ORTHOPTERAN ASSEMBLAGES IN EARLY SUCCESSION STAGES OF CLEAR–CUTS AND GRASSLANDS IN FRAGMENTED BEECH FORESTS

Anna Sliacka & Anton Krištín

Institute of Forest Ecology, Slovak Academy of Sciences, Štúrova 2, SK–960 53 Zvolen, Slovakia [asliacka@savzv.sk; kristin@savzv.sk]

Abstract: Fragmented forest landscape is composed from a variety of habitats influenced by succession. Deforested plots, showing distinct differences from the surrounding forests, were colonised by heliophilous insects, such as orthopterans. We studied the structure of Orthoptera assemblages in four clear–cuts and in four forest grassland habitats in two mountains of Central Slovakia. The Orthoptera were recorded by the sweeping method at monthly intervals in May – October 2010. Our research aims were to find out i) which species were able to colonise new–established deforested plots in deciduous forests dominated by beech, ii) differences in Orthoptera assemblage structure between the clear–cuts and grasslands (assumed main source habitats for clear–cut colonisation). Altogether 27 Orthoptera species were recorded in the one– and two–year–old clear–cuts, while only 21 in the grasslands. In the clear–cuts was evident dominance of Caelifera, while in the grasslands, the proportions of Ensifera and Caelifera were nearly the same. There were distinct differences in the species composition, abundance and frequency in Orthoptera assemblages structure between the grasslands and clear–cuts. Just 90.5% of the grassland species were also recorded in the clear–cuts, while only 70.4% species from the clear–cuts we also found in the grasslands. The clear–cuts were colonised by several grassland species and species of bare ground. The species composition of clear–cuts and grasslands varied among the localities, probably due to different clear–cut age, microclimate and vegetation structure in the two habitats.

Key words: Ensifera, Caelifera, deforestation, heliophilous insects, central Europe.

INTRODUCTION

Dispersional patterns of orthopterans in forest complexes and also in fragmented forest landscape with small patches of grasslands, is facilitated by the presence of ecotones, corridors and scattered shrub and tree greenery (Guido & Gianelle 2001; Deans et al. 2005). The number of Orthoptera species generally increases with the size of forest meadows and clear–cuts (Krištín & Hrúz 2005; Theuerkauf & Rouys 2006). However, also small meadows and pastures can provide appropriate amounts of food and favourable conditions promoting the reproduction of heliophilous orthopteran species (Marini et al. 2008; Fabriciusová et al. 2011). On the other hand, big forest grasslands are often exposed to disturbances such as mowing and grazing (Báldi & Kisbenedek 1999).

In case when the grasslands adjacent to forests are managed in an extensive way, the local orthopterans recede in refuges in the forest ecotones. The succession of forest vegetation at margins of forest grasslands acts, up to the certain moment, positively on the species composition in Orthoptera (Marini et al. 2009a, b; Fabriciusová et al. 2011;

Sliacka A & Krištín A, 2012: Orthopteran assemblages in early succession stages of clear–cuts and grasslands in fragmented beech forests. *Folia faunistica Slovaca*, 17 (4): 361–367.
Received 9 August 2012 ~ Accepted 24 October 2012 ~ Published 16 December 2012

 ISSN 1336–4529 (online) ISSN 1335–7522 (print)

Fartmann et al. 2012). Encroaching of forest meadows with woody plants has reducing effect on the size of permanent grasslands and may even lead to extinction of small forest meadows serving as important refuges for rare species (Gavlas 2003; Krištín & Hrúz 2005). Deforested plots created by forest disturbances in mixed (Laussmann 1993; Dalbeck 2011) and coniferous forests (Bergmann & Chaplin 1992; Clayton 2002; Jenni et al. 2007) were colonised by heliophilous Orthoptera. Little is known about habitat–associated (clear–cuts, grasslands) differences in the orthopteran assemblages in fragmented deciduous forests.

In this study we investigated: i) which species are able to colonise deforested plots in deciduous forests with dominant beech; ii) whether there are differences in the structure of Orthoptera assemblages between clear–cuts and grasslands in fragmented beech forests.

We assumed: a) less species in the clear–cuts (aged 1–2 years) than in the grasslands (expected main source habitats for clear–cuts colonisation); b) Ensifera more abundant in the deforested areas than in the grasslands; c) similar species phenology (seasonality in occurrence) in the clear–cuts and the grasslands.

MATERIAL AND METHODS

The study plots were situated in deciduous forests with dominance of beech (> 70%) in the Kremnické vrchy Mts and the Javorie Mts (Western Carpathians, Central Slovakia). In each mountain region, there were established two west–facing research plots in clear–cuts (aged 1–2 years) and two in grasslands, as the potential main source habitats for colonisation of the clear–cuts. The clear–cuts were in the direct contact with forest roads, and at the same time, isolated with min. 50 m wide forest from the surrounding grassland and open habitats. The clear–cut pairs (in each locality) exhibited only minimal differences in their abiotic characteristics (age, size, aspect, altitude). Each grassland pair in each mountain unit was situated in one valley, to guarantee similar vegetation structure and abiotic characteristics (Fig. 1).

The clear–cuts in the Kremnické vrchy Mts (48° 38’ 19” N; 19° 4’ 3” E; CC1, CC2; 486–541 m a. s. l.; 8,580 m^2 and 9,174 m^2; Fig. 1) were created by cutting in April – May 2009 applied in a 100–year–old beech ecosystem with admixed *Abies alba*. In September 2010, the plot was grown with natural regeneration (*Fagus sylvatica*, *Carpinus betulus*, *Tilia* spp., with an average height of 45 cm) covering 50–70% of the area of the two clear–cuts. Herbs and grasses (15–40 cm) covered 10–30%. The rests were bare soil plots or low vegetation under 10 cm (5–20%). In August, the vegetation reached (e.g. species of the genus *Cirsium* spp.) a maximum height of 130–170 cm.

The grasslands (GR1 and GR2; 328–362 m a. s. l.; each 10,000 m^2; Fig. 1) were at one side adjacent to the forest. The plot GR1 was primarily characterised with the species *Thymus vulgaris*, *Argimonia eupatoria*, *Vicia cracca*, *Dianthus carthusianorum, Euphorbia cyparissias*, *Achillea millefolium, Hypericum perforatum, Fragaria* spp., *Potentilla erecta*, *Trifolium medium*, *Galium verum*, *Trifolium arvense*, *Clinopodium vulgare*, *Knautia arvensis*, *Centaurea scabiosa*, *Lotus corniculatus*, *Carex hirta*, *Festuca rubra*, *Anthericum ramosum.* From the shrubs, typical was the presence of *Juniperus communis*, *Rosa canina*, *Prunus spinosa.*

The vegetation on plot GR2 mainly consisted of the species *Galium verum*, *Clinopodium vulgare*, *Argimonia eupatoria*, *Euphorbia cyparissias*, *Potentila* spp., *Plantago major*, *Cichorium intybus*, *Plantago lanceolata*, *Fragaria* spp., *Thymus vulgaris*, *Knautia arvensis*, *Daucus carota*, *Ononis spinosa*, *Centaurea phrygia*, *Achillea millefolium*, *Polygala vulgaris*, *Allium oleraceum*, *Vicia cracca*, *Cirsium arvense*, *Calamagrostis epigeios*, *Alopecurus pratensis*, *Brachypodium pinnatum*, *Agrostis capillaris*, *Carex hirta*, *Dactylis glomerata*, *Convolvulus arvensis*, *Arrhenatherum elatior*, *Trisetum flavescens.* The plot edge was created by a stand of *Pinus sylvestris*. The height of vegetation on GR1 and GR2 was max 60 cm, as the stands were grazed by cattle and mowed once a year. The meadows were situated 2400–2900 m southeast from the studied clear–cuts (Fig. 1).

The clear–cuts in the Javorie Mts were created by deforestation in January – February 2010 (48° 31’ 38” N; 19° 15’ 48” E; CC3–CC4; 459–520 m a. s. l.; 13,188 m^2 and 11,149 m^2; Fig. 1). The original forest consisted of *Fagus sylvatica* (75%), *Quercus* spp./ *Carpinus betulus* oak/hornbeam (25%) without

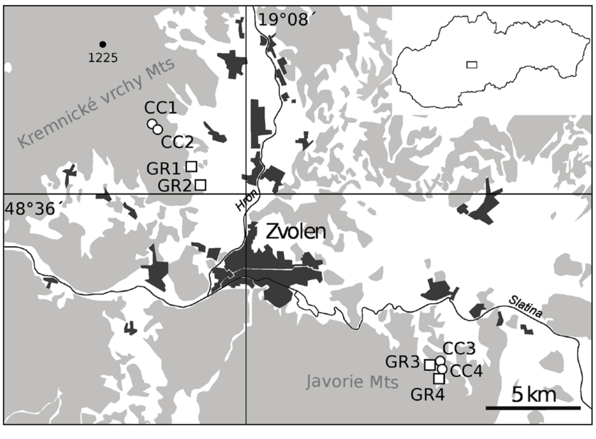

Figure 1. Position of four clear–cuts (CC1–CC4) and four grasslands (GR1–GR4) in beech forests in two mountains in Central Slovakia – the Kremnické vrchy Mts (1, 2); the Javorie Mts (3, 4); forest plots (grey); open plots (white); settlements (black).

developed herb understorey. The regeneration (oak/hornbeam/beech) tall on average 50 cm covered 30–50% of the clear–cut area. Herbs and grasses tall 15–150 cm were present on 20–40% of the area. The areas without vegetation cover and with vegetation lower than 10 cm made 10–50%.

The grasslands of a large forest meadow (ca 3 ha; western part of the meadow GR3, valley, eastern part of the meadow GR4; 478–497 m a. s. l.; ca 20,000 and 30,000 m^2; Fig. 1) in oak–hornbeam forests were managed by mowing (July 2010). The meadows were situated west from clear–cuts and there were isolated with a wide (80–200 m) forest stand. In the year 2010, these meadows were rather flooded, due to very high precipitation amount. For these two grasslands were characteristic the species *Sanguisorba minor*, *Hypericum perforatum*, *Euphorbia cyparissias*, *Galium verum*, *Calamagrostis epigejos*, *Centaurea phrygia*, *Mentha* spp., *Prunella vulgaris*, *Lysimachia vulgaris*, *Alopecurus pratensis*, *Agrostis capillaris*, *Daucus carota*, *Helictotrichon pubescens*, *Juncus effusus*, *Potentilla erecta*, *Alopecurus* spp., *Carex* spp., *Dianthus carthusianorum*, *Achillea millefolium, Luzula campestris*, *Lotus corniculatus*, *Cruciata glabra*, *Lysimachia nummularia*, *Leontodon hispidus*, *Trifolium medium*, *Campanula patula*, *Holcus lanatus.*

Orthoptera were collected (and released) at one–month intervals in May – October 2010 (always towards the end of month), by sweeping throughout vegetation (Gardinger et al. 2005). We used (250 sweepings/plot/visit) a sweeping net with a solid protective frame, circle–shaped, 35 cm diameter. The sweeping line was driven across a wide spectrum of microhabitats, representative for each clear–cut and grasslands: grasses, herbs, *Rubus* spp., shrubs (natural regeneration of clear–cuts, grassland ecotones) and bare soil in clear–cuts. We registered all captured individuals, and individuals identified visually and acoustically under the sweeping net.

During the season 2010, on all eight plots, we caught altogether 2,497 orthopterans, from which we identified 2,177 individuals belonging to 29 species (Table 1). The Orthoptera were identified and classified according to Kočárek et al. (2005). Not identified individuals were young nymphs of the genus *Tettigonia* (2), *Tetrix* (131) and nymphs Acrididae, especially the genus *Chorthippus* (187).

We evaluated the following parameters: the numbers of Orthoptera, Ensifera and Caelifera species, total abundance from six collections, relative frequency of the species on four grasslands and four clear–cuts (Fig. 2), seasonal variations in the species number in all clear–cuts and in all grasslands (mean ± SD; Fig. 3).

RESULTS

The total Orthoptera species number recorded in clear–cuts and grasslands in fragmented beech forests during one year was 29 (14 Ensifera, 15 Caelifera). In the clear–cuts were found 27 Orthoptera species (12 Ensifera, 15 Caelifera), in the grasslands 21 (11 Ensifera, 10 Caelifera). On the clear–cuts dominated Caelifera species, in the grasslands with dispersed shrub vegetation the proportions of Ensifera and Caelifera were very similar.

The Orthoptera species composition showed differences among the habitats (Table 1). In the clear–cuts, there occurred eight species not recorded in the grasslands (*Meconema thalassinum*, *Pholidoptera aptera, Platycleis grisea*, *Tetrix undulata*, *Chorthippus albomarginatus* – 1 individual, *Chorthippus vagans*, *Calliptamus italicus* and *Oedipoda caerulescens*). In the clear–cuts, there occurred additional grassland species characteristic also for the studied grass stands, such as *Metrioptera roeselii*, *Gryllus campestris*, *Euthystira brachyptera*, *C. albomarginatus*, *Chorthippus apricarius*, *Chorthippus dorsatus*, *Chorthippus parallelus*, *Chrysochraon dispar*, *Stenobothrus lineatus*. The species we have recorded altogether in the clear–cuts represented 90.5% of the species recorded in the grasslands. In the clear–cuts in the Kremnické vrchy Mts (CC1, CC2) we recorded 25 species from which eight were absent in the clear–cuts in the Javorie Mts (CC3, CC4; Table 1). In the clear–cuts in Javorie we observed 19 species with two (*Tettigonia viridissima*, *M. roeselii*) lacking in the clear–cuts in the Kremnické vrchy Mts (Table 1).

In the grasslands we found only 70.4% of the species found also in the clear–cuts. The species *Leptophyes albovittata* and *Metrioptera bicolor* were recorded only in the grasslands (Table 1). In the grasslands in the Kremnické vrchy Mts we recorded 21 species, in the Javorie Mts 16 species. The species *L. albovittata*, *M. bicolor*, *Tetrix subulata*, *Tetrix tenuicornis* and *Chorthippus apricarius* found in the grasslands in the Kremnické vrchy Mts were not recorded in the wet grasslands in the Javorie Mts.

The most abundant species in the clear–cuts (more abundant than in grasslands) were *P. griseoaptera*, *Tetrix tenuicornis*, *C. italicus*, *O. caerulescens*, *B. constrictus*, *T. cantans* (Table 1). In the grasslands we recorded higher abundance than on clear–cuts in the species *E. brachyptera*, *S. lineatus*, *C. apricarius*, *L. albovittata*, *C. parallelus*, *M. roeselii*, *C. dorsatus*, *Phaneroptera falcata*, *Decticus verrucivorus*, *M. bicolor*, *Isophya camptoxypha*, *T. viridissima* (Table 1).

On all four clear–cuts (100% frequency), we recorded ten Orthoptera species: four Ensifera (*B. constrictus*, *P. griseoaptera*, *T. cantans*, *M. thalassinum*) and six Caelifera (*E. brachyptera*, *C. biguttulus*, *C. brunneus*, *T. subulata*, *T. tenuicornis*, *T. undulata*; Fig. 2).

Table 1. Species composition and absolute abundance of Orthoptera in four clear–cuts and four grasslands in fragmented forest landscape in two mountains in Central Slovakia (Kremnické vrchy Mts CC1–2, GR1–2 and Javorie Mts CC3–4, GR3–4).

species	sp. abbrev.	clear–cuts				grasslands			
		CC1	CC2	CC3	CC4	GR1	GR2	GR3	GR4
Ensifera									
Tettigoniidae									
Barbitistes constrictus Br. v. Wattenwyl, 1878	Bcon	2	1	1	14	4			1
Isophya camptoxypha (Fieber, 1853)	Icam	2	1			10	12	1	
Leptophyes albovittata (Kollar, 1833)	Lalb					24	42		
Phaneroptera falcata (Poda, 1761)	Pfal		1	5	1	12	23	1	
Meconema thalassinum (Degeer, 1773)	Mtha	1	1	3	2				
Decticus verrucivorus (Linnaeus, 1958)	Dver	12	6	2		5	10	3	13
Metrioptera bicolor (Philippi, 1830)	Mbic					21	6		
Metrioptera roeselii (Hagenbach, 1822)	Mroe				1	9	8	16	14
Pholidoptera aptera Mařan, 1953	Papt	2							
Pholidoptera griseoaptera (Degeer, 1773)	Pgri	67	90	272	243	4	3	2	3
Platycleis grisea (Fabricius, 1781)	Plgr		2	3	7				
Tettigonia cantans (Fussli, 1775)	Tcan	8	8	6	7		2	2	1
Tettigonia viridissima Linnaeus, 1758	Tvir			2		2	5	2	2
Grylloidea									
Gryllidae									
Gryllus campestris Linnaeus, 1758	Gcam		1	8			2	8	3
Caelifera									
Tetrigidae									
Tetrix subulata (Linnaeus, 1758)	Tsub	8	3	9	12	5	4		
Tetrix undulata (Sowerby, 1806)	Tund	6	7	1	6				
Tetrix tenuicornis Sahlberg, 1893	Tten	15	25	20	4		4		
Acrididae									
Calliptamus italicus (Linnaeus, 1758)	Cita	44	50						
Oedipoda caerulescens (Linnaeus, 1758)	Ocae		52						
Euthystira brachyptera (Ocskay, 1826)	Ebra	5	29	8	3	92	118	67	39
Chorthippus albomarginatus (Degeer, 1773)	Calb		1						
Chorthippus apricarius (Linnaeus, 1758)	Capr	7				30	38		
Chorthippus biguttulus (Linnaeus, 1758)	Cbig	6	20	4	7	8	6	2	8
Chorthippus brunneus (Thunberg, 1815)	Cbru	9	20	19	5	6	4	1	3
Chorthippus dorsatus (Zetterstedt, 1821)	Cdor		2			10	18	5	10
Chorthippus parallelus (Zetterstedt, 1821)	Cpar	1	21			29	21	10	4
Chorthippus vagans (Eversmann, 1848)	Cvag	2	4		4				
Chrysochraon dispar (Germar, 1834)	Cdis		6	2		1		5	4
Stenobothrus lineatus (Panzer, 1796)	Slin		3	6	1	49	60	1	
Total number of orthopteran species		16	22	16	14	17	19	15	11
Ensifera (species number)		7	9	9	7	9	10	8	7
Caelifera (species number)		9	13	7	7	8	9	7	4
Total number of individuals (Orthoptera)		197	354	371	317	321	386	126	105

In all four grasslands (100% frequency) we found nine orthopteran species, from which four were Ensifera (*P. griseoaptera*, *D. verrucivorus*, *M. roeselii*, *T. viridissima)* and five Caelifera (*E. brachyptera*, *C. biguttulus*, *C. brunneus*, *C. apricarius*, *C. dorsatus*; Fig. 2).

The highest number of the species per clear–cut (9–18 / clear–cut; Fig. 3) in regular monthly captures was recorded in September. In the grasslands, we did not record significant increase in the species number, probably due to unidentifiable time–dependent changes to the vegetation structure caused by mowing and grazing (Fig. 3). The species composition in the grasslands and clear–cuts displayed seasonal–dependent variations. In May – July, the most probable to catch were early spring species represented e.g. by Ensifera species (*Isophya* spp., *B. constrictus*). In August – October, these species were rare, dominated by *D. verrucivorus*, *P. falcata*, *T. cantans*, *T. viridissima*, *C. italicus*, *C. brunneus*, *C. vagans*, *O. caerulescens*.

DISCUSSION

Fragmented forest landscape with a wide range of habitats (grasslands, ecotones, clearings, clear–cuts, young stands, forest roads and corridors) provides favourable conditions for a wide variety of Orthoptera species with different ecological demands (Nagy & Rácz 1996; Kati et al. 2003; Krištín & Hrúz 2005).

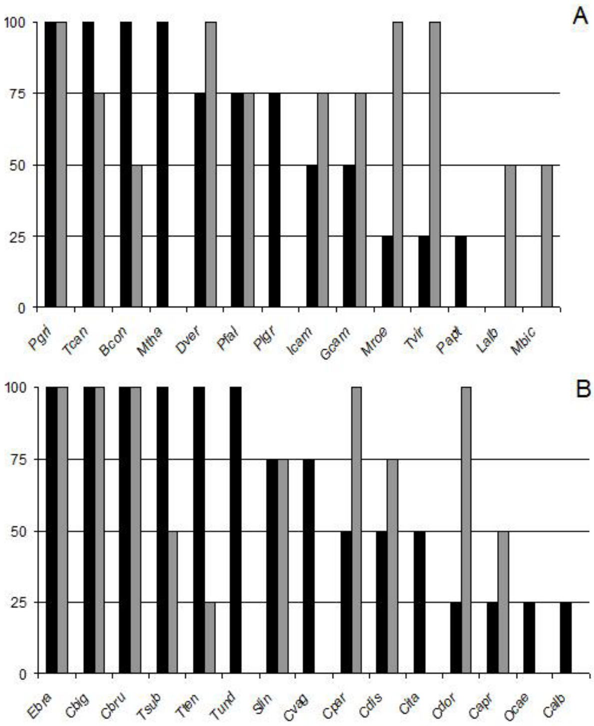

Figure 2. Frequency (%) of 29 orthopteran species in four clear–cuts (black) and in four grasslands (grey) in fragmented forest landscape (A: Ensifera; B: Caelifera). For the species abbreviations see Table 1.

In our study we compared the species composition of Orthoptera assemblages between two specific habitats in fragmented forest landscape with dominant beech. We found less Orthoptera species in grasslands than in clear–cuts, which is in accordance with findings of Dalbeck (2011) on forest stands damaged by beaver and grasslands. Contrarily, Laussmann (1993) recorded more species in grasslands (11) than in clear–cuts in mixed forests (9). Similarly, Jenni et al. (2007) found more species in grasslands and ruderal stands than in shrub and tree vegetation in burnt as well as unburnt plots.

We recorded more Orthoptera species in marginal parts of grasslands with shrub vegetation and in ecotones, in accordance with Marini et al. (2009 a,b), Fabriciusová et al. (2011), Fartmann et al. (2012). In the clear–cuts were dominant Caelifera, while in the grasslands the species proportions of Ensifera and Caelifera were very similar. Lower species number recorded in the grasslands was probably caused by changes to vegetation patterns (Ingrisch & Köhler 1998; Guido & Gianelle 2001; Picaud & Petid 2007), microclimate (Schmidt & Schlagbauer 1965), excessive rainfall and flooding of the habitats in the study year (Brust et al. 2007).

Some of the species occurring in the grasslands, e.g. *L. albovittata*, *M. roeselii*, *M. bicolor* did not colonise the clear–cuts, probably due to the badly fitting vegetation structure, which is in accordance with findings of Dalbeck (2011) in the forest damaged by beaver. For the clear–cuts were characteristic considerably fragmented microhabitats, often featuring a strong ecotonal character, which provided suitable conditions for the species preferring ecotones (Detzel 1998; Krištín & Hrúz 2005; Vadkerti & Szövényi 2005). The high proportion of shrubby vegetation and natural regeneration had positive influence especially on Ensifera species, several of them associated with shrubs and trees (Detzel 1998; Ingrisch & Köhler 1998).

The microclimate and shrubs in clear–cuts provided suitable conditions for the species *P. griseoaptera*,

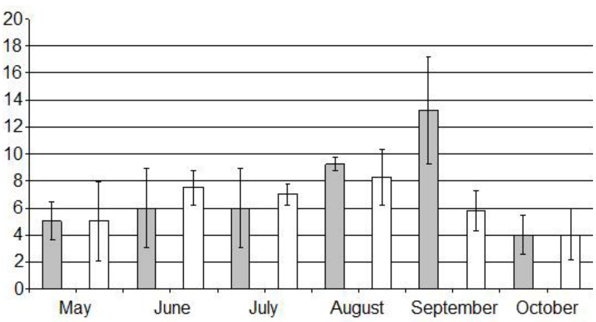

Figure 3. Seasonal variations in Orthoptera species number (mean ± SD) in four clear–cuts (grey) and four grasslands (white) in fragmented forest landscape.

exhibiting in our study significantly higher abundance from all the species in all clear–cuts. On the clear–cuts with a high proportion of natural regeneration we recorded more Caelifera species than in grasslands, which we may explain by drier character of clear–cuts and higher proportion of bare ground in them. Contrarily, Marini et al. (2009a) recorded the grasshopper (Caelifera) species numbers in grassland habitats decreasing with developing succession of woody plants.

On the clear–cuts we found characteristic species *C. brunneus*, *C. vagans*, similar as did Laussmann (1993), Jenni et al. (2007), Hochkirch et al. (2008). Similar as Detzel (1998), in the clear–cuts we recorded such species as *T. subulata*, *T. undulata* and *T. tenuicornis*, less grassland species as *E. brachyptera*, *C. dispar*, *C. parallelus*, *C. biguttulus.* Only in the clear–cuts (surprisingly, not in grasslands) we recorded species of erosion plots such as *C. italicus* and *O. caerulescens*, in accordance with Jenni et al. (2007). These species probably originated in some of not checked open habitats in the surroundings.

The seasonal occurrence of Orthoptera species varied in accordance with the species development (Detzel 1998). We have found that for recording all the Orthoptera species in the clear–cuts, there were necessary two collections in the turn of June/July and August/September. For example, in June we recorded the species *B. constrictus*, *I. camptoxypha* which are rare in August – October. On the other hand, in June most of the species of the genera *Tettigonia*, *Phaneroptera*, *Chorthippus* were caught in nymphal stages, equally as the species *C. italicus* and *O. caerulescens*, with the adults recorded in July/September.

The low number of the species recorded in the grasslands in May was probably caused by the high precipitation amount in April – May and subsequent grasslands flooding (e.g. Brust et al. 2007); and by the changes to the vegetation structure by mowing in July (Guido & Gianelle 2001; Fabriciusová et al. 2011).

Our study puts forward some interesting findings. In the one– and two–year–old clear–cuts we recorded more orthopteran species (27) than in the surrounding meadows (21). So we suppose than in the first two years of succession, the pioneer habitats of clear–cuts are colonised very quickly from the various surrounding habitats and homogeneous meadows were only one of potential source habitats. Consequently, the future research should focus on mapping and data collection from all potential source habitats at distance up to 300, or 500 m, based on the knowledge of mobility of the recorded species (e.g. Burrows & Morris 2003). In the clear–cuts were dominant Caelifera. In the grasslands, the proportions of Ensifera and Caelifera were very similar, probably due to the presence of dispersed shrub and tree vegetation. The clear–cuts were colonised by several grassland species and species of habitats with bare ground. In addition, the Orthoptera assemblage structure exhibited considerable differences in the species abundance and frequency between the clear–cuts and grasslands.

ACKNOWLEDGEMENT

The authors acknowledge P. Tuček and M. Mikuš for their assistance in the field, L. Naďo for ilustration and to colleagues B. Schieber, J. Kukla, M. Kuklová for help with identification of plants. D. Kudelová is acknowledged for help with English translation. This research was subsided from the projects VEGA 2/0157/11, VEGA 2/110/09, APVV 0497–10.

REFERENCES

Báldi A & Kisbenedek T, 1997: Orthopteran assemblages as indicators of grassland naturalness in Hungary. *Agric. Ecosyst. Environ.*, 66: 121–129.

Bergmann DJ & Chaplin SJ, 1992: Correlates of species composition of grasshopper (Orthoptera: Acrididae) communities on Ozark cedar glades. *The Southwestern Naturalist*, 37: 362–371.

Brust ML, Hoback WW & Wright RJ, 2007: Immersion tolerance in rangeland grasshoppers (Orthoptera: Acrididae). *J. Orthoptera Res.*, 16 (2): 135–138.

Burrows M & Morris O, 2003: Jumping and kicking in bush crickets. *J. Exp. Biol.*, 206: 1035–1049.

Clayton JC, 2002: The effects of clearcutting and wildfire on grasshoppers and crickets (Orthoptera) in an intermountain forest ecosystem. *J. Orthoptera Res.*, 11: 163–167.

Dalbeck L, 2011: Biberlichtungen als Lebensraum für Heuschrecken in Wäldern der Eifel. *Articulata*, 26: 97–108.

Deans AM, Malcolm JR, Smith SM & Bellocq MI, 2005: Edge effects and the responses of aerial insect assemblages to structural–retention harvesting in Canadian boreal peatland forests. *Forest Ecol. Manag.*, 204: 249–266.

Detzel P, 1998: Die Heuschrecken Baden–Württembergs. *Stutgart*, *Ulmer*, 580 pp.

Fabriciusová V, Kaňuch P & Krištín A, 2011: Response of Orthoptera assemblages to management of montane grasslands in the Western Carpathians. *Biologia*, 66: 1127–1133.

Fartmann T, Krämer B, Stelzner F & Poniatowski D, 2012: Orthoptera as ecological indicators for succession in steppe grassland. *Ecol. Indic.*, 20: 337–344.

Gardiner T, Hill J & Chesmore D, 2005: Review of the methods frequently used to estimate the abundance of Orthoptera in grassland ecosystems. *J. Insect Conser.*, 9: 151–173.

Gavlas V, 2003: Rovnokrídlovce (Ensifera, Caelifera) a modlivky (Mantodea) rôzne využívaných nelesných biotopov. *Vedecké štúdie 6/A, TU Zvolen*, 131 pp.

Guido M & Gianelle D, 2001: Distribution patterns of four Orthoptera species in relation to microhabitat heterogeneity in an ecotonal area. *Acta. Oecol*., 22: 175–185.

Hochkirch A, Gärtner AC & Brandt T, 2008: Effects of forest–dune ecotone management on the endangered heath grasshopper, *Chorthippus vagans* (Orthoptera: Acrididae). *B. Entomol. Res*., 98: 449–456.

Ingrisch S & Köhler G, 1998: Die Heuschrecken Mitteleuropas. *Westarp Wissenschaften, Magdeburg*, 460 pp.

Jenni S, Walter T, Moretti M, Jeanneret P, Obrist MK & Duelli P, 2007: Auswirkungen von Feuer, Meereshöhe und Vegetation auf die Heuschreckenfauna im Waldbrandgebiet oberhalb Leuk im Wallis. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft*, 80: 253–269.

Kati V, Dufrêne M, Legakis A, Grill A & Lebrun P, 2003: Conservation management for Orthoptera in the Dadia reserve, Greece. *Biol. Conserv*., 115: 33–44.

Kočárek P, Holuša J & Vidlička Ľ, 2005: Blattaria, Mantodea, Orthoptera & Dermaptera of the Czech and Slovak Republics. *Karoubek, s.r.o. Zlín*, 349 pp.

Krištín A & Hrúz V (eds.) 2005: Rovnokrídlovce (Orthoptera) a modlivky (Mantodea) Poľany: ekológia, rozšírenie a ochrana. *ŠOP SR, Správa CHKO – BR Poľana & Ústav ekológie lesa SAV, Zvolen*, 77 pp.

Laussmann H, 1993: Die Besiedlung neu entstandener Windwurflächen durch Heuschrecken. *Articulata*, 8: 53–59.

Marini L, Fontana P, Scotton M & Klimek S, 2008: Vascular plant and Orthoptera diversity in relation to grassland management and landscape composition in the European Alps. *J. Appl. Ecol*., 45: 361–370.

Marini L, Fontana P, Battisti A & Gaston KJ, 2009a: Response of orthopteran diversity to abandonment of semi–natural meadows. *Agric. Ecosyst. Environ.*, 132: 232–236.

Marini L, Fontana P, Battisti A & Gaston KJ, 2009b: Agricultural management, vegetation traits and landscape drive orthopteran and butterfly diversity in a grassland–forest mosaic: a multi–scale approach. *Insect Conserv. Diver*., 2: 213–220.

Nagy B & Rácz I, 1996: Orthopteroid Insect in the Bükk Mountain. *The Fauna of the Bükk National Park*, 95–123.

Picaud F & Petit DP, 2007: Primary succession of Orthoptera on mine tailings: role of vegetation. *Annales de la Société entomologique de France*, 43: 69–79.

Schmidt GH & Schlagbauer A, 1965: Die Orthopteren–Fauna und Pflanzengesellschaften der Kahlschläge des Arbergebietes im Bayerischen Wald, mit einem Beitrag zum Problem der Makropterie. *Zoomorphology*, 54: 643–668.

Theuerkauf J & Rouys S, 2006: Do Orthoptera need human land use in Central Europe? The role of habitat patch size and linear corridors in the Bialowieza Forest, Poland. *Biodivers. Conserv*., 15: 1497–1508.

Vadkerti E & Szövényi G, 2005: Habitat preference of four protected bush–cricket species (Orthoptera, Phaneropteridae, Isophya) in South Hungary. *Biologia*, 60 (5): 545–549.