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Composition of psocid taxocenoses (*Insecta: Psocoptera*) in *Fageti-Piceeta* s. lat. and *Piceeta* s. lat. forests in the Western Carpathian Mts.

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ABSTRACT: Psocid taxocenoses (*Psocoptera*) were studied in forest ecosystems of the Western Carpathian Mts. during 1997–2001. As a study frame were used altitudinal vegetation zones (according to Plíva 1971, 1991). Lower units of forest typological system (forest type complexes) were used for a classification of ecological conditions as well. Within this work can be the term "mountain spruce forest" understood as following communities of altitudinal vegetation zones (AVZ): the 7th – *Fageti-Piceeta* s. lat. and the 8th – *Piceeta* s. lat. These AVZ occur in the study area in the Moravskoslezské Beskydy Mts. in the Czech Republic and the Oravské Beskydy Mts. in the Slovakia 2,461 adults comprising 16 species were found in total: 12 species (eudominant species *Caecilius despaxi, Mesopsocus unipunctatus*, dominant species *Stenopsocus lachlani, Amphigerontia bifasciata* and *Caecilius burmeisteri*) were found in the 7th AVZ and an equal number of species was found in the 8th AVZ (eudominant species *Caecilius despaxi, Stenopsocus lachlani*). Taxocenoses of psocids were evaluated by Detrended Correspondence Analysis (DCA) and Divisive Cluster Analysis (DvClA). Material was compared with other material gained from various altitudinal vegetation zones in the Outer Western Carpathians Mts. Characteristic species composition of psocids in the 7th and 8th altitudinal vegetation zones were designated: the 7th AVZ – *Caecilius despaxi – Amphigerontia bifasciata – Mesopsocus unipunctatus – Stenopsocus lachlani,* the 8th AVZ is identical but with different species dominance.

Keywords: *Psocoptera*; taxocenoses; diversity; forest ecosystems; altitudinal vegetation zones; *Fageti-Piceeta* s. lat.; *Piceeta* s. lat.; Moravskoslezské Beskydy Mts.; Oravské Beskydy Mts.; Western Carpathian Mts.

In general, psocids are a rarely studied insect order. Thanks to their size, quiet coloration and relatively difficult way of collecting and preparation, they are at the edge of entomologists' interests. The psocids were studied only in some areas of the Czech Republic, mostly in various mountains of Moravia and Silesia – the Hrubý Jeseník Mts., Králický Sněžník Mt. (Obr 1949) and the Moravskoslezské Beskydy Mts. (Obr 1952, 1965). Only occasional captures are published from other areas. A complex psocopterological research was initiated in a territory of the Czech Republic and Slovakia in year 1997.

Only faunistic data are mostly known from our country at present, however, Holuša (2001) also studied an ecological problem of psocid taxocenoses composition dependence on vegetation tier in the Mazák Nature Reserve, located in the Moravskoslezské Beskydy Mts. (Holuša 2003b). In the Podbeskydská pahorkatina Hills was further evaluated psocid occurrence within the frame of forest type complexes in the Nature Reserve Kamenec (Holuša 2005). Moreover, Mückstein and Holuša (2003) studied the composition of psocid taxocenoses in different ecosystem types and its dependence on naturalness level of forest ecosystems in the region of the Žďárské vrchy Hills.

The aim of the systematic study of psocids, conducted in the Western Carpathian Mts. in years 1997–2001, was to define species diversity and characteristic species composition of psocids in particular vegetation zones and to prove an applicability of vegetation zones or lower units of geobiocenological or forest typological systems in zoocenological studies.

"Mountain spruce forest" is a commonly used term, but its definition is usually not very clear and well understood. It is possible to use one of the vegetation classification systems – the geobiocenological system (Zlatník 1959, 1976; Buček, Lacina 1999) or the forest typological system (Plíva 1971, 1991) to specify it. "Mountain spruce forest" is analogous to the 6th and 7th altitudinal vegetation zone according to the geobiocenological system and according to the forest typological system it corresponds with the 7th and 8th AVZ (cf. Holuša 2003a).

METHODS

A net of equally distributed geobiocenological research plots was situated in regions of eastern Moravia, eastern Silesia and northern Slovakia in the territory of Polonic and Westcarpathian biogeographical subprovinces (i.e. in the region of the Western Carpathians). Plots were selected in all altitudinal vegetation zones occurring in this region, i.e. from the 3rd (communities of *Querci-Fageta* s. lat.) to the 9th (communities of *Pineta mugi* s. lat.). Plots were placed in such parts of forest stands, which represent a particular altitudinal vegetation zone and in which it was possible to collect representative material of psocids. Approximately the same number of permanent plots was placed in all altitudinal vegetation zones. Permanent plots were marked out in the best-preserved parts of nature reserves and additional plots were selected in modified parts of nature reserves or in managed forests.

Sampling was carried out in the same way in all AVZ during the research and material from the 7th (i.e. *Fageti-Piceeta* s. lat.) and the 8th (i.e. *Piceeta* s. lat.) AVZ is presented in this study. The research was conducted in years 1997–2001.

Material was obtained from the permanent sampling sites during the vegetation period (from the beginning of May up to the middle of September). Samples were collected by sweeping with a sweep net of 50 cm mouth in diameter. Branches of trees and bushes were beaten with the same sweep net in the extent of about 1 m from the branch end and up to approximately 2.5 m height. These methods were also complemented by an individual collecting of adults. During sweeping and beating, 30 sweepings or beatings were carried out in each locality. Caught psocids were sucked into the exhauster and stored in a small test tube with 70% alcohol. All samples were collected and determined by author. The evidence material is deposited in 70% alcohol in the author's collection. Articles by Günther (1974) and Lienhard (1998) were used for determination; nomenclature, zoogeographical distribution and ecological demands pursuant to Lienhard (1977, 1998).

Samples were sorted into vectors, which represent "habitats of psocids". Following factors were taken into account for the purpose of material sorting: biogeographical region, ecological conditions (according to the forest type complexes) and tree or shrub species, from which was material obtained (samples were also distinguished according to the capture method; captured either in the herb layer or by the Malaise trap). For example: BE5Ssm, where BE denotes the Beskydský biogeographical region (No. 3.10), 5S represent forest type complexes 5S (i.e. *Abieto-Fagetum mesotroficum*) and sm is an acronym for the tree species *Picea abies*.

Diversity was evaluated by Shannon-Wiener (H_S) and Brillouin diversity index (H_B). Both indexes, Shannon-Wiener and Brillouin, were computed according to Kaesler and Mulvany (1976a,b). Diversity indexes of individual habitats were calculated from a total number of captured specimens, however, in case of a higher number of specimens these were reduced to a constant number (30, 60, 120 and 240) (Table 1). Some material was excluded from statistical processing because of a small number of collected specimens in some plots (i.e. species in a lower number than 5 specimens or 2 species even less than 3 specimens) to prevent data distortion.

Detrended Correspondence Analysis – DCA

Detrended Correspondence Analysis (DCA), according to Gauch (1982), Hill (1974) and Hill and Gauch (1980), proceeds from the method of Principal Component Analysis (PCA) used for non-linear data. In the DCA-analysis, axes were adjusted in order to prevent criteria deformation by the axis ends. The unit length of axes corresponds with average species dispersion. This unit remains without change in various parts of axes. The DCA ordination method has a quite heuristic character. Interpretation of axes and ordination positions of particular species is based on their ecology with a view to habitat characteristics. Modified SW Decorana was used to process the DCA analysis, which was adapted for zoocenological data processing (Povolný, Znojil 1990).

Table 1. Values of indexes of diversity and equitability for particular psocid biotopes in the altitudinal vegetation zones of *Fageti-Piceeta* s. lat. and *Piceeta* s. lat.

Biotope	Nsp	N	N_c				30				60				120				240			
			H_S	E_S	H_B	E_B	H_S	E_S	E_B	H_B	E_B	H_S	E_S	H_B	H_S	E_S	H_B	E_B	H_S	E_S	H_B	E_B
BE7Fbk	1	7	–	–	–	–																
BE7Fsm	10	199	1.504	0.684	1.582	0.687	1.237	0.774	1.481	0.784	1.365	0.776	1.523	0.784	1.469	0.739	1.574	0.744				
BE7Sbk	3	21	0.700	0.743	0.836	0.761																
BE7Sjiv	2	17	0.167	0.281	0.224	0.323																
BE7Sjr	2	4	0.347	0.774	0.562	0.811																
BE7Spod	3	3	0.597	1.000	1.099	1.000																
BE7Ssm	7	369	1.083	0.570	1.118	0.575	0.845	0.628	1.009	0.650	0.988	0.616	1.109	0.631	1.053	0.602	1.132	0.613	1.069	0.587	1.116	0.593
BE7Zbk	4	17	0.489	0.433	0.660	0.476																
BE7Zsm	9	357	1.095	0.512	1.133	0.516	0.847	0.657	1.005	0.676	0.902	0.630	1.002	0.644	1.080	0.600	1.159	0.608				
BE8Zbk	4	6	0.798	0.922	1.242	0.896																
BE8Zkos	5	20	0.788	0.596	1.010	0.627																
BE8Zma	6	310	0.349	0.200	0.372	0.207	0.255	0.330	0.311	0.361	0.266	0.259	0.312	0.281	0.331	0.225	0.370	0.240				
BE8Zpod	3	5	0.599	0.881	0.950	0.865																
BE8Zsm	8	500	1.272	0.624	1.303	0.627	1.010	0.696	1.206	0.713	1.204	0.711	1.346	0.722	1.174	0.655	1.258	0.663	1.250	0.652	1.303	0.657
OR7Ssm	4	21	1.062	0.913	1.270	0.916																
OR8Sjr	3	13	0.711	0.810	0.898	0.818																
OR8Ssm	9	393	1.168	0.545	1.206	0.549	0.941	0.726	1.101	0.738	1.038	0.664	1.155	0.675	1.114	0.635	1.191	0.642	1.148	0.570	1.200	0.574
OR8Zjan	5	8	1.015	0.952	1.494	0.928																
OR8Zkos	3	16	0.464	0.512	0.602	0.548																
OR8Zsm	7	143	1.143	0.618	1.217	0.625	1.009	0.696	1.198	0.710	1.113	0.656	1.245	0.666								

Nsp – number of species, N – number of specimens, H_S – Shannon-Wiener index of diversity, E_S – equatibility, H_B – Brillouin index of diversity, E_B – equatibility

Indexes of diversity for individual habitats from total number of captured specimens (N), in case of greater number of specimens were reduced for constant number of specimens – 30, 60, 120 and 240

Divisive Cluster Analysis – DvClA

Divisive Cluster Analysis (DvClA) represents a method of hierarchic divisive classification (Gower 1967; Orlóci 1976). The ordination of groups is performed twice by "Reciprocal averaging" (RA). All vectors are projected into the main axis as a super-ellipsoid. In the second phase, partial complexes of vectors are divided according to species ordinate in particular vectors and according to abundance of particular species (indicators) as well. These indicators are automatically selected by the program in compliance with species spectrum of particular vectors (habitats) to end parts of ordination axis. Used modification – Twinspan algorithm comes from a gradual division of habitats and species. Every processed file is ordinated by RA method, whereupon characteristic species (or biotopes) are associated with axes ends. Central parts of axes are ordinated consequently. On the base of acquired results, it is searched for species combinations, which are characteristic for parts of ordination axes and can be used as appropriate "tools for cuts" (Hill 1974). This method was modified for the purpose of this study, because the first version is defined for phytocenological studies only. Column heads represent abbreviations of biotopes. Numbers in columns below indicate the division of appropriate algorithm (every habitat is divided, marked 0 or 1). There are species names in the left column and on the right is one algorithm division of species spectrums in groups. The main field represents the semiquantitative relative frequency of particular species in groups corresponding with their biotopes. Explanations: – species does not occur, 1 – rare species, 2 – very scarce, 3 – scarce, 4 – common, 5 – very common to subdominant, 6 – dominant. Groups of psocid species and groups of habitats were organized to increase their clearness so that there is an evident species transfer within biotopes in the diagonal direction from the left upper corner to the right lower corner.

Acronyms of trees and shrubs (investigated tree species): sm – *Picea abies*, bk – *Fagus sylvatica*, kos – *Pinus mugo*, jan – *Juniperus communis nana*, jiv – *Salix caprea*, jr – *Sorbus aucuparia*; pod – copse, ma – Malaise trap.

Next psocid communities were classified in the following study plots: 7F – *Fageto-Piceetum acidophilum*; 7S – *Fageto-Piceetum mesotrophicum*; 7Z – *Fageto-Piceetum humile*; 8S – *Piceetum mesotrophicum*; 8Z – *Sorbeto-Piceetum.*

RESULTS AND DISCUSSION

2,461 adults comprising 16 species were found in total: 12 species (eudominant species *Caecilius despaxi, Mesopsocus unipunctatus*, dominant species *Stenopsocus lachlani, Amphigerontia bifasciata* a *Caecilius burmeisteri*) were found in the 7th AVZ

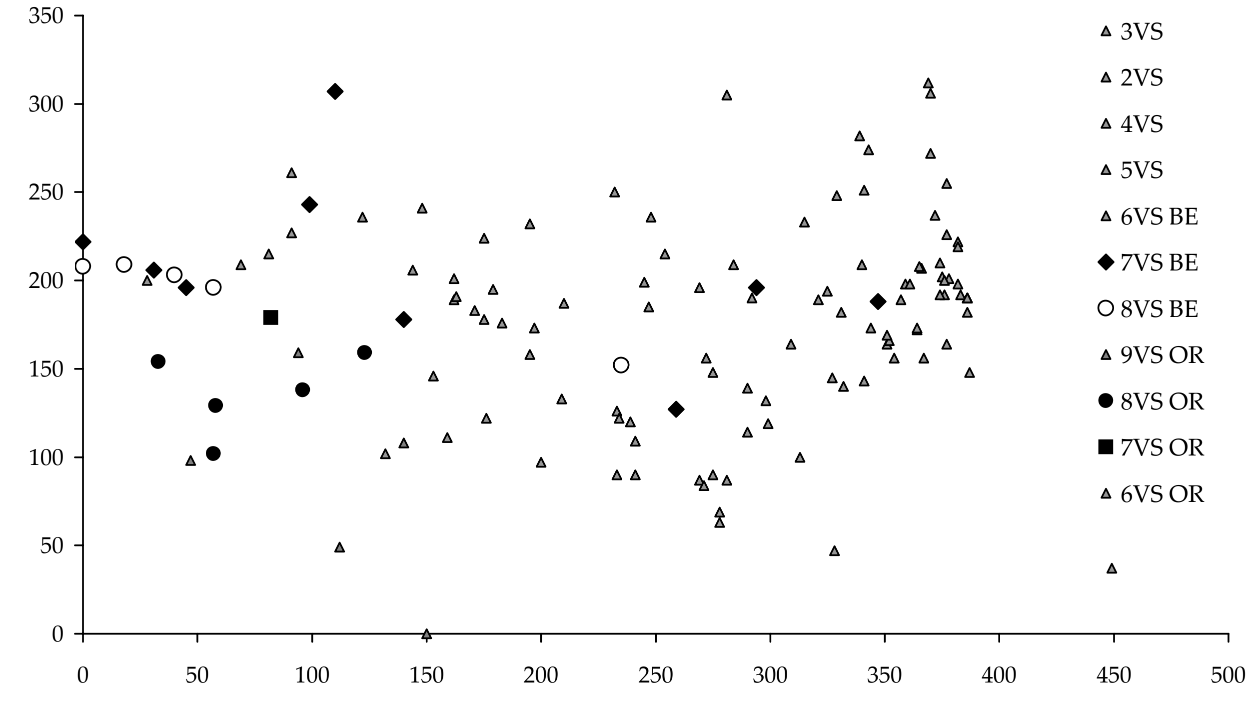

Fig. 1. DCA analysis of psocid biotopes (axis x – gradient of altitudinal vegetation zones, q – gradient of hydricity)

and an equal number of species was found in the 8th AVZ (eudominant species *Caecilius despaxi, Stenopsocus lachlani*). Species spectrum and dominancy found in the 7th and 8th AVZ in the Moravskoslezské Beskydy Mts. differ from those in the Oravské Beskydy Mts. mainly by representation of *Mesopsocus unipunctatus*.

Resulting from the comparison of tree colonization, *Picea abies* was the most colonized tree species in community 7F and 8S. There were found higher values of diversity indexes in the communities 7F and 8Z (Table 1) and the highest value was calculated for *Picea abies* in forest type complex 7F.

The DCA-analysis might be interpreted as follows, the *x*-axis denotes an influence of altitudinal vegetation zones and *q*-axis refers to an influence of hydricity. These factors might raise a presumption of mutual correlation, but all AVZ included habitats with high hydricity – flooded habitats, water logging and peaty habitats as well as dry or desiccate habitats. Because every AVZ comprehends a large scale of habitats – from dry to peaty habitats, hydricity of habitat does not correlate with altitude within collected material. Habitats of the 7th AVZ are situated "higher" than habitats of the 8th AVZ in the graph of *x*-*q* axis (Fig. 1) and thus it is possible to state that biotopes of the 8th AVZ are more "moist". A field of habitats of the 7th AVZ is situated along the *x*-axis, i.e. along altitudinal vegetation zones. The difference is then in the hydricity of habitats of the Oravské and Moravskoslezské Beskydy Mts. habitats of the 7th and 8th AVZ in the Moravskoslezské Beskydy Mts. create a homogenous dotted field situated "higher" than a habitat field of the Oravské Beskydy Mts.

Taxocenosis of the 7th (*Fageti-Piceeta* s. lat.) altitudinal vegetation zone

Eudominant species *Caecilius despaxi, Mesopsocus unipunctatus* and dominant species *Stenopsocus lachlani, Amphigerontia bifasciata, Caecilius burmeisteri* were found on the base of total dominancy in the 7th AVZ. In the natural communities, *Caecilius despaxi, Mesopsocus unipunctatus* were eudominant and as dominant species were identified *Caecilius burmeisteri, Amphigerontia bifasciata* and *Stenopsocus lachlani. Picea abies* was the most abundantly colonized tree species, whereas *Fagus sylvatica* was colonized by a poorer species spectrum (max. 4).

In the DvClA-analysis, habitats of the 7th AVZ occur in two groups. Habitats of broad-leaf trees (*Fagus sylvatica, Sorbus aucuparia*) form groups A-I-b (not illustrated in Fig. 2) and habitats with *Picea abies* and *Salix caprea* occur in group B-II-b-1, i.e. the 5th–9th AVZ group.

In the DCA-analysis, habitats of the 7th AVZ create a field, which is located on the left side of the whole dotted field (along *x*-axis). It forms the highest AVZ together with fields of the 8th and 9th AVZ. Only single habitats of the 7th AVZ occur in the field of the 4th and 5th AVZ.

From the view of hydricity (*q*-axis), habitats of the 7th AVZ are on the same level as those of the 4th–6th AVZ.

Diversity indexes H_S reach values from 0.17 to 1.50, H_B 0.22–1.59. The highest values were calculated for habitat BE7Fsm with reduced number N_{30} H_S 1.24 and H_B 1.48, higher values also showed habitat BE7Ssm with reduced number N_{30} H_S 0.85 and H_B 1.01.

Characteristic species composition of the 7th AVZ was defined: *Caecilius despaxi – Amphigerontia bifasciata – Mesopsocus unipunctatus – Stenopsocus lachlani*. These species, occurring in the 7th AVZ, are missing in the lower and middle altitudinal vegetation zones.

Taxocenosis of the 8th (*Piceeta* s. lat.) altitudinal vegetation zone

Eudominant species *Caecilius despaxi, Stenopsocus lachlani* were found on the base of total dominancy in the 8th AVZ. In the natural communities were identified *Stenopsocus lachlani* and *Caecilius despaxi* as eudominant and *Caecilius burmeisteri* as dominant species. The most diverse species spectrum with the highest abundance was on *Picea abies.* Other tree species are colonized by a higher number of psocid species as well, however, in lower abundances.

In the DvClA-analysis, habitats of the 8th AVZ create group B-II-b-1, only individually they occur in group B-II-a. Group B-II-b covers biotopes of the 5th–9th AVZ and group B-II-a biotopes of the 4th–8th AVZ where only several habitats (*Pinus mugo, Juniperus communis nana*) come under. In the DCA-analysis, habitats of the 8th AVZ lie along the *x*-axis on the left side. This dotted field is not situated along the *x*-axis in the same way as the field of the 7th AVZ because the field of the 8th AVZ shows higher moisture according to the gradient of the *q*-axis.

Diversity indexes H_S reach values 0.35–1.27, H_B 0.37–1.49. The highest values were found within habitats BE8Zsm with reduced number N_{30} H_S 1.01 and H_B 1.21, similarly high values of indexes were

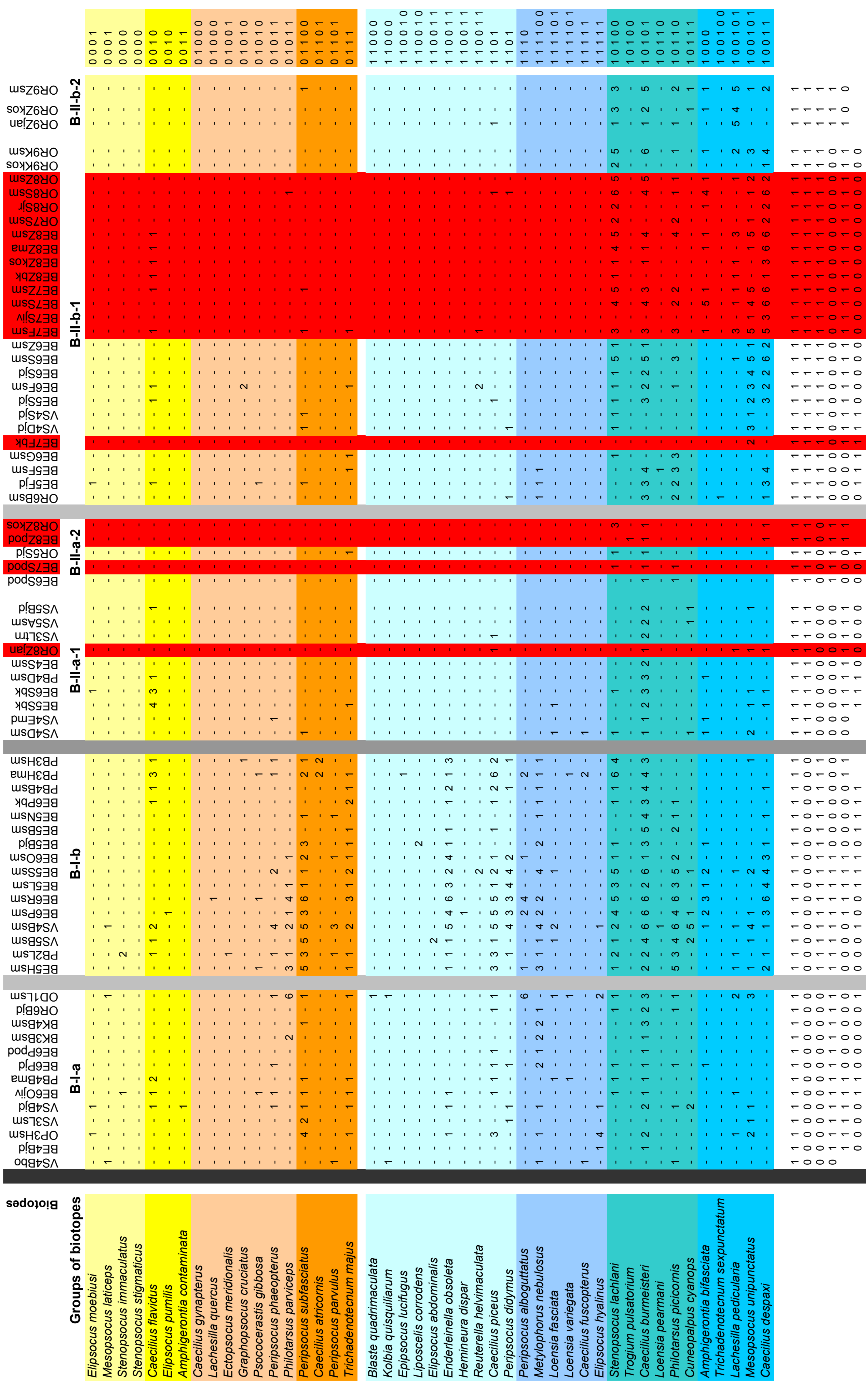

Fig. 2. Results of DvCIA-analysis – Twinspan algorithm; biotopes of the 7th and 8th AVZ are marked with red colour (with regard to the table extent, right third of the whole graph, i.e. subgroup B, is illustrated only)

found within habitat OR8Zsm with reduced number N_{30} H_S 1.01 and H_B 1.20.

Characteristic species composition of the 8th AVZ is identical with the 7th AVZ: *Caecilius despaxi – Amphigerontia bifasciata – Mesopsocus unipunctatus – Stenopsocus lachlani*. However, it differs in dominancy of *Caecilius despaxi* (lower) and *Lachesilla pedicularia* is more abundant.

CONCLUSION

Compositions of psocid taxocenoses are influenced by tree species composition in "mountain spruce forests" that correspond with the 7th and 8th AVZ. It is mainly valid for the 7th AVZ, where *Fagus sylvatica* is still edificator (it means subdominat tree). This influence is not important in the 8th AVZ because *Fagus sylvatica* occurs only individually here and in the stage of low tree or shrub.

There are no significant differences in taxocenoses of the 7th and 8th AVZ, although the species spectrums are not identical. The taxocenoses differ in dominances, but characteristic species combinations of psocids are the same. This result supports a correct classification of the 7th AVZ as "spruce forests".

It is possible to say that altitudinal vegetation zones proved to be a suitable frame for the definition of "mountain spruce forest" as well as for zoocenological studies. AVZ and lower units of geobiocenological, respectively forest typological system, together with description of tree species composition and naturalness level form a perfect base for studies focused on the animal taxocenoses structure. Furthermore, they might be a perfect tool for evaluation of changes in forest ecosystems in the future. We confirmed the hypothesis that psocids, as a part of forest ecosystem, fully comply with the theorem of geobiocenoses (Zlatník 1976). Geobiocenoses are composed of specific biocenoses in conjunction with abiotic environment; the biocenose is formed not only by plants or trees as the main community determinants, but an important part constitutes the zoocenose as well. On the basis of long-standing studies of "forest pests", Stolina (1975) considers the geobiocenological units, AVZ and groups of forest types, as suitable frames for autecological studies of species. These studies can consequently serve as determinants of habitat specifications (i.e. occurrence, localities of occurrence, survival ability).

Altitudinal vegetation zones are units, which complexly conjugate ecological factors of ecosystems in landscape segments and they are a perfect frame for animal studies. According to results, psocid taxocenoses are dependent on the main ecological factors of environment, therefore AVZ are the most appropriate units considering changes of the main ecological factors in landscape segments. This study also confirmed that AVZ are the main factor with the greatest influence on variability of psocid taxocenoses. Finally, the order of psocids can serve as a suitable tool for the geobiocenological classification of ecosystems.

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Složení taxocenóz pisivek (*Insecta: Psocoptera*) v lesních ekosystémech bukových smrčin (*Fageti-Piceeta* s. lat.) a smrčin (*Piceeta* s. lat.) v západních Karpatech

ABSTRAKT: Během období 1997–2001 byly v lesních ekosystémech v oblasti západních Karpat studovány taxocenózy pisivek (*Psocoptera*). Jako rámce pro studium byly použity vegetační stupně podle systému geobiocenologie, resp. lesnické typologie (Plíva 1971, 1991). Pro klasifikaci stanoviště (tj. ekologických podmínek) byly použity jednotky – soubory lesních typů lesnicko-typologického systému. V práci pod pojmem "horské smrkové lesy – přirozené smrčiny" jsou chápány vegetační stupně (VS): 7. (tj. buko-smrkový) – společenstva *Fageti-Piceeta* s. lat. a 8. (tj. smrkový) – společenstva *Piceeta* s. lat. Tyto vegetační stupně se vyskytují v oblasti Moravskoslezských Beskyd na území České republiky a v oblasti Oravských Beskyd na Slovensku. Celkově byly zjištěno 2 461 imag v 16 druzích: v 7. VS bylo zjištěno 12 species (eudominantní druhy *Caecilius despaxi, Mesopsocus unipunctatus*, dominantní druhy *Stenopsocus lachlani, Amphigerontia bifasciata* a *Caecilius burmeisteri*), stejný počet druhů byl zjištěn v 8. VS (eudominantní druhy *Caecilius despaxi, Stenopsocus lachlani*). Taxocenózy pisivek byly vyhodnoceny statistickými metodami – detrendovanou korespondenční analýzou (DCA) a shlukovou divizní analýzou (DvClA). Materiál byl vyhodnocen v rámci širšího srovnání materiálu pocházejícího i z ostatních VS v rámci vnějších západních Karpat. Charakteristické druhové kombinace pisivek pro jednotlivé VS byly zjištěny: pro 7. VS – *Caecilius despaxi – Amphigerontia bifasciata – Mesopsocus unipunctatus – Stenopsocus lachlani,* pro 8. VS je charakteristická druhová kombinace identická s rozdílem v druhové dominanci.

Klíčová slova: *Psocoptera*; taxocenózy; diverzita; lesní geobiocenózy; vegetační stupně; *Fageti-Piceeta* s. lat.; *Piceeta* s. lat.; Moravskoslezské Beskydy; Oravské Beskydy; západní Karpaty

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