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ECOLOGY OF DIPLURANS (DIPLURA) IN XEROTHERMOPHILOUS OAK WOOD ECOSYSTEMS (SW SLOVAKIA)

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Abstract: This paper refers to the research on diplurans (Diplura) in the area of Martinský les wood which is a rare isolated refuge of natural oak wood stands (*Aceri tatarici-Quercetum* Zólyomi, 1957) being situated in lowland close to the town Senec in SW Slovakia. Periodical random soil samples were taken from 3 various sites in one locality during the vegetation period 2004 and 2005 at three week intervals. Totally 91 specimens of diplurans were collected. The diversity recorded in the locality has included 2 dipluran species (*Campodea plusiochaeta* Silvestri, 1912; *Campodea augen* Silvestri, 1912). The RDA analysis shows that *Campodea plusiochaeta* prefers a natural stand to a monoculture or initial stages of succession. On the contrary *Campodea augens* appears as indifferent to the variables tested, it is supposed to be classified as an euryvalent species.
Keywords: Diplura, oak woods, diversity

INTRODUCTION

In fact there haven't been many papers published on diplurans in Slovakia yet, however rather sporadic data have brought knowledge on six species found in Slovakia (Paclt, 1956a). Furthermore diplurans were mostly recorded only as fellow species in research on other Apterygota in area of Žitný ostrov (Paclt, 1956b, 1959), in Orava (Paclt, 1962), in Nízke Tatry Mts. (Nosek, 1967) or in Malé Karpaty Mts. (Nosek, 1986). The determination key on diplurans with their distribution in former Czechoslovakia was elaborated by Rusek (1964). However since that time some new species have been already recorded in Slovakia (Rusek, 1966). Morphology, anatomy and partially systematics of diplurans from former Czechoslovakia were summarized by Obenberger (1955), Kratochvíl (1959) and Nosek (1984). The most recent research paper from Slovakia dealing with diplurans comes from Devínska kobyla hill in Malé Karpaty Mts. (Majzlan et Kisková, 1994). From the recent research works in the neighbouring countries it is necessary to mention a long-term study on primary succession of dipluran communities on deposits of the former chemical factory in the area of Karviná, the Czech Republic (Rusek, 2005). By this time there are only 16 species of diplurans known from Slovakia (Rusek, 1964, 1966).

From this point of view we particularly emphasize research on diplurans in conservatory areas, as it may underline their ecological value.

MATERIAL AND METHODS

Periodical random soil samples were taken by standard quadrate-method by the metal square (10 cm high and with size of 25 x 25 cm = 1/16 m^2) (Balogh, 1958) from 3 various sites in one locality during the vegetation periods 2004 and 2005 at three week intervals. Total number of samples per site was 16. The material was extracted from the soil samples by a standard method in Tullgren funnels (Figure 1) for 5 days without previous sieving to avoid damage to very fragile diplurans. The whole extracted material of invertebrates was preserved in 96% ethyl alcohol and the obtained diplurans were mounted for identification on permanent

Figure 1. Tulgren funnels applied for extraction (Photo M. Dubovský, 2004)

slides to the Swan medium. Determination refers to the keys by Rusek (1964) and Kratochvíl (1959).

(Di)similarity among the study sites as well as sampling seasons were analysed using the test of independence (chi-square test with Yates correction and Fisher's exact test) performed by Statgraphics software (Manugistic, 1993) being based on quantitative and qualitative variables of the taxocoenoses evaluated. Redundancy analysis (RDA) ordination technique was applied for testing the significance of environmental variables including study sites and years of sampling by Canoco for Windows 4.0 (Ter Braak, 1988). Effects of environmental variables on adult Diplura were evaluated by the Monte Carlo permutation test where the gradient variables have included: thickness of soil surface horizon of mixed organo-mineral (Ao horizon), age of the forest stands, % cover of forest ground layer (E1), % cover of understory trees and shrubs layer E2, % cover of canopy layer (E3), pH of soil measured in H_2O (pH H_2O), pH of soil measured in KCl (pH KCl), the total CO and CO_2 content in the soil (% CO_x), the total mould content in the soil (% mould) , the total nitrogen content in the soil (% N_{tot}).

STUDY AREA

The research refers to the area of Martinský les which is a rare isolated refuge of natural oak wood stands (*Aceri tatarici-Quercetum* Zólyomi 1957) situated in a lowland. It is only 445.60 ha large and located in the vicinity of the town Senec in SW Slovakia (48°16´ N,

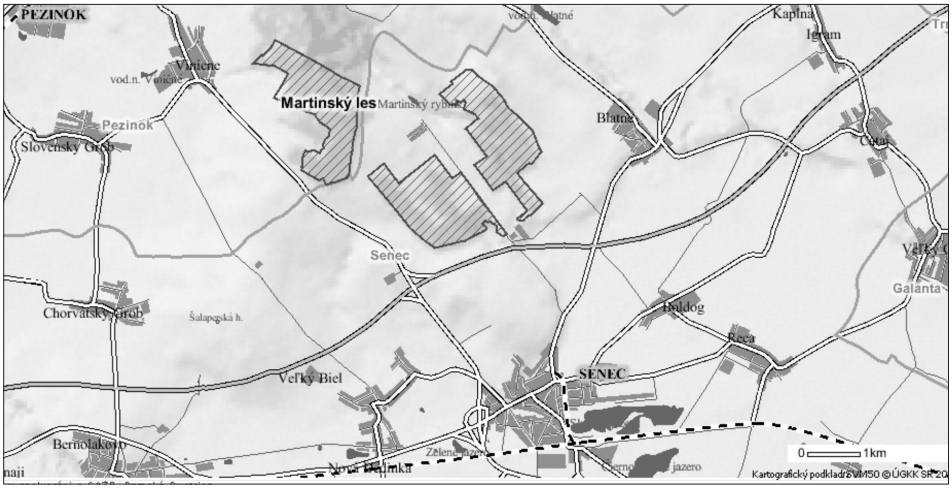

Figure 2. Map of the study area (www.sopsr.sk)

17°22´ E; 185 m a. s. l) (Figure 2). It represents a unique locality with almost all the oak species occuring in the country on a relatively small area. Since 2004 this area has been integrated in the National list of the Suggested European Special Areas of Conservation. The study area consisted of three sites:

The research site A (Figure 3) is a 90 year old 8.71 ha large seminatural oak forest (*Aceri tatarici–Quercetum* Zólyomi, 1957) covered particularly by *Quercus robur, Quercus fraineto, Quercus cerris, Quercus petraea agg., Ulmus minor,* with a high diverse undergrowth of *Acer campestre, Lithospermum purpurocaeruleum, Dictamnus albus*. *Ulmus minor, Cornus mas, Melica uniflora, Ligustrum vulgare*. Soil layer (A_0 horizon) is 3 cm thick.

The site B (Figure 4) represents a 20 year old 9.74 ha large oak (*Quercus petrea*) same age monoculture with almost no undergrowth. Soil layer (A_0 horizon) is 0.5 cm thick.

The site C (Figure 5) represents a deforested 10 year old 5 ha large open area in initial stage of its succession with natural expansion of *Quercus petrea*, *Robinia pseudoacacia*, *Rosa canina, Acer campestre* and covered by grass vegetation of *Arrhenatherum ealtius*. Soil layer (A_0 horizon) is 1 cm thick.

The site characteristics are shown in the Table 1. All the 3 plots sites were in a close contact.

Table 1. Basic pedological and phytocoenological variables at the study plots

Site	**A**	**B**	**C**
Age of stand (years)	90	20	10
Ao horizon (cm)	3.0	0.5	1.0
Cover E3 (%)	75	95	0
Cover E2 (%)	30	0	50
Cover E1 (%)	90	0	95
pH H_2O	5.4	5.8	5.3
pH KCL	4.8	4.9	4.2
COx (%)	4.3	3.6	2.5
Humus (%)	7.4	6.2	4.3
Ntot (%)	1	0.6	0.6

RESULTS

Totally 91 specimens of diplurans were collected. A complete review of the gathered Diplura is presented in the Table 3. Most of them (62) occurred in the 90 year old stand (site A). The quantity was lower at the site B (18) and C (11).

The species richness recorded in the locality has included 2 dipluran species (Table 3):

Table 3. Survey of the recorded diplurans

Period	**2004**				**2005**				**Σ**			
Site	**A**	**B**	**C**	**Σ**	**A**	**B**	**C**	**Σ**	**A**	**B**	**C**	**Σ**
Campodea augens (SILVESTRI, 1936)	5	7	1	**13**	14	9	9	**32**	19	16	10	**45**
Campodea plusiochaeta (SILVESTRI, 1912)	5	0	0	**5**	8	0	0	**8**	13	0	0	**13**
Juvenils	28	2	0	**30**	2	0	1	**3**	30	2	1	**33**
Σ	38	9	1	**48**	24	9	10	**43**	62	18	11	**91**

Figure 3. Research site A (Photo M. Dubovský, 2004)

Figure 4. Research site B (Photo M. Dubovský, 2004)

Figure 5. Research site C (Photo M. Dubovský, 2004)

In total45 specimens of *Campodea augens* (13 ind. in 2004, 35 ind. in 2005), 13 individuals of *Campodea plusiochaeta* (5 ind. in 2004, 8 ind. in 2005) and 33 juvenils (30 in 2004, 3 in 2005) were extracted from the samples.

By testing the explanatory variables by Monte carlo permutation test only age of stand ($P < 0.05$) was statistically significant in the analysis. This could be caused by a low number of sites analysed. From the RDA results (Figure 6) it appears that *Campodea plusiochaeta* (Diplura) positively correlates with the gradient of age of stand. As the first ordination axis explains only 44,7% of species variability (both first and second axes explain 97.7% together; the significance of the first axis is $P= 0.033$), this may be also caused by its interactions to different microclimatic conditions, especially higher humidity and lower temperature, because in the 10 year old stand there is not any cover of E3 and E2 is only 50% what has in fact a direct influence to the temperature of soil. Moreover this could be caused by troffic requires, because in this stand the surface horizon is more diverse and in the 20 year old monoculture the top layer consists of mainly oak leaves. In any case we can say that this species prefers a natural stand instead of a monoculture or initial stages of succession in conditions of lowland oak wood. Unfortunately any information on nourishment of these species is insufficient by now.

On the contrary *Campodea augens* appears as indifferent to the gradient of age of stand even though its occurrence positively correlates with the younger stands. It is supposed to be classified as euryvalent under these conditions.

By accompanying Test of independence from the view of Diplura, communities in all stands are significantly different (χ^2=13.6139, P=0.0011) and occurrence of species in researched stands is stable in time (with Yates correction χ^2 = 0.1004, P = 0.7514 and Fisher's exact test two-tail significance P = 1.000).

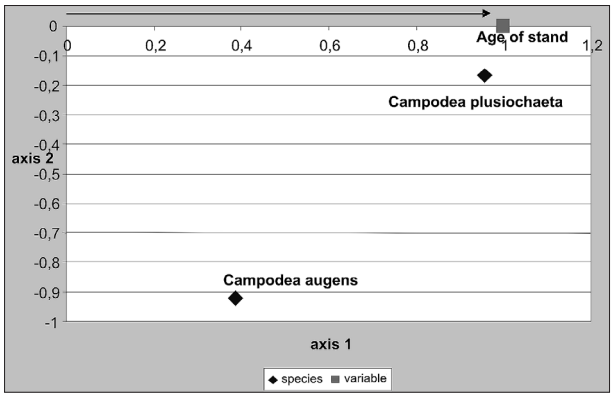

Figure 6. Redundancy analysis (RDA) biplot of the studied species response to environmental variables

DISCUSSION

Diplura as a minor component of the soil macrofauna are found consistently in soils at low densities and have highly aggregated distributions. It relates wit their way of life as well as their distribution in aggregations. So it is no wonder that we have collected only 91 specimens of only 2 species of this insect. But of course the statistical method is suit to this type of data and we can depend on it and express some clear enclosures.

***Campodea augens* Silvestri, 1936**, a common species in Slovakia (Paclt, 1956a), occurs under stones and in mouldering tree-stumps, under lose bark of trees, leafy and needle litter and humus soil (Nosek, 1967). It may be classified as a Palaeogene element (Majzlan, 2005). This species is typical for the whole Carpathian district especially in natural localities (for example oak forests) (Paclt, 1956a; Kratochvíl, 1959). Paclt (1956a) even considered it as a Carpathian element. In Slovakia the species is very abundant except for floodplain forests (Nosek, 1957).

***Campodea plusiochaeta* Silvestri, 1912**, lives under stones, under loose bark of trees, in moist needle-litter (Nosek, 1967; Kratochvíl, 1959). Nosek (1967) considered it as an euryplastic species. It is shown up from a large number of European countries, from USA and northern Africa (Paclt, 1956a).

CONCLUSIONS

The diversity of Diplura recorded in the locality has included only 2 species. *Campodea plusiochaeta* prefers a natural stand to a monoculture or initial stages of succession. *Campodea augens* occurs in all studied sites and appears as indifferent to studied conditions, so it is supposed to be classified as euryvalent under these conditions. As absolute majority of tested variables was statistically unsignificant with exception of age of forest, we can suppose that taxocoenoses of diplurans in oak forest are affected either by the soil moisture (which was not measured but can be impressed by a forest pattern) or by any unmeasured environmental variable.

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