The species richness decreased significantly toward the edge. At site two, an abrupt change in the structure of the Heteroptera assemblage denoted a sharp boundary near to the edge in the juniper forest. The species richness did not change toward the juniper edge.

According to the RDA and rank correlation methods, the cover of dicotyledonous plants, mosses and lichens, bare soil surface and leaf litter had a significant joint effect on the species richness and composition of true bug assemblages.

The characteristic species of the grasslands responded differently to the edges. Specialist herbivorous bugs seemed to be affected more strongly and negatively by edges than generalist herbivorous and predaceous species.

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