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Historical and functional aspects of plant biodiversity – an example on the flora of the Vukova Gorica region (Central Croatia)

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ABSTRACT

ALEGRO, A., LJ. MARKOVIĆ, O. ANTONIĆ & S. BOGDANOVIĆ (2006). Historical and functional aspects of plant biodiversity: the example of the flora of the Vukova Gorica region (Central Croatia). *Candollea* 61: 135-166. In English, English and French abstracts.

Vukova Gorica region, located in the Western part of Central Croatia and displaying an area of 3.2 km^2, has a vascular flora of 531 taxa from 96 families. Seven main habitat types were recognised. For each type of habitat, biological and chorological spectra have been calculated, as well as a cross-spectrum representing the relationship between the chorological types and the life forms. The spectra were analysed using correspondence analysis (CA). The present state of diversity can be considered as the result of the natural and historical circumstances and the extensive anthropogenic impact. It is concluded that the human impact was essential for the richness of the flora and its chorological structure. The high α-diversity index recorded on the studied area shows that Vukova Gorica region is one of the floristically richest region of Croatia.

RÉSUMÉ

ALEGRO, A., LJ. MARKOVIĆ, O. ANTONIĆ & S. BOGDANOVIĆ (2006). Aspects historiques et fonctionnels de la biodiversité des plantes: l'exemple de la flore de la région de Vukova Gorica (Croatie centrale). *Candollea* 61: 135-166. En anglais, résumés anglais et français.

La région de Vukova Gorica se situe dans la partie occidentale du centre de la Croatie et comprend une aire de 3,2 km^2. Sa flore vasculaire est composée de 96 familles et de 531 taxa. Des spectres biologiques et chorologiques ont été calculés pour chaque type d'habitat de même qu'un spectre croisé représentant la relation entre les types chorologiques et les formes vivantes. Les spectres ont été analysés selon l'analyse de correspondance (AC). L'état actuel de la diversité peut être considéré comme étant le résultat des circonstances naturelles et historiques et d'un impact anthropogénique extensif. Il en est conclu que l'impact humain est essentiel pour la richesse et la structure chorologique de la flore. L'index de diversité-α élevé de la région étudiée montre que la région florale de Vukova Gorica est l'une des plus riches de Croatie.

KEY-WORDS: flora – diversity – chorological types – life forms – cross-spectrum – Vukova Gorica region – Croatia

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Introduction

Biodiversity studies have often been considered only in terms of species richness for a given area. Species richness, however, is only one aspect of biodiversity. The complex regional patterns of species assemblages may be originated from the operation and interaction of historical, causal and functional factors (BISBY, 1995). A statistical approach to floristic data can provide some explanations for the patterns of distribution of different groups of plant species.

The historical and functional aspects of plant biodiversity are considered in this paper where (1) we describe the vascular flora of the studied area with the species richness and the main habitats where species are found, (2) we quantify the relationships between the phytogeographical affinities of species, reflecting their history, and their distribution within the habitat types, (3) we quantify the relationships between species life forms and their distribution within the habitat types, (4) we distribute the species in groups with same life form and chorotype in order to analyse the flora from a biogeographical and structural point of view, and (5) we compare the flora richness of the studies area with the other parts of Croatia using α-diversity index.

This is the first attempt to evaluate the flora of some part of Croatia by the simultaneous interconnection of chorological, life-form and habitat data. The flora of the continental part of Croatia has not been systematically studied until now. Furthermore, the analyses of a few areas provide independent presentations of chorological and life-form spectra, regardless to the habitat types (cf. ŠEGULJA, 1977; HULINA, 1989; STANČIĆ, 1994; ŠEGULJA & al., 1998; ŠOŠTARIĆ & MARKOVIĆ, 1998; REGULA-BEVILACQUA & ŠEGULJA, 2000). Similar approach of describing biodiversity by species richness and basic spectra was commonly used in a majority of traditional analyses of the floras around the world. Some of the first consistent and detailed statistical approaches to study associations between life-forms, phytogeographical elements and the distribution of species within the habitats have been carried out for the flora of Terra Nova National Park (Newfoundland, Canada) (CHAREST & al., 2000) and for the flora of Euganean Hills (North-Eastern Italy) (VILLANI & al., 2003).

Study area

The studied area of Vukova Gorica (Fig. 1) is located in Central Croatia and belongs to the West-Pannonian macroregion, spreading alongside the Kupa river (i.e. the border with the Republic of Slovenia) in a total length of 5 km. The area is bordered by the Kupa river on the North and North-West and roads on the South and South-East. The total surface of the area is 3.2 km^2. The elevation ranges from 149.5 to 255.6 m. The area includes the following small villages Johi, Glavica, Vukova Gorica and Gornje Prilišće. According to the climate classification by Köppen (BERTOVIĆ, 1975), it belongs to the temperate C climate and is located on the "continentally line", i.e. on the boundary between continental and maritime annual precipitation regime (FILIPČIĆ, 1996). Therefore, the precipitations are evenly distributed throughout the year with 680 mm during the vegetation period (April-October), and this represents 51% of the total annual amount. The average yearly temperature is 9.7° C (16-17° C during the vegetation period). The coldest month is January (average temperature of -1.6° C) and the hottest is July (21.1° C). The area belongs to the Croatian karst with geological basis composed by Jurassic limestone, Jurassic and Cretaceous dolomites and alluvial deposits on some parts of the Kupa bank. These rocks are covered with several types of brown soils, relict terra rossa and alluvial soils above river deposits. The landscape is wavy, spotted with numerous shallow dolines (sinkholes). The special peculiarity of the region is a 60 m deep canyon of the Kupa river, exposed to the North, with vertical rocks in some parts.

After the Turkish wars, the area has been repopulated beginning in year 1554. In year 1805, there were 826 inhabitants, in 1935 approximately 2000 inhab. (in broader area), and in 1991 only 183 inhab. until now. The result of centuries long, but moderate human activity, is a mosaic landscape composed of a variety of habitats. Besides natural forest vegetation (oak-hornbeam, beech and gallery woods alongside the river), also shrubs, grasslands, meadows, and other rural habitats are present.

Materials and methods

The area has been floristically studied in the period between 1996 and 2004. The specimens, collected in all seasons, have been prepared for identification. Regarding the allochtonous species, only naturalised and invasive plants *sensu* RICHARDSON & al. (2000) were collected, and not the cultivated ones.

The habitat types have been recognised during the field work and later grouped into seven major types:

- B (□) – beech forest (association *Lamio orvalae-Fagetum* (Horvat 1938) Borhidi 1963), developed in the Kupa canyon;
- OH (▲) – oak-hornbeam forest (association *Epimedio-Carpinetum betuli* (Horvat 1938) Borhidi 1963), climazonal vegetation of the region;
- G (◊) – grasslands and meadows (predominantly different communities from alliance *Bromion erecti* (Koch 1926) Br.-Bl. 1936) and few patches of association *Arrhenatheretum elatioris* Br.-Bl. ex Scherrer 1925);
- M (+) – moist shrubs and gallery woods alongside the river with *Salix* spp., *Alnus* spp., *Populus nigra* and *Fraxinus excelsior* as dominant tree species;
- S (■) – vegetation of margins and shrubs of woodland edges and roadsides;
- W (♦) – weeds and ruderal habitats;
- A (B) – aquatic habitats (plants in the river).

Flora Europaea (TUTIN & al., 1964-1980, 1993) was mainly used to identify the plant material. In the case of problematic taxa, other floras and monothematic keys were considered (e.g. KOPP & SCHNEEBELI-GRAF, 1998; DELFORGE, 2001; HÖRANDL & al., 2002).

The nomenclature used follows NIKOLIĆ (1994, 1997, 2000). Habitat type, life-form and chorological type were attributed to each taxon of the check-list. Some taxa growing in two or more habitat types were equally considered for each habitat type in the further analyses.

Life-form categories of Raunkier's system (RAUNKIER, 1934), as presented by ELLENBERG & al. (1991) and OBERDORFER (1994), were accepted:

- P – Phanaerophytes;
- Ch – Chamaephytes;
- H – Hemicryptophytes;
- T – Therophytes;
- G – Geophytes;
- Hy – Hydrophytes.

If more than one life form was quoted for a single taxon, the most appropriate one was chosen considering field observations in the studied area.

Chorological types follow system proposed by HORVATIĆ (1963, 1967-68):

1. medit – Mediterranean (incl. submediterranean);
2. illyr-balc – Illyrian-Balkan;
3. S-europ – South-European;
4. atlant – Atlantic;
5. E-europ-pont – East-European-Pontic;
6. SE-europ – Southern-East-European;

7. C-europ – Central-European;
8. europ – European;
9. europ-asiat – Eurasiatic;
10. circ-holoarct – Circumholoarctic;
11. cosmop – Cosmopolites;
12. neoph – Neophytes.

For the taxa not listed there, OBERDORFER (1994), PIGNATI (1982), SIMON & al. (1992), HORVAT (1929), HORVAT & al. (1974) were used. When more than one chorological type was given by these sources for a single taxon, the most appropriate was chosen and accorded with Horvatić's system. The biological and chorological spectra were prepared for the total flora and for each type of habitat. For the purposes of statistical analysis, the Atlantic chorological group was unified with the European group. In addition, the E-European-Pontic and SE-European group were also considered as one group. The reason for these agglomerations was the low number of species in the Atlantic group (one species) and in the SE-European group (three species), which can decrease the resolution of statistical analysis. The cross-spectra were prepared by considering the number of species of every chorological group and life form for each habitat type, and by considering the number of species of every life-form for each chorological group. In order to visualize the data structure, a correspondence analysis (CA) was carried out on the basis of the two-way contingency tables with the values of cross-spectra.

The results of CA analysis are presented in ordination diagrams, where groupings of variables are emphasized by arbitrary superimposed ellipses. However, the studied data set has three dimensions and analysis of all possible two-way marginal tables cannot substitute the analysis of whole three-way table (LEGENDRE & LEGENDRE, 1998). Therefore, log-linear contingency table analysis was performed. Large proportion of zero frequencies (number of species in particular combinations of life form, chorological type and habitat) in the cited three-way contingency table allowed computation of log-linear analysis impossible. To avoid this, all zero frequencies of these combinations were replaced by value 1 and other frequencies were multiplied by 100. Positive differences between observed species frequencies and those expected by chance for particular combinations of habitat type, chorological type and life-form are presented graphically. Log-linear analysis was also used for the testing of differences between observed and expected number of species in two-way combinations of habitat and chorological types (regardless of the life forms), as well as habitat types and life forms (regardless of the chorological types). In order to compare the biodiversity of Vukova Gorica region with some other specific regions in Croatia, the logarithmic regression between area and number of species was computed (HOBOHM 2000a, 2000b) through all the regions. On the basis of the formula of the regression line, the α-diversity indices were computed and compared for all regions. Correspondence analysis was carried out using the PC-ORD 4.14 package (MCCUNE & MEFFORD, 1999), while log-linear analysis and regression were done using the Statistica 7 package (Stasoft, Inc.).

Results

In the course of the research, 531 taxa of vascular plants from 96 different families were found (Appendix 1). The largest group are dicots (*Magnoliatae*) with 410 taxa from 72 families or 77.2% of total flora found. Monocots (*Liliatae*) are represented by 99 species from 11 families, followed by ferns (*Pteridophyta*) in 18 taxa, and finally by gymnosperms (*Coniferophytina*) in 4 taxa. The most numerous families (Table 1) are *Asteraceae* s.l., *Poaceae*, *Fabaceae*, *Lamiaceae*, and *Rosaceae*.

Table 1. – Families represented in the flora of Vukova Gorica with 10 or more taxa.

Family	No of species	% of total flora
Asteraceae s.l.	60	11.30
Poaceae	44	8.29
Asteraceae s.s.	38	7.16
Fabaceae	35	6.59
Lamiaceae	32	6.03
Rosaceae	23	4.33
Cichoriaceae	22	4.14
Brassicaceae	21	3.95
Ranunculaceae	21	3.95
Scrophulariaceae	20	3.77
Apiaceae	19	3.58
Caryophyllaceae	17	3.20
Liliaceae	16	3.01
Cyperaceae	14	2.64
Polygonaceae	10	1.88
Orchidaceae	10	1.88

137 taxa were found in the beech forests, 94 in the oak-hornbeam forests, 160 in the grasslands, 59 in the moist shrubs and gallery woods, 115 in the shrubs and the vegetation of woodland edges, 57 in the weed and the ruderal vegetation, and 12 in the aquatic habitats.

The phytogeographical spectrum is presented in Table 2. The interrelationship between the habitat types and chorotypes given by CA (Fig. 2) shows grouping of the forest vegetation (B, OH) with the Illyrian-Balkan chorotype (I). The weed and ruderal vegetation (W) is closest to the neophytes (II). The aquatic habitats (A) have isolated position nearest to the Circumholoarctic chorotype (III). The shrub and margin vegetation (S) is situated between SE-European and Mediterranean chorotype on one side, and neophytes on the other side (IV). The grasslands (G)

Table 2. – The percentages of chorological types in the habitat types of Vukova Gorica.

		Habitat types						
Chorotypes	**Total No**	**B**	**OH**	**G**	**M**	**S**	**W**	**A**
Medit	7	1.46	1.06	1.25	0.00	0.86	1.75	0.00
Illyr-balc	14	8.76	6.38	0.00	0.00	0.00	0.00	0.00
S-europ	56	13.14	12.77	15.63	3.39	5.17	3.51	7.69
SE-europ-pont	13	1.46	1.06	2.50	3.39	2.59	1.75	0.00
C-europ	48	15.33	15.96	8.75	5.08	5.17	0.00	0.00
Europ	50	9.49	11.70	10.00	15.25	7.76	7.02	0.00
Europ-asiat	164	30.66	34.04	32.50	38.98	37.07	15.79	7.69
Circ-holoarct	45	8.76	7.45	6.88	15.25	3.45	3.51	38.46
Cosmop	116	10.95	8.51	22.50	15.25	32.76	50.88	46.15
Neoph	18	0.00	1.06	0.00	3.39	5.17	15.79	0.00

and the moist shrubs and gallery woods (M) have relatively central position, closest to the Central- and South-European, European and Eurasiatic chorotypes (V). Similar tendencies are also evident in results of log-linear analysis (Table 3, Fig. 3). Weed and ruderal vegetation (♦) is characterised by high frequency of cosmopolites and neophytes. High frequency of cosmopolites and Eurasiatic plants in the shrub and margin vegetation (■) is evident, and that was not so clear in previous analysis. Connection of grassland vegetation (◊) with S-European plants is more emphasized than in CA. Furthermore, it is clear shown that frequencies of Illyrian-Balkan and C-European species are higher in beech forest (□) than in oak-hornbeam forest (▲).

Table 3. – Comparisons of observed species frequencies and those expected by chance using Chi-square test (as a part of log-linear analysis of frequency tables) (see main text).

Comparison	Chi-square	Degrees of freedom	*P*
Habitats vs. chorological types*	205.14	54	<0.01
Habitats vs. life-forms*	770.61	30	<0.01
Chorological types vs. life-forms (for habitat 1)	1538.43	45	<0.01
Chorological types vs. life-forms (for habitat 2)	3578.83	45	<0.01
Chorological types vs. life-forms (for habitat 3)	4243.39	45	<0.01
Chorological types vs. life-forms (for habitat 4)	2473.56	45	<0.01
Chorological types vs. life-forms (for habitat 5)	3274.17	45	<0.01
Chorological types vs. life-forms (for habitat 6)	3521.27	45	<0.01
Chorological types vs. life-forms (for habitat 7)	3012.68	45	<0.01

Table 4 presents spectrum of life-forms. The hemicryptophytes are the most representated group in the grassland vegetation, the geophytes and phanerophytes in the forest vegetation, the therophytes in the weed and ruderal vegetation. The hydrophytes are naturally present only in the water habitats. These relations are clearly confirmed by the log-linear analysis (Fig. 4).

Table 4. – The percentages of life forms in the habitat types of Vukova Gorica.

		Habitat types						
Life forme	Total No	B	OH	G	M	S	W	A
P	60	11.68	31.91	0.63	18.64	11.30	0.00	0.00
Ch	21	2.92	5.32	6.25	3.39	0.87	1.75	0.00
H	285	55.47	37.23	71.88	54.24	62.61	21.05	8.33
T	84	2.19	3.19	8.75	11.86	20.87	73.68	0.00
G	72	27.74	22.34	12.50	11.86	4.35	3.51	16.67
Hy	9	0.00	0.00	0.00	0.00	0.00	0.00	75.00

The cross-spectrum representing the interrelationship between the chorological types and life forms (Table 5) shows that phanerophytes, hemicryptophytes and therophytes are composed of all chorological groups. The most uniform are hydrophytes represented with Circumholoarcitc chorotype and cosmopolites. Given by CA, Figure 5 shows relationship between the therophytes and neophytes (I), the isolated position of hydrophytes closest to the Circumholoarctic chorotype (II), the close relation between geophytes and South- and Central-European plants (III), and the almost central position of hemicryptophytes closest to Illyrian-Balkan, European and Eurasiatic chorotypes (IV). Chamaephytes are also isolated to some degree and closest to the Central-European plants (V). The position of the phanerophytes reflects their diversity with regard to chorological types.

Table 5. – Cross-spectrum representing percentages of chorological types in each life form.

		Life forms [%]					
Chorotypes	**Total No**	**P**	**Ch**	**H**	**T**	**G**	**Hy**
Medit	7	1.67	0.00	1.42	1.18	1.35	0.00
Illyr-balc	14	1.67	0.00	2.48	1.18	6.76	0.00
S-europ	56	10.00	19.05	12.06	2.35	13.51	0.00
SE-europ-pont	13	5.00	0.00	2.48	2.35	1.35	0.00
C-europ	48	16.67	28.57	7.09	1.18	13.51	0.00
Europ	49	11.67	19.05	8.87	8.24	9.46	0.00
Europ-asiat	164	33.33	19.05	35.82	20.00	31.08	0.00
Circ-holoarct	45	5.00	4.76	9.93	2.35	9.46	44.44
Cosmop	116	10.00	9.52	18.79	47.06	13.51	55.56
Neoph	18	5.00	0.00	1.06	14.12	0.00	0.00

The results of the log-linear analysis of the three-way contingency table are presented in Figure 6. The relations with the most outstanding frequencies important for the explanation of the structure of the flora are:

- Eurasiatic hemicryptophytes in grassland vegetation (◊);
- Complex structure of the vegetation of margins and shrubs (■) with cosmopolitic and neophytic therophytes;
- European and S-European hemicryptophytes.

High frequency of Eurasiatic and Illyrian-Balkanic geophytes is characteristic for beech wood (□), and this latter also for oak-hornbeam forest (▲). However, for forest vegetation, important combinations of Central-European, European phanerophytes and S-European hemicryptophytes are occurring, the latter especially for beech forest. Weed and ruderal vegetation (♦) is characterised by cosmopolitic and neophytic therophytes. Aquatic vegetation (B) is characterised by hydrophytes of cosmopolitic and circumholoarctic distribution. In the vegetation of moist shrubs and gallery woods (+), high frequencies have European phanerophytes and hemicryptophytes, as well as circumholoarctic hemicryptophytes.

The logarithmic regression between the number of species and areas of nine floristically well studied specific regions, in the non Eumediterranean parts of Croatia, is shown (Fig. 7). On the basis of the regression formula, α-diversity indices have been calculated (Table 6). The Vukova Gorica area has comparatively a high α-diversity index, and therefore it can be considered as one of the floristically richest region of Croatia.

Table 6. – Surfaces, numbers of species and α-diversity indices of some areas in Croatia.

Areas	**area/km²**	**No of species**	**α-diversity index**
Papuk	336.00	1500	0.0682
Vukova Gorica	3.20	530	0.0487
Učka	160.00	1200	0.0402
Krapinske toplice	3.00	492	0.0224
Risnjak	64.10	936	0.0173
Medvednica	228.26	1202	0.0079
Plitvice	294.82	1267	0.0070
Paklenica	102.00	809	-0.0892
Konjšćina	32.00	584	-0.1230

Discussion

The great floristic diversity of the studied area cannot only be explained by the moderate climate and the specific geographical position between the South- and Central-European floristic regions, but also by habitat diversity formed as a result of extensive anthropogenic influence.

According to the map of the natural potential vegetation of Croatia (TRINAJSTIĆ, 1987), the studied area should be covered with oak-hornbeam (OH) and beech (B) forests, as it was in the past for the whole inland area of Croatia (ŠOŠTARIĆ, 2004). In both types of natural climazonal vegetation together, 177 species were found. If we add the species of the water habitats, tree, shrub and some herbaceous species of gallery vegetation of the river banks, as well as some species of woodland clearings, the total number of taxa is around 250. In comparison to the 531 taxa of real recent flora, it is clear that the majority of the species is living on the habitats created by a moderate human activity during the past centuries. A similar doubling of species number can be read out from the graphs presented by KORNECK & al. (1998) for the flora of Germany and by SUKOPP & TREPL (1987) for the flora of Central Europe. The history of flora can be read out from the spectra of chorological types. Hence, endemic Illyrian-Balkan plants are strictly limited to the beech and oak-hornbeam forests, which is also shown in log-linear analysis. This indicates that forests are in the area the oldest vegetation type, which has persisted long enough to create and maintain suitable conditions for specific plant species. Some of the plant species growing there (e.g. *Epimedium alpinum*, *Lamium orvala*, *Hacquetia epipactis*, *Omphalodes verna*, *Cardamine enneaphyllos*) can be considered as relicts of the old Tertiary flora extinct in Central Europe during the Ice Ages. This shows more or less continuous development of the forest vegetation in South-European refugia. Furthermore, ŠOŠTARIĆ (2004) states that during the postglacial periods, up to the Subatlantic, there was no natural or anthropogenic devastation resulting in the loss of forest cover. As a result, the beech woods of Croatian part of west Balkan are floristically the richest ones in the whole of its area of distribution in Europe (HORVAT, 1949, 1962; HORVAT & al., 1974). Furthermore, relatively high portions of S-European and Central-European plants (especially represented by geophytes) are also significant for the flora of forests, indicating the transitional position of the studied area between the two phytogeographical regions.

Grasslands (G) are seminatural habitats formed during prehistorical and historical times by timbering and burning the woodland in order to obtain room and food for live stocks (cf. BONN & POSCHOLD, 1998). According to ŠOŠTARIĆ (2004), anthropogenic impacts on the forest vegetation in the continental part of Croatia has beginning early in the Neolithic, and the development of grasslands for animal grazing started perhaps between the Bronze Age until the Iron Age. However, these processes have given traces in their recent flora; Illyrian-Balkan plants lack completely, and the total amount of cosmopolites is higher than in wood vegetation. Grasslands have central position between S-European, Central-European, European and Eurasiatic plants. The higher frequency of S-European plants, which corresponds with geographical position of the area, is pointed in log-linear analysis.

Both the wood and grassland vegetations are free from neophytes. This can be explained by the "immunity" of natural, undisturbed plant communities against hemerochoric species, or by the immigration conditions as discussed by SUKOPP & TREPL (1987).

The vegetation of the margins and shrubs of the woodland edges and the roadsides (S) has always been under strong and constant human impact. As a consequence, the flora is dominated by Eurasiatic plants and cosmopolites. In Figure 2, this vegetation type is located between SE-European-Pontic and Mediterranean plants on one side, and neophytes on the other. Such position indicates that these habitats are relatively warm and dry, enabling the existence of the plants originating from South and South-East, but some degree of instability has allowed the colonisation of neophytes. Results of log-linear analysis show higher frequencies of therophytic cosmopolites and therophytic neophytes in this type of vegetation. However, this tendency is even more prominent in the weed and ruderal vegetation (W). Constant and profound anthropogenic disturbance through tilth of gardens, orchards, vineyards, crops, live stock breeding and similar activities, has given a flora characterised by a high amount of therophytic neophytes and cosmopolites.

Very specific habitats are those influenced by water. The aquatic habitats (A) are floristically the poorest and the simplest ones. The water is a main and dominant ecological factor and, therefore, the resulting flora has no special phytogeographical peculiarities. Circumholoarctic species, besides the cosmopolites ones, are dominant. Moist shrubs and gallery woods alongside the river (M) comprise terrestrial and semiterrestrial (inundated) habitats and consequently are more complex. Mediterranean and Illyrian-Balkan plants lack, but the frequency of Eurasiatic and Circumholoarctic hemicryptophytes and Eurasiatic phanerophytes is the highest among all terrestrial habitat types. This shows again the influence of water as an equalizing ecological factor.

The cross-spectrum shows that the geophytes, phanerophytes and hemicryptophytes are the closest group to many chorological groups. Therefore, plants belonging to these life forms are the main basis of diversity from chorological point of view. Hemicryptophytes, phanerophytes and therophytes are the most diverse life forms, composed of all chorological groups, but with the prevalence of Eurasiatic plants. The high share of European plants is significant for phanerophytes and especially for chamaephytes. Chamaephytes and geophytes are also characterised by high share of South- and Central-European plants. Therefore, these life forms, especially quantitatively superior geophytes, mainly cause the transitional phytogeographical position of the studied area as previously discussed. Therophytes are characterised, besides Eurasiatic group, by neophytes. As already presented, neophytes are connected mostly with the weed and ruderal vegetation. Therefore, this life form can also be an indication of human disturbance because this life form is typical for sinantropic and ruderal species. Hydrophytes, the plants which inhabit the Kupa river, are representatives of only two groups, Circumholoarctic and cosmopolites. This also indicates that water flora does not reflect local phytogeographical peculiarities.

The α-diversity index of the studied area is high, and compared with areas of other specific regions in Croatia, it indicates that the Vukova Gorica region is one of the most floristically rich region of Croatia.

In conclusion, it can be stated that the flora of the studied area is the result of natural and historical circumstances and long yet extensive anthropogenic impact in one of the most diverse areas of Croatia.

Unfortunately, diminishing of the diversity of the flora is to be expected. The main threat to the present state of diversity is the loss of seminatural habitats. Grasslands, which are the richest habitat type in the studied area, are especially threatened. The process of grassland degradation started with the decline in population and substantial reduction in traditional methods of managing. Without cattle and regular mowing, grasslands gradually turned into shrubs and forests (Radović, 2000), which are unsuitable habitats for most open habitat species.

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Appendix 1. – List of the taxa of vascular plants found in the Vukova Gorica region.

	Chorotype	Life form	Habitat
PTERIDOPHYTA			
Equisetaceae			
Equisetum arvense L.	10	H	W
Equisetum hiemale L.	10	H	M
Equisetum sylvaticum L.	10	H	B
Aspleniaceae			
Asplenium ruta-muraria L.	10	H	B,OH,S
Asplenium scolopendrium L.	10	H	B
Asplenium trichomanes L.	11	H	B,OH
Athyriaceae			
Athyrium filix-femina (L.) Roth	10	H	B,OH
Cystopteris fragilis (L.) Bernh.	11	H	B
Matteuccia struthiopteris (L.) Tod.	10	H	M
Dryopteridaceae			
Dryopteris affinis (Lowe) Fraser-Jenk.	8	H	B
Dryopteris carthusiana (Vill.) H. P. Fuchs	10	H	B
Dryopteris dilatata (Hoffm.) A. Gray	10	H	B
Dryopteris filix-mas (L.) Schott	11	H	B,OH
Gymnocarpium robertianum (Hoffm.) Newman	10	G	B
Polystichum aculeatum (L.) Roth	11	H	B
Polystichum setiferum (Forskål) Woyn.	10	H	B
Hypolepidaceae			
Pteridium aquilinum (L.) Kuhn	11	G	G
Polypodiaceae			
Polypodium vulgare L.	11	H	B,OH
SPERMATOPHYTA			
CONIFEROPHYTINA			
Cupressaceae			
Juniperus communis L.	10	P	G
Pinaceae			
Abies alba Mill.	3	P	B
Pinus strobus L.	12	P	OH
Pinus sylvestris L.	9	P	OH
MAGNOLIOPHYTINA			
Magnoliatae			
Aceraceae			
Acer campestre L.	8	P	B,OH
Acer obtusatum Willd.	2	P	OH
Acer pseudoplatanus L.	7	P	OH

	Chorotype	Life form	Habitat
Adoxaceae			
Adoxa moschatellina L.	10	G	OH
Amaranthaceae			
Amaranthus hybridus L.	11	T	W
Amaranthus lividus L.	11	T	W
Amaranthus retroflexus L.	11	P	W
Apiaceae			
Aegopodium podagraria L.	9	H	B,OH,M
Aethusa cynapium L.	9	T	S
Angelica sylvestris L.	9	H	G,M,S
Anthriscus sylvestris (L.) Hoffm.	9	H	B,OH
Astrantia major L.	8	H	B
Carum carvi L.	9	H	G
Chaerophyllum hirsutum L.	7	H	B
Daucus carota L.	9	H	G
Eryngyum amethystinum L.	1	H	G
Hacquetia epipactis (Scop.) DC.	2	H	B
Heracleum sphondylium L.	9	H	G,M
Pastinaca sativa L.	9	H	G
Peucedanum cervaria (L.) Lapeyr.	5	H	G
Peucedanum oreoselinum (L.) Moench	8	H	G
Pimpinella major (L.) Huds.	8	H	S
Pimpinella saxifraga L.	9	H	G
Sanicula europaea L.	11	H	B,OH
Selinum carvifolia (L.) L.	9	H	S
Torilis japonica (Houtt.) DC.	9	H	S
Apocynaceae			
Vinca minor L.	7	Ch	OH
Araliaceae			
Hedera helix L.	7	P	B,OH
Aristolochiaceae			
Asarum europaeum L.	9	H	B,OH
Asteraceae			
Achillea millefolium L.	11	H	G
Ambrosia artemisiifolia L.	12	T	S,W
Anthemis arvensis L.	11	T	W
Arctium lappa L.	9	H	M
Artemisia vulgaris L.	11	Ch	S
Bellis perennis L.	7	H	G,S
Buphthalmum salicifolium L.	7	H	OH
Carlina acaulis L.	3	H	G
Carlina vulgaris L.	7	H	G

	Chorotype	Life form	Habitat
Centaurea jacea L.	9	H	G
Centaurea macroptylon Borbàs	8	H	G,S
Centaurea nigrescens Willd.	3	H	G,S
Centaurea pannonica (Heuff.) Simonk.	5	H	G
Centaurea scabiosa L.	9	H	G
Cirsium arvense (L.) Scop.	9	G	S,W
Cirsium montanum (Willd.) Spreng.	3	H	S
Cirsium oleraceum (L.) Scop.	9	H	M
Cirsium vulgare (Savi) Ten.	9	H	S
Conyza canadensis (L.) Cronquist	12	T	W
Doronicum austriacum Jacq.	3	H	B
Erechtites hieracifolia (L.) DC.	12	T	S
Erigeron annuus (L.) Pers.	12	H	W
Eupatorium cannabinum L.	9	H	S
Galinsoga ciliata (Raf.) S. F. Blake	12	T	W
Galinsoga parviflora Cav.	12	T	W
Inula conyza DC.	3	H	B
Inula helenium L.	12	H	S
Inula salicina L.	9	H	G
Leucanthemum vulgare Lam.	9	H	G
Petasites hybridus (L.) P. Gaertner, B. Mey. & Scherb.	9	G	M
Pulicaria dysenterica (L.) Bernh.	3	H	M
Rudbeckia laciniata L.	12	H	M
Senecio erucifolius L.	9	H	G
Senecio nemoralis subsp. *fuchsii* (C. C. Gmel.) Čelak.	7	H	B,M
Senecio ovirensis (Koch) DC.	7	H	B
Serratula tinctoria L.	9	G	OH
Solidago virgaurea L.	9	H	OH,G
Telekia speciosa (Schreb.) Baumg.	5	H	M
Balsaminaceae			
Impatiens glandulifera Royle	12	T	M
Impatiens noli-tangere L.	9	T	M
Berberidaceae			
Berberis vulgaris L.	9	P	OH
Epimedium alpinum L.	2	G	B,OH
Betulaceae			
Alnus glutinosa (L.) Gaertn.	9	P	M
Alnus incana (L.) Moench.	10	P	M
Alnus x *pubescens* Tausch	10	P	M
Betula pendula Roth	9	P	OH
Boraginaceae			
Echium vulgare L.	8	H	G,S
Myosotis arvensis (L.) Hill.	9	T	S
Myosotis ramosissima Rochel	9	T	W

	Chorotype	Life form	Habitat
Myosotis scorpioides L.	10	H	M
Omphalodes verna Moench	2	H	B
Pulmonaria officinalis L.	8	H	B,OH
Symphytum officinale L.	8	H	M,S
Symphytum tuberosum L.	3	G	B,OH
Brassicaceae			
Alliaria petiolata (M. Bieb.) Cavara & Grande	9	H	B
Arabidopsis thaliana (L.) Heynh.	11	T,H	W
Arabis hirsuta (L.) Scop.	11	H	S,W
Armoracia rusticana P. Gaertner, B. Mey. & Scherb	11	G	M
Barbarea vulgaris R. Br.	11	H	S
Brassica rapa L.	12	T	W
Capsella bursa-pastoris (L.) Medik.	11	T	S,W
Cardamine amara L.	9	H	M
Cardamine bulbifera (L.) Crantz	7	G	B
Cardamine enneaphyllos (L.) Crantz	3	G	B
Cardamine flexuosa With.	11	H	B
Cardamine hirsuta L.	11	T,H	S,W
Cardamine impatiens L.	9	H	B
Cardamine pratensis L.	10	H	G
Cardamine trifolia L.	2	G	B
Cardamine waldsteinii Dyer	2	H	B
Cardaminopsis arenosa (L.) Hayek	8	T	B
Lunaria annua L.	6	H	S
Lunaria rediviva L.	8	H	B
Rorippa sylvestris (L.) Besser	9	H	S
Sinapis arvensis L.	11	T	W
Campanulaceae			
Campanula patula L.	8	H	G
Campanula persicifolia L.	9	H	B
Campanula trachelium L.	9	H	B,OH,S
Cannabidaceae			
Humulus lupulus L.	9	H	M,S
Caprifoliaceae			
Sambucus ebulus L.	8	H	S
Sambucus nigra L.	8	P	S
Viburnum opulus L.	9	P	S
Carpinaceae			
Carpinus betulus L.	7	P	OH

	Chorotype	Life form	Habitat
Caryophyllaceae			
Arenaria serpyllifolia L.	11	T	W
Cerastium glomeratum Thuill.	11	T	W
Cerastium sylvaticum Waldst.	8	H	B,OH
Cucubalus baccifer L.	9	H	S
Lychnis flos-cuculi L.	9	H	G
Minuartia viscosa (Schreb.) Schinz & Thell	6	T,H	W
Moehringia muscosa L.	3	H	B
Moehringia trinervia (L.) Clairv.	9	B	
Myosoton aquaticum (L.) Moench	9	G	M
Saponaria officinalis L.	11	H	M
Silene dioica (L.) Clairv.	9	H	B
Silene latifolia subsp. *alba* (Mill.) Greuter & Burdet	9	T,H	S
Silene vulgaris subsp. *angustifolia* Hayek	3	Ch	G
Stellaria graminea L.	9	H	G
Stellaria holostea L.	9	Ch	B,OH
Stellaria media (L.) Vill.	11	T,H	W
Stellaria nemorum subsp. *glochidisperma* Murb.	7	H	B
Celastraceae			
Euonymus europaeus L.	9	P	OH,S
Euonymus latifolius (L.) Mill.	1	P	OH
Euonymus verrucosus Scop.	5	P	B
Chenopodiaceae			
Chenopodium album L.	11	T	W
Chenopodium polyspermum L.	9	T	W
Cichoriaceae			
Aposeris foetida (L.) Less.	3	H	B,OH
Cichorium intybus L.	11	H	G,S
Crepis biennis L.	7	H	G,S
Crepis capillaris (L.) Wallr.	11	T	G
Hieracium laevigatum agg.	10	H	OH
Hieracium murorum L.	9	H	B
Hieracium piliferum Hoppe	3	H	G
Hieracium pilosella L.	5	G	
Hieracium sabaudum L.	7	H	OH
Hieracium virosum Pall.	9	H	OH
Hypochoeris radicata L.	3	H	G
Lactuca serriola L.	11	H	W
Lactuca virosa L.	9	T,H	S
Lapsana communis L.	9	H	OH
Leontodon autumnalis L.	9	H	G
Leontodon hispidus L.	8	H	G
Mycelis muralis (L.) Dumort.	7	H	B
Picris hieracioides L.	9	H	S,W
Sonchus asper (L.) Hill	9	T	S

	Chorotype	Life form	Habitat
Sonchus oleraceus L.	11	T	S
Taraxacum officinale Weber	11	H	G,S
Tussilago farfara L.	9	H	S
Cistaceae			
Helianthemum nummularium (L.) Mill.	7	Ch	G
Convolvulaceae			
Calystegia sepium (L.) R. Br.	11	H	S,W
Convolvulus arvensis L.	11	H	S,W
Cornaceae			
Cornus mas L.	3	P	B,OH
Cornus sanguinea L.	8	P	B,OH
Corylaceae			
Corylus avellana L.	8	P	B,OH
Crassulaceae			
Sedum sexangulare L.	7	Ch	G
Cucurbitaceae			
Echinocystis lobata (Michx.) Torr. & A. Gray	12	T	M
Cuscutaceae			
Cuscuta epithymum (L.) L.	9	T	G
Dipsacaceae			
Dipsacus fullonum L.	11	H	S
Knautia arvensis (L.) Coult.	9	H	G
Knautia drymeia Heuff.	2	H	B,OH
Scabiosa columbaria L.	3	H	G
Succisa pratensis Moench	9	H	G
Ericaceae			
Calluna vulgaris (L.) Hull	4	Ch	G
Euphorbiaceae			
Euphorbia brittingeri Samp.	3	H	G
Euphorbia carniolica Jacq.	2	H	B
Euphorbia cyparissias L.	9	H	S
Euphorbia dulcis L.	7	G	B
Euphorbia esula L.	9	H	W
Euphorbia exigua L.	3	T	W
Euphorbia helioscopia L.	11	T	W
Mercurialis perennis L.	8	G	B,OH

	Chorotype	Life form	Habitat
Fabaceae			
Anthyllis vulneraria subsp. *polyphylla* (DC.) Nyman	7	H	G
Astragalus glycyphyllos L.	9	H	S
Chamaecytisus supinus (L.) Link	8	Ch	OH
Chamaespartium sagittale (L.) P. E. Gibbs	3	Ch	G
Coronilla varia L.	8	H	S
Dorycnium pentaphyllum subsp. *herbaceum* (Vill.) Rouy	3	H	G
Genista germanica L.	7	Ch	G
Hippocrepis comosa L.	3	H	G
Lathyrus niger (L.) Bernh.	8	G	OH
Lathyrus pratensis L.	9	H	S
Lathyrus sylvestris L.	8	H	S
Lathyrus tuberosus L.	9	H	G
Lathyrus vernus (L.) Bernh.	8	G	B
Lotus corniculatus L.	11	H	G
Lotus uliginosus Schkuhr	9	H	G
Medicago lupulina L.	11	T	G,S
Medicago sativa subsp. *falcata* (L.) Arcang.	9	H	M
Medicago sativa L. subsp. *sativa*	11	H	G,S
Melilotus alba Medik.	9	H	S
Melilotus officinalis (L.) Pall.	9	H	S
Ononis spinosa L.	8	Ch	G
Robinia pseudacacia L.	12	P	S
Trifolium arvense L.	9	T	G
Trifolium campestre Schreb.	11	T	G
Trifolium fragiferum subsp. *bonannii* (C. Presl) Soják	11	H	G
Trifolium montanum L.	9	H	G
Trifolium patens Schreb.	3	T	G
Trifolium pratense L.	9	H	G
Trifolium repens L.	11	H	G,S
Vicia cassubica L.	8	H	W
Vicia cracca L.	9	H	G,S
Vicia dumetorum L.	9	H	S
Vicia sativa subsp. *cordata* (Hoppe) Asch. & Graebn.	5	G	
Vicia sepium L.	9	H	M
Vicia tetrasperma (L.) Schreb.	9	T	G
Fagaceae			
Castanea sativa Mill.	3	P	OH
Fagus sylvatica L.	7	P	B
Quercus cerris L.	3	P	OH
Quercus petraea (Matt.) Liebl.	7	P	OH
Fumariaceae			
Corydalis cava (L.) Schweigg. & Körte	9	G	B
Corydalis solida (L.) Clairv.	9	G	B
Pseudofumaria alba (Mill.) Lidén	1	H	B

	Chorotype	Life form	Habitat
Gentianaceae			
Centaurium erythraea Rafn.	11	T,H	G
Gentiana asclepiadea L.	3	H	B,OH
Gentiana cruciata L.	9	H	G
Geraniaceae			
Geranium columbinum L.	9	T	S
Geranium phaeum L.	3	H	B
Geranium robertianum L.	11	T,H	B,OH
Geranium sanguineum L.	3	H	G
Globulariaceae			
Globularia punctata Lapeyr.	3	H	G
Haloragaceae			
Myriophyllum spicatum L.	11	Hy	A
Hydrophyllaceae			
Phacelia tanacetifolia Benth.	12	T	W
Hypericaceae			
Hypericum hirsutum L.	11	H	S
Hypericum humifusum L.	11	T,H	S
Hypericum perforatum L.	11	H	G
Junglandaceae			
Juglans regia L.	12	P	OH
Lamiaceae			
Ajuga genevensis L.	9	H	G
Ajuga reptans L.	9	H	G,S
Calamintha sylvatica Bromf.	3	H	B
Clinopodium vulgare L.	11	H	G,S
Galeopsis pubescens Besser	7	T	M
Galeopsis speciosa Mill.	8	T	M
Glechoma hederacea L.	10	H	G,S
Glechoma hirsuta Waldst. & Kit.	3	H	B,OH
Lamiastrum galeobdolon (L.) Ehrend. & Polatschek	9	Ch	B,OH
Lamium maculatum L.	9	H	M
Lamium orvala L.	2	H	B
Lamium purpureum L.	9	T	W
Lycopus europaeus L. subsp. *europaeus*	9	H	M
Lycopus europaeus subsp. *mollis* (A. Kern.) Skalický	9	H	M
Melissa officinalis L.	1	H	S
Melittis melissophyllum L.	7	H	OH
Mentha arvensis L.	10	H	W
Mentha longifolia (L.) Huds.	11	H	S
Origanum vulgare L.	9	H	G

	Chorotype	Life form	Habitat
Prunella laciniata (L.) L.	3	H	G
Prunella vulgaris L.	11	H	G
Salvia glutinosa L.	9	H	B
Salvia pratensis L.	8	H	G
Salvia verticillata L.	3	H	S
Saturea montana L.	3	Ch	OH
Scutellaria galericulata L.	10	M	
Stachys annua (L.) L.	8	T	W
Stachys officinalis (L.) Trevis.	8	H	G
Stachys palustris L.	10	G	G
Stachys sylvatica L.	9	H	B,OH
Teucrium chamaedrys L.	3	Ch	G
Thymus pulegioides L.	9	Ch	G
Linaceae			
Linum catharticum L.	11	T	G
Linum usitatissimum L.	12	T	S
Lythraceae			
Lythrum salicaria L.	11	H	M
Malvaceae			
Malva alcea L.	3	H	S
Malva sylvestris L.	11	H	S
Oleaceae			
Fraxinus ornus L.	3	P	OH
Ligustrum vulgare L.	7	P	OH
Fraxinus excelsior L.	8	P	M
Onagraceae			
Circaea lutetiana L.	11	H	B
Epilobium hirsutum L.	9	H	S
Epilobium parviflorum Schreb.	9	H	S,W
Epilobium tetragonum subsp. *lamyi* (F. W. Schultz) Nyman	7	H	B
Oxalidaceae			
Oxalis acetosella L.	11	H,G	B,OH
Oxalis stricta L.	12	T	W
Papaveraceae			
Chelidonium majus L.	11	H	S
Papaver rhoeas L.	11	T	W
Plantaginaceae			
Plantago lanceolata L.	11	H	G
Plantago major L.	9	H	S
Plantago media L.	9	H	G

	Chorotype	Life form	Habitat
Polygalaceae			
Polygala comosa Schkuhr	9	H	G
Polygala vulgaris L.	9	H	G
Polygonaceae			
Fallopia convolvulus (L.) Á. Löve	11	T	M,S
Polygonum aviculare L.	11	T	S,W
Polygonum lapathifolium L.	11	T	M
Polygonum mite Schrank	8	T	M
Polygonum persicaria L.	11	T	W
Rumex acetosa L.	11	H	G
Rumex acetosella L.	11	H,G	G
Rumex crispus L.	11	H	G
Rumex obtusifolius L.	9	H	G
Rumex patientia L.	5	H	S
Portulacaceae			
Portulaca oleracea L.	11	T	W
Primulaceae			
Anagalis arvensis L.	11	T	W
Cyclamen purpurascens Mill.	2	G	B,OH
Lysimachia nummularia L.	8	Ch	W
Lysimachia punctata L.	5	H	S
Lysimachia vulgaris L.	9	H	S
Primula vulgaris Huds.	3	H	OH,G
Pyrolaceae			
Monotropa hypopytis L.	10	G	B
Ranunculaceae			
Aconitum lycoctonum subsp. *vulparia* (Rchb.) Nyman	9	H	B
Aconitum variegatum L.	7	H	B
Actaea spicata L.	9	H	B
Anemone nemorosa L.	11	G	B,OH
Anemone ranunculoides L.	9	G	B,OH
Clematis vitalba L.	7	P	B,OH,S
Helleborus dumetorum Waldst. & Kit.	7	G	B,OH
Helleborus niger subsp. *macranthus* (Freyn) Schiffn.	2	G	B,OH
Hepatica nobilis Schreb.	11	H	B
Isopyrum thalictroides L.	9	G	B
Ranunculus acris L.	11	H	G
Ranunculus auricomus L.	9	H	B
Ranunculus bulbosus L.	9	G	G
Ranunculus ficaria L.	8	H	M
Ranunculus lanuginosus L.	7	H	B
Ranunculus repens L.	11	H	G,S
Ranunculus sardous Crantz	11	H	G

	Chorotype	Life form	Habitat
Ranunculus trichophyllus Chaix	10	Hy	A
Thalictrum aquilegiifolium L.	9	H	B
Thalictrum lucidum L.	8	H	M
Thalictrum minus L.	11	H	G
Rhamnaceae			
Frangula alnus Mill.	11	P	S
Rhamnus catharticus L.	9	P	S
Rosaceae			
Agrimonia eupatoria L.	10	H	G
Aruncus dioicus (Walter) Fernald	11	H	B
Crataegus laevigata (Poir.) DC.	8	P	B,OH
Crataegus monogyna Jacq.	9	P	B,OH
Filipendula vulgaris Moench	9	H	G
Fragaria vesca L.	11	H	B,OH
Geum urbanum L.	11	H	S
Potentilla erecta (L.) Raeusch.	9	H	G
Potentilla heptaphylla L.	7	H	G
Potentilla micrantha DC.	3	H	B
Potentilla reptans L.	11	H	G
Prunus avium L.	7	P	OH
Prunus cerasifera Ehrh.	5	P	OH
Prunus fruticosa Pall.	9	P	OH
Prunus spinosa L.	9	P	S
Pyrus piraster Burgsd.	9	P	B,OH
Rosa arvensis Huds.	7	Ch	B
Rosa canina L.	11	P	S
Rubus bifrons Tratt.	11	P	S
Rubus caesius L.	9	P	S
Rubus hirtus Waldst. & Kit.	7	P	S
Sanguisorba minor Scop.	9	H	G
Sorbus torminalis (L.) Crantz	9	P	B
Rubiaceae			
Cruciata glabra (L.) Ehrend.	3	H	G
Cruciata laevipes Opiz	3	H	G,S
Galium album Mill.	7	H	G
Galium aparine L.	11	T	S
Galium mollugo L.	9	H	G
Galium odoratum (L.) Scop.	9	G	B,OH
Galium sylvaticum L.	7	G	B
Galium verum L.	11	H	G

	Chorotype	Life form	Habitat
Salicaceae			
Populus nigra L.	11	P	M
Populus tremula L.	9	P	OH,S
Salix alba L. subsp. *alba*	9	P	M
Salix alba subsp.*vitellina* (L.) Arcang.	9	P	M
Salix caprea L.	9	P	OH,S
Salix purpurea L.	9	P	M
Salix triandra L.	9	P	M
Saxifragaceae			
Chrysosplenium alternifolium L.	10	H	B
Saxifraga cuneifolia L.	3	H	B
Scrophulariaceae			
Chaenorhinum minus (L.) Lange	8	T	W
Cymbalaria muralis P. Gaertner, B. Mey. & Scherb.	3	H	B,OH
Euphrasia stricta J. F. Lehm.	8	T	G
Kickxia elatine (L.) Dumort.	1	T	W
Kickxia spurina (L.) Dumort.	9	T	W
Lathraea squamaria L.	9	G	B,OH
Linaria vulgaris Mill.	9	G	G,S
Melampyrum pratense L.	9	T	OH
Melampyrum velebiticum Borbás	2	T	OH
Rhinanthus minor L.	10	T	G
Scrophularia nodosa L.	10	H	S
Verbascum blattaria L.	11	H,T	S
Veronica agrestis L.	9	T	W
Veronica beccabunga L.	10	Hy	A
Veronica chamaedrys L.	9	Ch	G
Veronica montana L.	3	H	B
Veronica officinalis L.	9	H	G
Veronica persica Poir.	11	T	W
Veronica serpyllifolia L.	11	H	G
Veronica urticifolia Jacq.	7	Ch	B
Solanaceae			
Physalis alkekengi L.	3	H	S
Scopolia carniolica Jacq.	2	H	B
Solanum dulcamara L.	11	Ch	M
Solanum nigrum L.	11	T	S
Staphyleaceae			
Staphylea pinnata L.	3	P	B
Thymeleaceae			
Daphne mezereum L.	9	P	B,OH

	Chorotype	Life form	Habitat
Tiliaceae			
Tilia cordata Mill.	8	P	OH
Tilia platyphyllos Scop.	7	P	OH
Ulmaceae			
Ulmus minor Mill.	5	P	M
Ulmus glabra Huds.	11	P	B
Urticaceae			
Urtica dioica L.	11	H	S
Urtica urens L.	11	T	S
Valerianaceae			
Valeriana officinalis L.	9	H	G,S
Verbenaceae			
Verbena officinalis L.	10	T,H	S
Violaceae			
Viola alba subsp. *scotophylla* (Jord.) Nyman	3	H	G
Viola alba Besser subsp. *alba*	3	H	G
Viola arvensis Murray	11	T	W
Viola hirta L.	9	H	G
Viola odorata L.	8	H	G,S
Viola reichenbachiana Boreau	7	H	B,OH
Vitaceae			
Vitis vinifera L.	11	P	S
MAGNOLIOPHYTINA			
Liliatae			
Alismataceae			
Alisma plantago-aquatica L.	11	Hy	A
Amaryllidaceae			
Galanthus nivalis L.	9	G	B,OH
Leucojum vernum L.	8	G	M
Araceae			
Arum maculatum L.	7	G	B
Cyperaceae			
Carex buekii Wimm.	8	G,Hy	M
Carex caryophyllea Latourr.	9	G	G
Carex digitata L.	9	H	B,OH
Carex divulsa subsp. *leersii* (Kneuck.) W. Koch	7	H	S
Carex elata All.	8	H	M
Carex flacca Schreb.	11	G	G,S

	Chorotype	Life form	Habitat
Carex hirta L.	9	H	M,S
Carex pallescens L.	10	H	G
Carex pilosa Scop.	9	H	B,OH
Carex remota L.	10	H	M
Carex sylvatica Huds.	8	H	B,OH
Eleocharis palustris (L.) Roem. & Schult.	11	A	
Scirpus lacustris L.	10	G,Hy	A
Scirpus sylvaticus L.	10	G	A
Dioscoreaceae			
Tamus communis L.	3	G	M
Iridaceae			
Crocus vernus (L.) Hill	3	G	G
Juncaceae			
Juncus effusus L.	9	H	S
Juncus inflexus L.	9	H	S
Luzula pilosa (L.) Wild.	10	H	B,OH
Juncus compressus Jacq.	11	G	A
Juncus tenuis Willd.	11	H	S
Luzula campestris (L.) Lam. & DC.	11	H	G
Liliaceae			
Allium carinatum L.	8	G	G
Allium ursinum L.	7	G	B,M
Allium vineale L.	7	G	G
Anthericum ramosum L.	7	H	G
Asparagus tenuifolius Lam.	3	G	OH
Colchicum autumnale L.	7	G	G,S
Convallaria majalis L.	10	G	OH
Erythronium dens-canis L.	2	G	B
Gagea lutea (L.) Ker-Gawl.	9	G	B
Lilium martagon L.	9	G	B,OH
Ornithogalum pyramidale L.	3	G	G
Ornithogalum umbellatum L.	3	G	G
Paris quadrifolia L.	9	G	B
Polygonatum multiflorum (L.) All.	10	G	B
Scilla bifolia L.	3	G	B
Veratrum album L.	9	H	M
Orchidaceae			
Cephalanthera damasonium (Mill.) Druce	3	G	G
Dactylorhiza fuchsii (Druce) Soó	9	G	B
Dactylorhiza maculata (L.) Soó	9	G	B
Listera ovata (L.) R. Br.	9	G	B,OH
Neottia nidus-avis (L.) Rich.	9	G	B,OH
Orchis morio L.	7	G	G

	Chorotype	Life form	Habitat
Orchis simia Lam.	1	G	G
Orchis tridentata Scop.	3	G	G
Platanthera bifolia (L.) Rich.	9	G	G
Epipactis helleborine (L.) Crantz	9	G	B
Poaceae			
Agrostis capillaris L.	10	H	G
Agrostis stolonifera L.	9	H	A
Anthoxanthum odoratum L.	9	H	G
Arrhenatherum elatius (L.) J. & C. Presl	8	H	G
Brachypodium rupestre (Host) Roem. & Schult.	11	H	G
Brachypodium sylvaticum (Huds.) P. Beauv.	9	H	B,OH
Briza media L.	9	H	G
Bromus commutatus Schrad.	8	T	G
Bromus erectus Huds.	11	H	G
Bromus hordeaceus L.	11	T	G
Bromus ramosus Huds.	9	H	B
Bromus sterilis L.	11	T	S
Calamagrostis epigejos (L.) Roth	8	G	G
Calamagrostis varia (Schrad.) Host	9	H	OH
Cynodon dactylon (L.) Pers.	11	G	S,W
Cynosurus cristatus L.	11	H	G
Dactylis glomerata L.	9	H	G,S
Deschampsia caespitosa (L.) P. Beauv.	11	H	M
Dichanthium ischaemum (L.) Roberty	3	H	W
Digitaria sanguinalis (L.) Scop.	11	T	W
Echinochloa crus-galli (L.) P. Beauv.	11	T	W
Elymus repens (L.) Gould	11	G	G,S
Festuca gigantea (L.) Vill.	9	H	B
Festuca pratensis Huds.	9	H	G
Glyceria maxima (Hartm.) Holmb.	9	H,Hy	M
Glyceria plicata (Fr.) Fr.	11	H,Hy	M
Holcus lanatus L.	9	H	G
Koeleria pyramidata (Lam.) P. Beauv.	7	H	G
Lolium perenne L.	8	H	G
Melica nutans L.	5	B	
Melica uniflora Retz.	7	G	B,OH
Molinia caerulea subsp. *arundinacea* (Schrank) H. Paul	10	H	M
Panicum capillare L.	12	T	W
Phalaris arundinacea L.	10	H,Hy	M
Phleum pratense L.	10	H	G
Poa angustifolia L.	11	H	G
Poa annua L.	11	T,H	S,W
Poa palustris L.	10	H	OH
Poa pratensis L.	10	H	G
Poa trivialis L.	9	H	G
Sesleria tenuifolia Schrad.	1	H	B

	Chorotype	Life form	Habitat
Setaria pumilla (Poir.) Schult.	11	T	W
Sorghum halepense (L.) Pers.	11	G	G
Trisetum flavescens (L.) P. Beauv.	10	H	G
Potamogetonaceae			
Potamogeton lucens L.	10	Hy	A
Potamogeton natans L.	11	Hy	A
Potamogeton perfoliatus L.	11	Hy	A

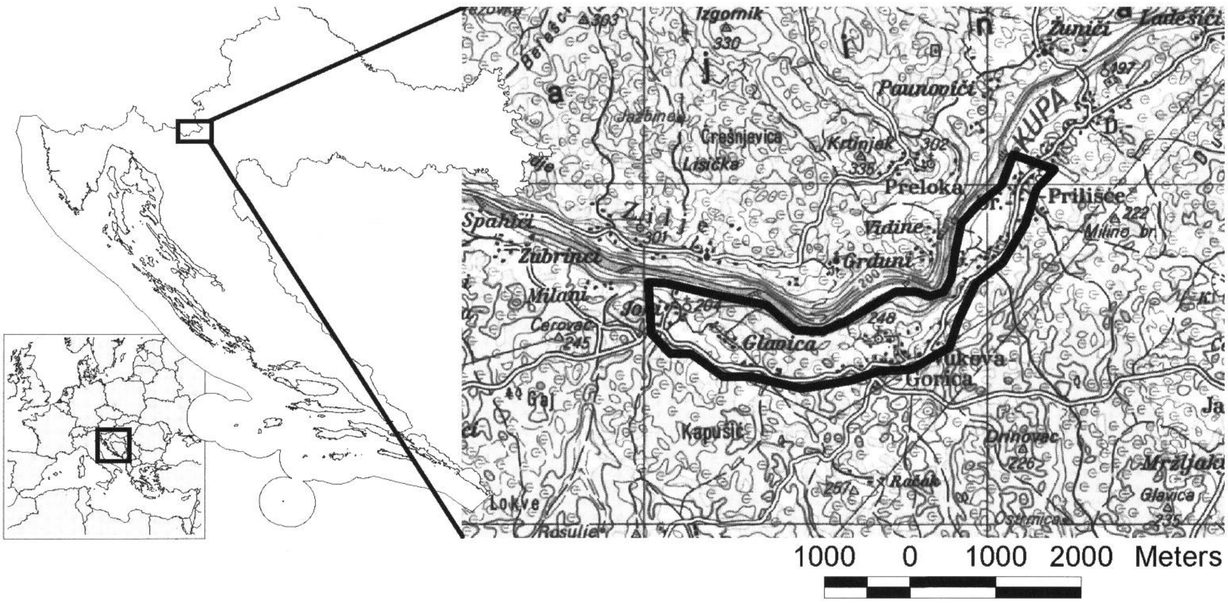

Fig. 1. – Geographical position of the study area.

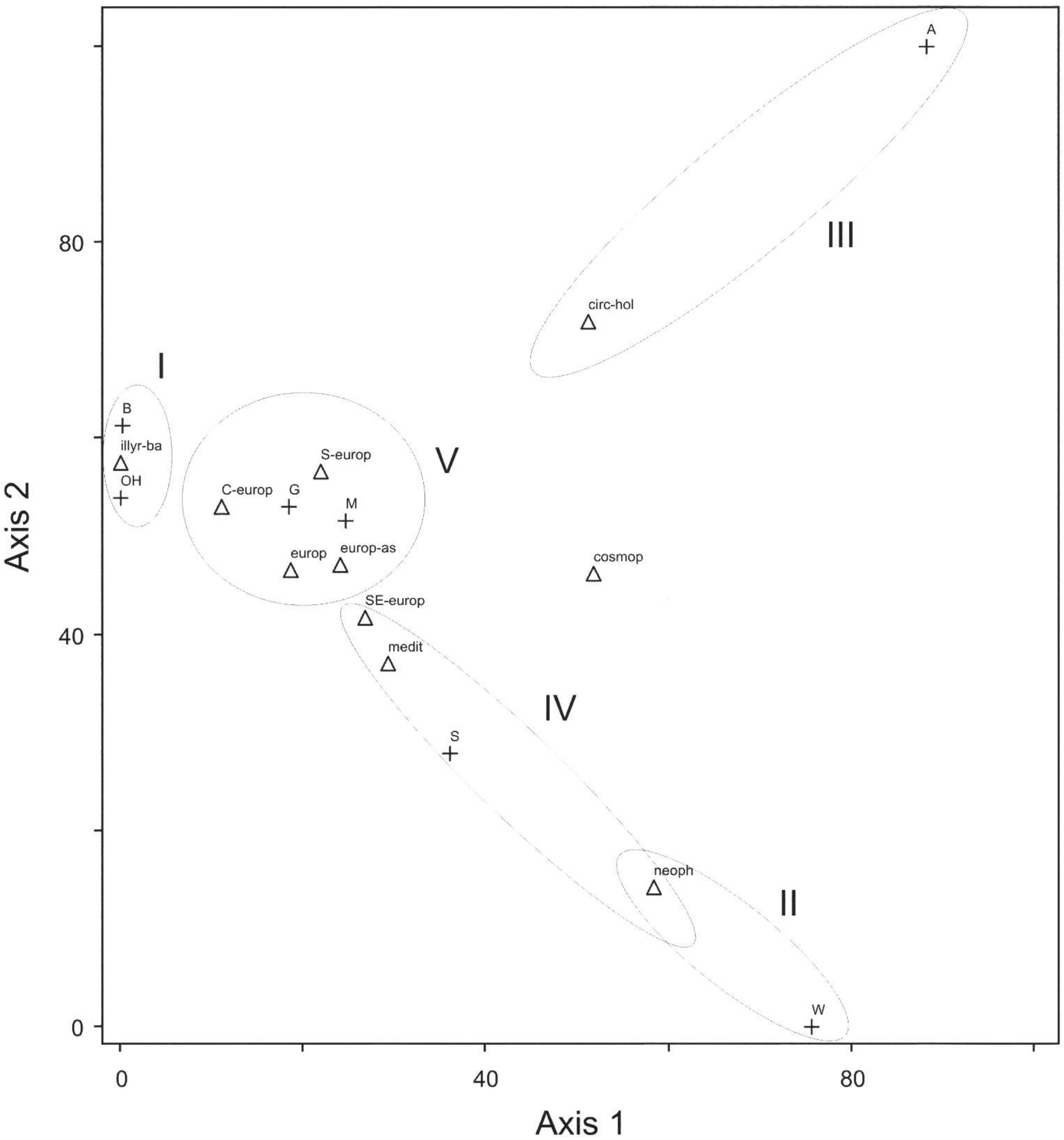

Fig. 2. – Correspondence analysis (CA) explaining the relationships between chorological types and habitats.

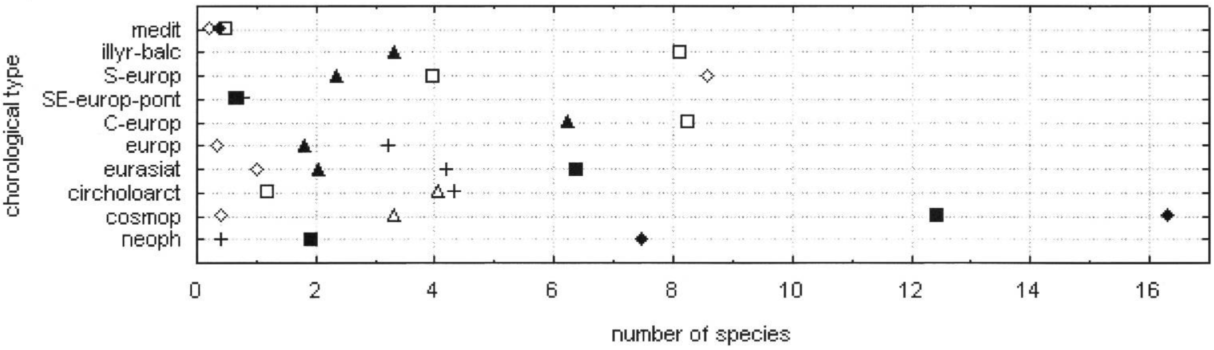

Fig. 3. – Log-linear analysis explaining the differences between observed species frequencies and those expected by chance (according to log-linear analysis of frequency tables) for particular combinations of habitat type and chorological type (negative differences not shown). Symbols used (in brackets): B (□) – beech forest; OH (▲) – oak-hornbeam forest; G (◊) – grasslands and meadows; M (+) – moist shrubs and gallery woods; S (■) – margins and shrubs; W (♦) – weeds and ruderal habitats; and A (B) – aquatic habitats.

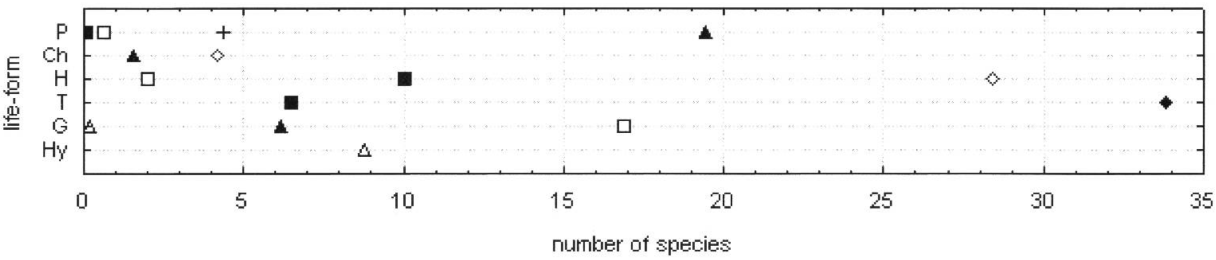

Fig. 4. – Log-linear analysis explaining the differences between observed species frequencies and those expected by chance (according to log-linear analysis of frequency tables) for particular combinations of habitat type and life-form (negative differences not shown). Symbols used (in brackets): B (□) – beech forest; OH (▲) – oak-hornbeam forest; G (◊) – grasslands and meadows; M (+) – moist shrubs and gallery woods; S (■) – margins and shrubs; W (♦) – weeds and ruderal habitats; and A (B) – aquatic habitats.

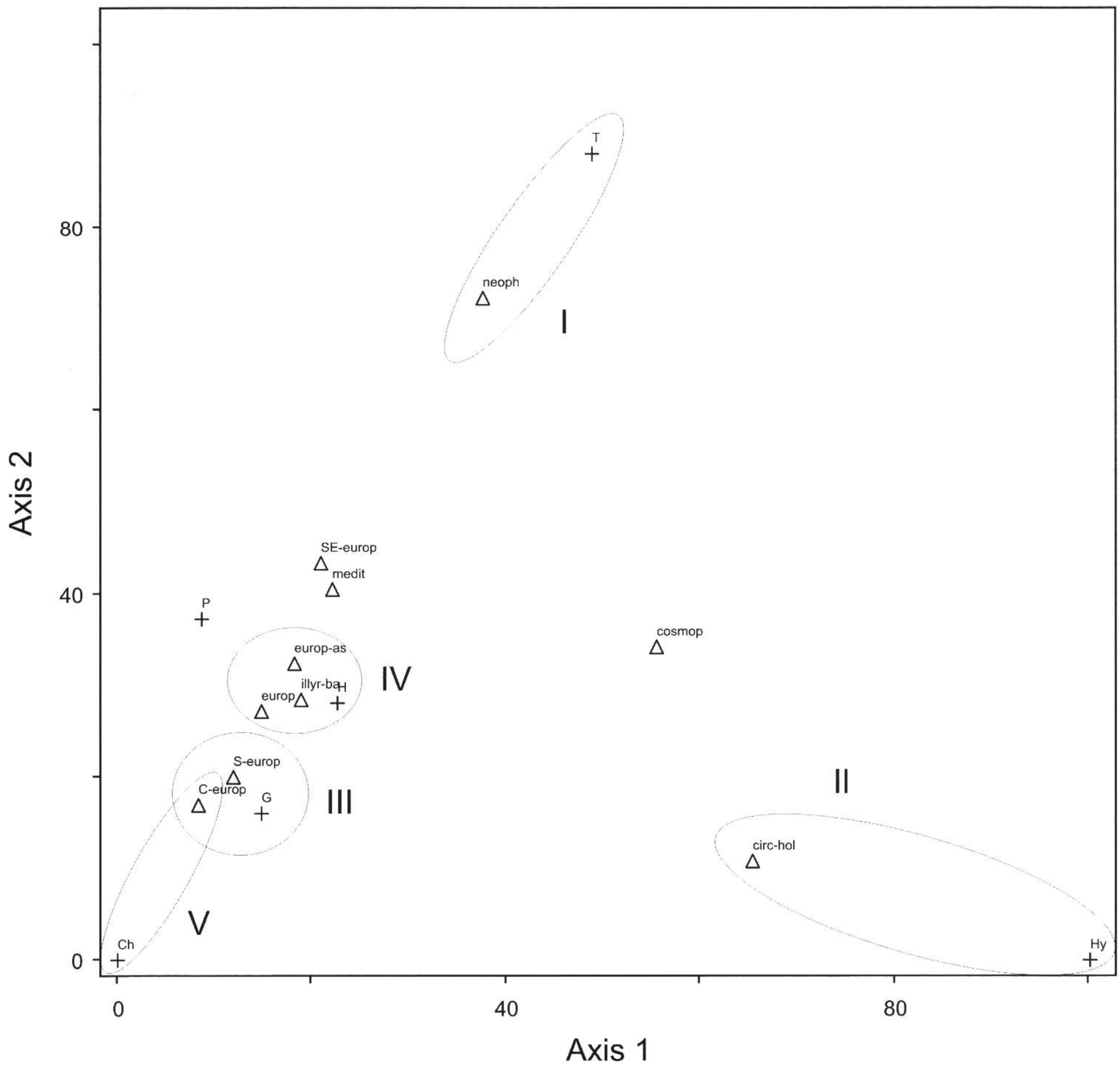

Fig. 5. – Correspondence analysis (CA) explaining the relationships between chorological types and life forms.

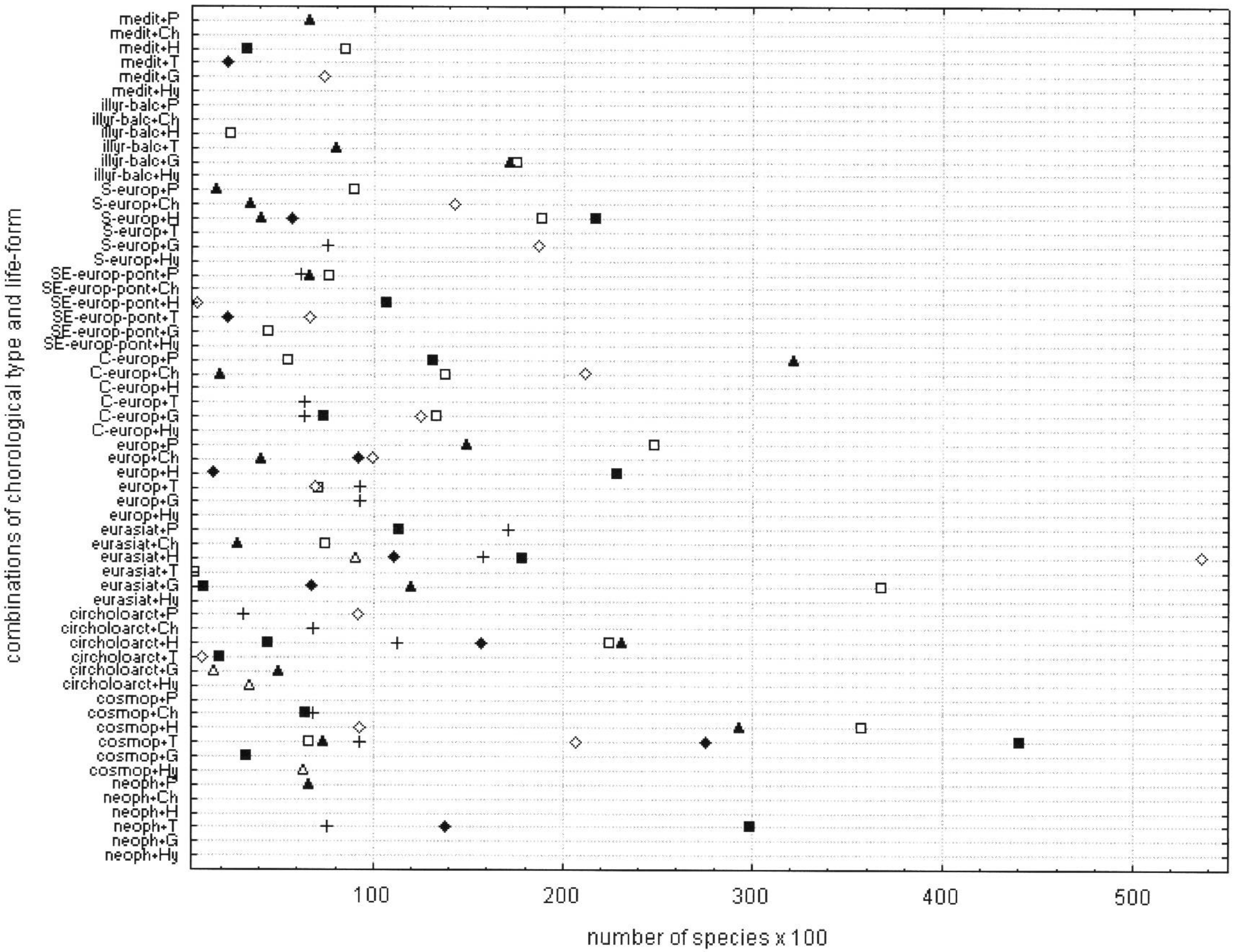

Fig. 6. – Log-linear analysis explaining the differences between observed species frequencies and those expected by chance (according to log-linear analysis of frequency tables) for particular combinations of habitat type, chorological type and life-form (negative differences not shown). Symbols used (in brackets): B (□) – beech forest; OH (▲) – oak-hornbeam forest; G (◊) – grasslands and meadows; M (+) – moist shrubs and gallery woods; S (■) – margins and shrubs; W (♦) – weeds and ruderal habitats; and A (B) – aquatic habitats.

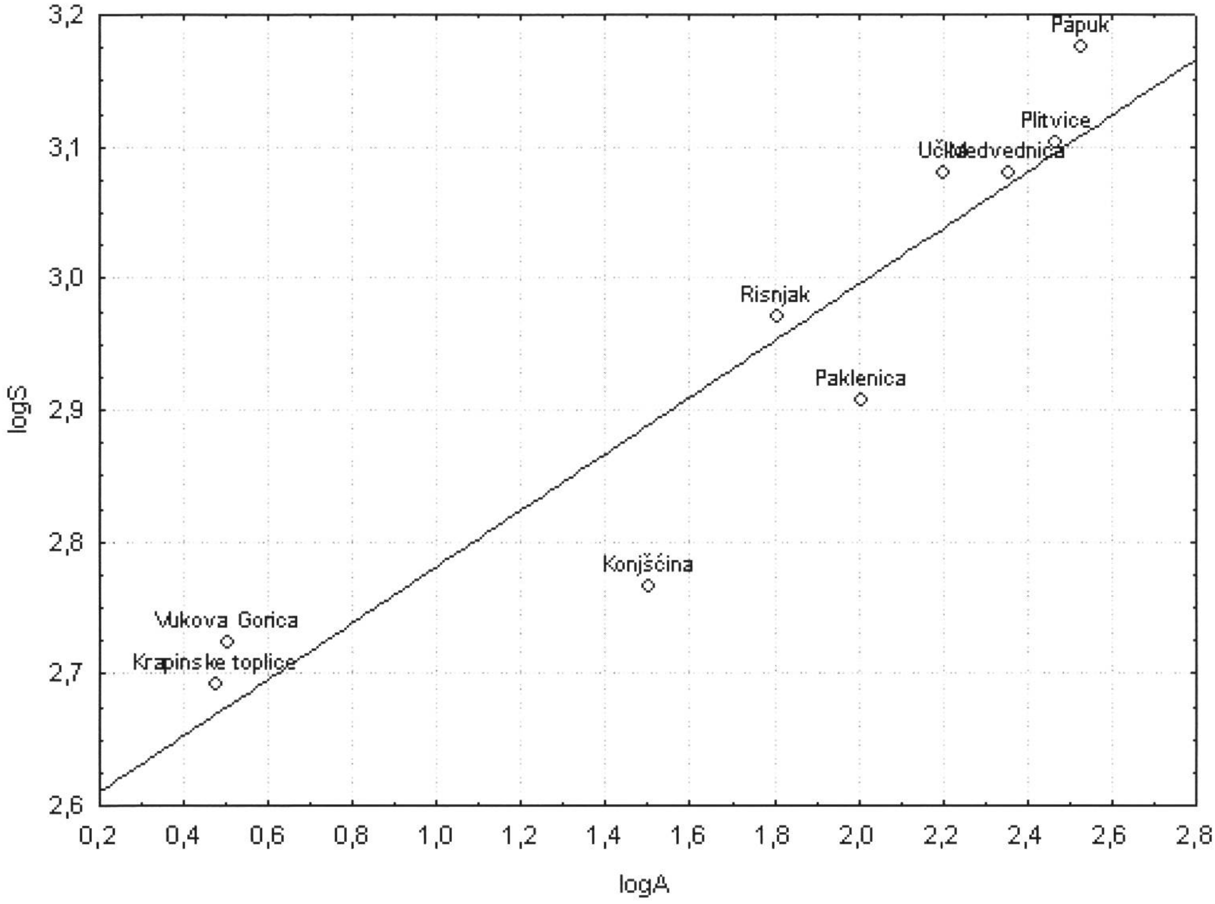

Fig. 7. – Logarithmic regression between the number of species (S) and area (A in km^2) of some specific regions in Croatia. The line follows equation: logS = 0,2139logA + 2,5675.