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Floristical, Ecological and Structural Diversity of Vegetation of Forest Fringes of the Northern Croatia Along a Climatic Gradient

By

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With 5 Figures

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Summary

ČARNI A., FRANJIĆ J., ŠILC U. & ŠKVORC Ž. 2005. Floristical, ecological and structural diversity of vegetation of forest fringes of the Northern Croatia along a climatic gradient. – *Phyton* (Horn, Austria) 45(2): 287–303, with 5 figures. – English with German summary.

The forest fringe vegetation was sampled along a transect from the western to the eastern part of Croatia. In this direction the continentality of the climate increases (e. g. the sum of precipitation per year decreases, the mean annual and extreme temperature increase). The changes in species composition, Ellenberg indicator values and plant functional groups (life history form, life span, phenological groups and classification to the families) have been studied. According to the PCA the vegetation types were settled and communities were defined. On the basis of the species composition the Ellenberg indicator values and plant functional groups were calculated. The analysis shows that the pH on one side and moisture and nutrient on the other (microsite) are perpendicular to the temperature, continentality and altitude (climate). These are two main axes of division of communities. The new association *Origano-Campanuletum bononiensis* is described. Since both mesophilous and thermophilous communities appear over the whole phytogeographical gradient, the changes in functional plant traits in direction continentality, temperature and alti-

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tude have been studied. The proportion of therophytes, annual and biannual plants are higher in the more continental region, whereas in the more humid region geophytes are more common. In the continental parts, that are less favorable, the species of the family *Fabaceae* are more abundant, since they can fix nitrogen from the air. The analysis of the phenological groups shows that in the continental part the vegetation has only one peak of flowering, whereas in more humid areas the flowering period is well distributed throughout the whole vegetation period.

Zusammenfassung

ČARNI A., FRANJIC J., ŠILC U. & ŠKVORC Ž. 2005. Floristische, ökologische und Struktur-Diversität von Waldsaum-Gesellschaften entlang eines klimatischen Gradienten im nördlichen Kroatien. – *Phyton* (Horn, Austria) 45(2): 287–303, mit 5 Abbildungen. – Englisch mit deutscher Zusammenfassung.

Entlang eines Transektes von West- nach Ost-Kroatien wurde die Waldsaumvegetation mit der Methode Braun-Blanquet aufgenommen. Entlang dieses Transektes steigt die Kontinentalität des Klimas (z.B. nimmt die jährliche Niederschlagssumme ab, die Jahresmitteltemperaturen, sowie die Temperaturrextremwerte steigen). Die Änderungen der Artenzusammensetzung, der Zeigerwerte nach Ellenberg und der funktionellen Gruppen der Arten (Lebensform, Ausdauer, phänologische Gruppen und Familienzugehörigkeit) wurden studiert. Aufgrund der Ergebnisse der PCA wurden die Vegetationstypen abgegrenzt und die Pflanzengesellschaften definiert. Die Berechnung der Ellenberg-Zeigerwerte und der funktionellen Artengruppen basiert auf der Artenkombination. Die Auswertung zeigt, daß die Achse, die den pH-Wert und die Feuchtigkeits- und Nährstoffverhältnisse repräsentiert, senkrecht auf die Achse steht, die Temperatur, Kontinentalität und Höhe (Klima) repräsentiert. Dies sind die beiden Hauptachsen für die Gliederung in Gesellschaften. Die Assoziation *Origano-Campanuletum bononiensis* wird neu beschrieben. Da sowohl meso- als auch thermophile Gesellschaften über den gesamten phytogeographischen Gradienten vorkommen, wurden die Änderungen der Verteilung der funktionalen Pflanzenmerkmale (functional plant traits) für Kontinentalität, Temperatur und Höhe untersucht. Dabei wurde festgestellt, daß die Zahl [pro Aufnahme] der Therophyten, der annuellen und biennen Arten in den kontinentaleren Teilen höher ist, während in den humideren Teilen des Gebietes Geophyten häufiger sind. In den ungünstigeren kontinentalen Teilen kommen Vertreter der Familie *Fabaceae*, die Luftstickstoff fixieren können, häufiger vor. Die Analyse der phänologischen Gruppen zeigt für den kontinentalen Teil nur einen Gipfel in der Kurve, während in den humideren Gebieten die Blühperiode gut über die gesamte Vegetationsperiode verteilt ist.

1. Introduction

In the frame of the joint project it was decided to sample and elaborate the forest fringe vegetation in northern Croatia. Fringes are vegetation types that are formed under long lasting human impact on the forest. Different management (mowing, grazing, cutting) forms these very diverse and complicated linear formations. In the modern intense agriculture these traditional features are endangered since they are either eliminated from

the landscape or left to the process of reforestation. The light conditions are about 30–50% of the full insolation, the temperature is lower than in the contact non-forest surfaces, concerning top-soil, nitrogen and phosphorus have also the intermediate position between non-forest and forest sites (DIERSCHKE 1974, MUCINA & KOLBEK 1993).

R. TÜXEN was the first who described the syntaxa appearing on the forest edges in 1952 (TÜXEN 1952). He separated fringe (Saum) communities dominated by high stalked species and grasses from the mantle dominated by shrubs. In the continental part of Europe, the fringe communities on nutrient-rich sites are classified within the Galio-Urticetalia and on more humid sites within the Filipendulion (RODWELL & al. 2002). However, this research focused only on the fringes classified within the Trifolio-Geranietea. The Trifolio-Geranietea vegetation has already been elaborated on a national scale in some European countries (e.g. MÜLLER 1978, MUCINA & KOLBEK 1993, BIONDI & al. 2001 etc.). Some broader syntheses have also been provided (DIERSCHKE 1974, DE FOUCAULT & al. 1983, VALACHOVIČ 2004, ČARNI 2005). The present syntaxonomic division of the class Trifolio-Geranietea in the continental part of Croatia is as follows. There is one order Origanetalia vulgaris that can be divided into two alliances Geranion sanguinei appearing on the warm, nutrient poor sites and Trifolion medii found on mesic sites that are rich in nutrients. Since these communities are limited by summer drought, they disappear towards east and south Europe (VAN GILS & KEYSERS 1977). Therefore they are classified among the syntaxa with central European distribution pattern (PIGNATTI & al. 1995).

Furthermore, in recent years the research studies have been stressing the importance of plant functional diversity as an important factor in ecosystem functioning (DÍAZ & CABIDO 2001). We tried to select the key environmental factors and functional plant groups in these communities. In our study we tried to filter abiotic and biotic factors other than the continentality (that corresponds with temperature and altitude) (LAVOREL & GARNIER 2002). As the relevés are classified into a single syntaxonomical class, or even order, it could be anticipated that they contain a certain degree of uniformity. The vegetation of thermophilous and mesophilous stands was sampled across the region. This enables us to detect the gradient of continentality expressed mainly in diminishing of precipitation and augmentation of the annual and extreme temperature.

2. Methods

The relevés were made in the continental part of Croatia and partly in the neighbouring regions of Slovenia according to the central European method (BRAUN-BLANQUET 1964). The field data have been imported in the Turboveg database (HENNEKENS & SCHAMINÉE 2001) and elaborated by Juice program (TICHÝ 2002). For the numerical analyses the programme package CANOCO 4.02 (TER BRAAK & ŠMILAUER

2002) was used. The cover values were transformed into the ordinal scale as proposed by VAN DER MAAREL (1979). Using Principal Component Analysis (PCA), the main groups of communities presenting the vegetation types were established. The ecological factors were estimated using Ellenberg indicator values (ELLENBERG & al. 1992). The correlation was calculated applying the Canonical Correspondence Analysis (CCA). As the communities are poorly described by the list of species composition (WHITTAKER 1975), we establish the plant functional traits according to KLOTZ & al. 2002 to estimate their ecological function.

Tab. 1. Traits (according to KLOTZ & al. 2002).

Trait	Classes in the matrix
Life form	T: therophytes, G: geophytes, H: hemicryptophytes, C: chamaephytes, P: phanerophytes
Longevity	A: annual, b: biannual, p: perennial
Phenology	0: not available; 1: <i>Corylus-Leucojum</i> -phase, pre-spring; 2: <i>Acer platanoides-Anemone nemorosa</i> -phase, start of early spring; 3: <i>Prunus avium-Ranunculus auricomus</i> -phase, end of early spring; 4: <i>Fagus-Lamium-Strum</i> -phase, start of mid spring; 5: <i>Sorbus aucuparia-Galium odoratum</i> -phase, end of mid spring; 6: <i>Cornus sanguinea-Melica uniflora</i> -phase, start of early summer; 7: <i>Ligustrum-Stachys sylvatica</i> -phase, end of early summer; 8: <i>Clematis vitalba-Galium sylvaticum</i> -phase, mid-summer; 9: <i>Hedera-Solidago</i> -Phase, early autumn; 10: Autumn-phase, autumn.
Family	percentage of <i>Fabaceae</i> and <i>Poaceae</i> from the total species composition

In order to identify the predominant plant traits along the gradient, the matrix of 349 species $\times$ 56 plots (relevés) was multiplied by the matrix of 349 species $\times$ 21 traits that was analysed by means of CCA (DÍAZ BARRADAS & al. 1999, PECO & al. 2005). The nomenclature of plant species is according to EHRENDORFER 1973.

3. Description of the Investigated Area

The research area encompasses the northern (continental) part of Croatia and partly neighbouring parts of Slovenia. The territory was checked and the relevés were taken in the areas from Gorjanci and Žumberak in the west to Bansko Brdo in the east (Fig. 1). The highest mountains reach over 1000 m: Gorjanci and Žumberak 1178 m, Ivančica 1059 m, Medvednica 1030 m, Papuk 953 m, others are lower: Kalnik 642 m, Dilj 401 m, Bilogora 307 m and Bansko Brdo 244 m.

ILIJANIĆ 1963 divided the continental part of Croatia into three climatic regions: in the western part (up to Zagreb, indicated as Area 1 in the text) with a mean yearly rainfall between 1000 and 1200 mm, in a transitional zone from Zagreb to the Orljava river (not far from Slavonski Brod) with a mean yearly rainfall between 800 and 1000 mm (Area 2). In the eastern part of the country (Area 3), there is between 600 and 800 mm of mean yearly rainfall. The mean yearly temperature increases from 10.4 in

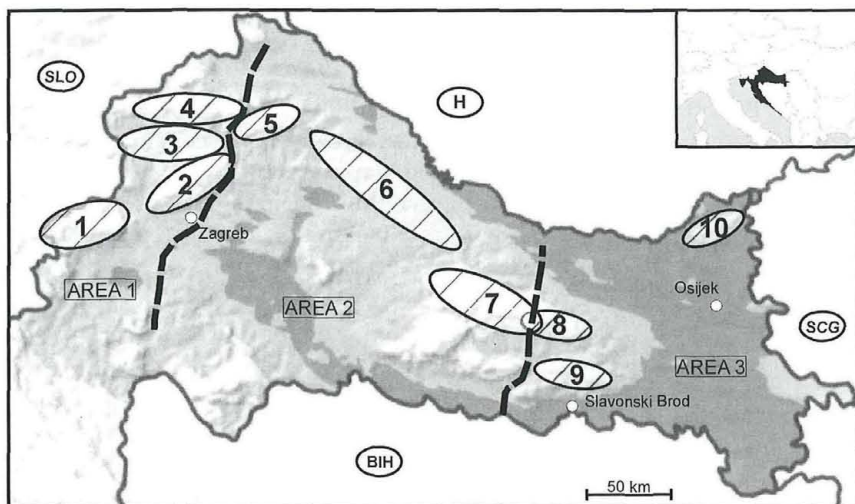


Fig. 1. The research area in Croatia and Slovenia. Sampling regions: 1 – Gorjanci-Žumberak, 2 – Medvednica, 3 – Hrvatsko Zagorje, 4 – Ivančica, 5 – Kalnik, 6 – Bilogora, 7 – Papuk, 8 – Krndija, 9 – Dilj, 10 Bansko Brdo.

the west to 11.6 in the east (ILJANIĆ 1963). Towards the eastern part of the country the character of the climate becomes more and more continental. The climatic conditions are represented by climatic diagrams (Fig. 2) (WALTHER & LIETH 1960).

From the phytogeographical point of view, the area is classified within the Euro-Siberian-North American region (TRINAJSTIĆ 1998). The potential natural vegetation in the lowland is a floodplain forest mainly dominated by *Fraxinus angustifolia* and *Quercus robur*, followed by mixed forests of *Quercus* sp. div. and *Carpinus betulus*, whereas the beech forests are found on the top of the mountains. (FUKAREK & JOVANOVIĆ 1983, BOHN & al. 2003). The relevés were taken in the beech and partly in the *Quercus-Carpinus* vegetation belt.

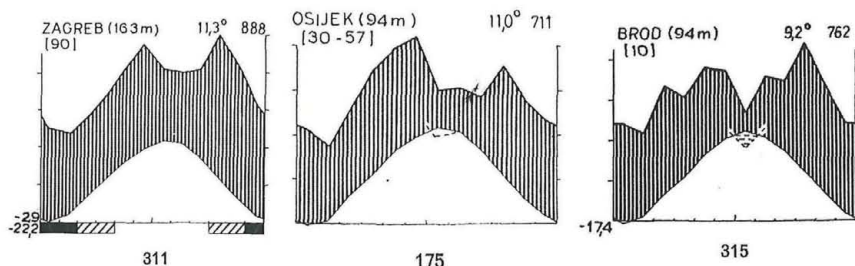


Fig. 2. Climatic diagrams for Zagreb, Slavonski Brod and Osijek (from WALTER & LIETH 1960).

4. Results and Discussion

4.1 Species Composition

The PCA (Fig. 3) of cover data was used to analyse the main variation trends based on species composition. The main groups of communities that appear in the region were detected and classified into the syntaxa. There can be noticed the gradient from thermophilous communities to mesophilous on the Axis 1, and the gradient from heliophilous to the sciophilous on the Axis 2. The communities have been classified into the associations, as follows.

Syntaxonomical scheme

Trifolio-Geranietea T. MÜLLER 1961

Origanetalia vulgaris T. MÜLLER 1961

Trifolion medii T. MÜLLER 1962

Trifolio-Agrimonetum eupatoriae T. MÜLLER 1962 (Tab. 1/1–8)

Trifolio-Melampyretum nemorosi DIERSCHKE 1973 (Tab. 1/9–22)

Geranion sanguinei Tx. in MÜLLER 1961

Origano-Campanuletum bononiensis ass. nova hoc loco (Tab. 1/23–29)

Peucedanetum cervariae KAISER 1926 (Tab. 1/30–32)

Bupleuro longifolii-Laserpitietum latifolii T. MÜLLER 1978 (Tab. 1/33–46)

Laserpitietum sileris SPRINGER 1987 (Tab. 1/47–56)

Description of the syntaxa

Trifolio-Agrimonetum eupatoriae is the central association of the alliance and can be found on mesic sites all over the continental part of Croatia. The dominant species is *Trifolium medium*, while *Agrimonia eupatoria* is partly subdominant. Besides these species *Clinopodium vulgare*, *Centaurea jacea*, *Galium verum*, *Achillea millefolium* agg., and *Erigeron annuus*, are occurring with higher cover values. This fringe type can be found on the edges of grasslands of the *Arrhenatherion* and on the edges of mesophilous grasslands of the *Brometalia*. It was found at altitudes up to 400 m.

Trifolio-Melampyretum nemorosi is easy to find at the beginning of summer because of the golden and violet flowering characteristic species. In addition to the dominant species *Melampyrum nemorosum*, there are also *Centaurea jacea*, *Clinopodium vulgare*, *Knautia drymeia*, *Brachypodium rupestre*, *Galium verum*, to mention only the most abundant ones. In Croatia stands were found in the entire research area on the most humid and nutrient-rich sites. It forms wood margins of hornbeam forests as well as of submontane beech and oak forests. It is in contact with the *Arrhenatherion* grasslands and mesophilous grasslands of the Brome-

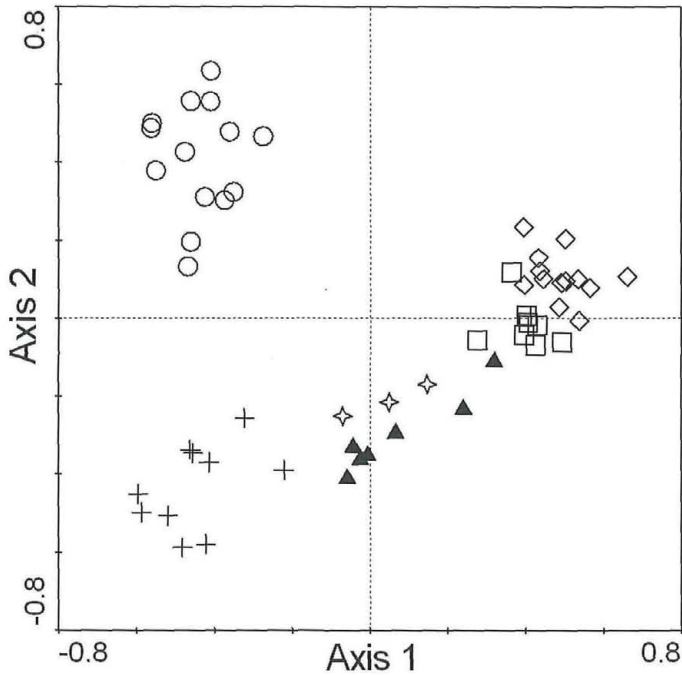


Fig. 3. PCA according to species composition $\square$ Trifolio-Agrimonieta eupatoria; $\diamond$ Trifolio-Melampyretum nemorosi (Trifolion medii), $\blacklozenge$ Origano-Campanuletum bononiensis, $\diamond$ Peucedanetum cervariae, $\circ$ Bupleuro longifolii-Laserpitietum latifolii, $+$ Laserpitietum sileris (Geranion sanguinei). Eigenvalues for first two axes are 0,175 and 0,101 respectively.

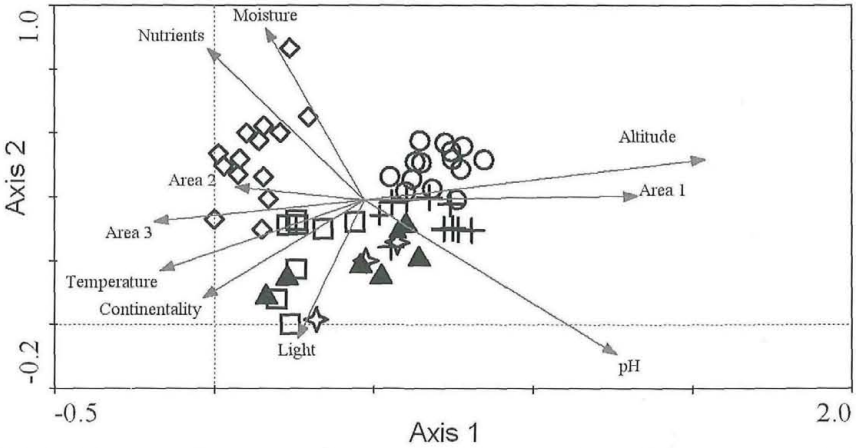


Fig. 4. DCA ordination of sites along main environmental variables considering plant functional traits. Signs for associations see Fig 3.

Table 1, continuation.

20: +; *Melampyrum pratense* 44: +, 47: +; *Melilotus officinalis* 22: +; *Mentha longifolia* 4: +; *Molinia arundinacea* 33: 1, 49: +, 54: +; *Ononis spinosa* 16: +; *Orchis ustulata* 47: +; *Ornithogalum pyrenaicum* 11: +, 43: +; *Ostrya carpinifolia* 44: +; *Oxalis stricta* 5: +; *Paris quadrifolia* 35: +; *Polygala chamaebuxus* 54: +; *Polygala vulgaris* 17: +, 20: +, 32: +; *Populus tremula* 38: +; *Potentilla argentea* 19: +; *Lathyrus niger* 25: +; *Potentilla recta* 32: +; *Primula veris* 8: +, 25: +; *Prunella grandiflora* 50: +, 55: +; *Prunus spinosa* 4: 1, 7: +; *Pseudosimachion spicatum* s. *barrelieri* 46: +; *Pulicaria dysenterica* 16: +; *Pulmonaria officinalis* 9: +, 17: +, 34: +; *Quercus cerris* 43: +; *Quercus pubescens* 55: +; *Rhamnus cathartica* 43: +, 46: +; *Rosa gallica* 5: 1, 8: +, 9: +; *Rosa pendulina* 33: +, 34: +; *Rubus caesius* 6: +; *Rubus idaeus* 41: +; *Rumex sanguineus* 21: +; *Salvia glutinosa* 48: +; *Salvia nemorosa* 23: +; *Sambucus ebulus* 7: +, 19: +; *Sanguisorba minor* 32: +, 38: +, 55: +; *Sanicula europaea* 44: +; *Scabiosa triandra* 49: +, 51: +; *Scorzonera austriaca* 49: +; *Scrophularia nodosa* 14: +, 45: +; *Sedum maximum* 8: +, 25: +; *Senecio ovatus* 35: +, 38: +; *Sesleria kalnikensis* 34: +, 47: +; *Solidago canadensis* 15: +, 19: 1; *Solidago gigantea* 15: +; *Sorbus aria* 33: +; *Stachys sylvatica* 34: +, 35: +, 45: +; *Tanacetum vulgare* 21: +; *Torilis japonica* 21: +, 22: +; *Tragopogon orientalis* 8: +, 50: +; *Trifolium alpestre* 25: +; *Trifolium ochroleucon* 7: +, 12: +; *Trifolium repens* 7: +, 9: +; *Trifolium rubens* 34: +, 40: +; *Veratrum nigrum* 25: +, 37: +; *Verbascum nigrum* 32: +; *Veronica arvensis* 38: +; *Veronica serpyllifolia* 49: +; *Vicia angustifolia* 2: +, 21: +, 22: +; *Vicia cracca* 3: +, 4: +, 5: +; *Vicia dumetorum* 45: +; *Vicia grandiflora* 3: +, 5: +; *Vicia tetrasperma* 15: +, 22: +; *Vinca minor* 1: +; *Vincetoxicum hirundinaria* 19: +, 25: 2, 28: 1;

Localities:

1. Kalnik, 18.6.2001, 485m, E, 20°, 15m², lat. 46°07'55", long. 16°27'52", 2. Kalnik, 24.6.2001, 490 m, E, 10°, 18 m², 460807, 162741, 3. Podgorač, 20.6.2001, 188m, SW, 10°, 15 m², 453836, 164634, 4. Granice, 12.7.2001, 250 m, E, 3°, 10 m², 452442, 180657; 5. Podgorač, 20.6. 2001, 213 m, SSW, 10°, 15 m², 453834, 164639, 6. Granice, 12.7.2001, 250 m, N, 2°, 10 m², 452439, 180657; 7. Mokreš, 12.7.2001, SSE, 2°, 10 m², 452244, 180512, 8. Kalnik, 11.7.2001, 398 m, W, 2°, 30 m², 455448, 160245; 9. Kalnik, 11.7.2001, 395 m, SW, 2°, 15 m², 455447, 160246; 10. Podgorač, 20.6.2001, 188 m, SWW, 10°, 15 m², 453836, 164634, 11. Kalnik, 24.6.2001, 455 m, SSE, 5°, 10 m², 460743, 162629; 12. Kalnik, 24.6.2001, 460 m, W, 5°, 10 m², 460758, 162633, 13. Kalnik, 24.6.2001, 470 m, SEE, 5°, 10 m², 460808, 162747; 14. Mokreš, 11.7.2001, 190 m, E, 3°, 452254, 180508, 15. Mokreš, 11.7.2001, 200 m, W, 2°, 20 m², 452256, 180504, 16. Medvednica, 29.6.2001, 383 m, -, 0°, 10 m², 455443, 160237, 17. Lohor, 29.6.2001, 373 m, W, 5°, 20 m², 460927, 160409, 18. Levanjska Varoš, 11.7.2001, 162 m, E, 3°, 15 m², 451717, 181051, 19. Mokreš, 11.7.2001, 180m, S, 2°, 10 m², 452246, 180510, 20. Kalnik, 24.6.2001, 512 m, E, 5°, 10 m², 460805, 162730, 21. Granice, , 11.7.2001, 150 m, -, 0°, 15 m², 452647, 181135, 22. Granice, 11.7.2001, 120 m, -, 0°, 15 m², 452634, 181024, 23. Lohor, 29.6.2001, 319 m, W, 20°, 10 m², 460913, 160418, 24. Sovski Dol, 11.7.2001, 244 m, SSE, 10°, 10 m², 451751, 180309, 25. Veliki Papuk, 11.7.2001, 550 m, S, 5°, 20 m², 452838, 173829, 26. Mališćak, 11.7.2001, 545 m, WNW, 5°, 10 m², 452818, 173817, 27. Mališćak, 11.7.2001, 530 m, SSW, 5°, 15 m², 452815, 173819, 28. Mališćak, 11.7.2001, 488 m, NE, 20°, 10 m², 452815, 173823, 29. Mališćak, 11.7.2001, 510 m, N, 10°, 15 m², 452815, 173820, 30. Oštrc, 29.6.2001, 396 m, SW, 2°, 25 m², 454745, 154010, 31. Oštrc, 29.6. 2001, 402 m, SE, 10°, 15 m², 455721, 160533, 32. Musić, 203 m, E, 10°, 15 m², 451719, 181031, 33. Oštrc, 29.6.2001, 715 m, S, 30°, 10 m², 454543, 153859, 34. Oštrc, 29.6.2001, 595 m, S, 25°, 15 m², 454606, 153858, 35. Gorjanci/Žumberak, Trdinov vrh, 5.6.1998, 1100 m, NE, 7°, 40 m², 36. Gorjanci/Žumberak, 8.6.1998, 980 m, N, 5°, 13 m², 37. Gorjanci/Žumberak, nad Pendirjevko, 8.6.1998, 980, NW, 3°, 25 m², 38. Gorjanci/Žumberak, Planina v Podbočju, 10.6.1998, 710 m, NE, 15°, 7 m², 39. Gorjanci/Žumberak, Ravna Gora, 17.6.1999, 990 m, E, 2°, 25 m², 40. Gorjanci/Žumberak, under Trdinov vrh, 17.6.1999, 1100 m, W, 10°, 7 m², 41. Gorjanci/Žumberak, under Trdinov vrh, 17.6.1999, 1090 m, E, 10°, 9 m², 42. Gorjanci/Žumberak, under Trdinov vrh, 17.6.1998, 1120 m, SE, 10°, 12 m², 43. Gorjanci/Žumberak, Planina, 17.6.1998, 690 m, N, 12°, 8 m², 44. Gorjanci/Žumberak, Gradec, 10.6.1999, 610 m, NNW, 15°, 9 m², 45. Gorjanci/Žumberak, Planina, 10. 6.1998, 720 m, NNE, 10°, 15 m², 46. Gorjanci/Žumberak, Planina, 10.6.1998, NNW, 10°, 25 m², 47. Oštrc, 29.6. 2001, 690 m, NW, 20°, 10 m², 454553, 153855, 48. Oštrc, 29.6.2001, 554 m, NNW, 20°, 10 m², 454611, 153909, 49. Gorjanci/Žumberak, 5.6.1998, 1100m, NNE, 3°, 50 m², 50. Gorjanci/Žumberak, Ravna Gora, 8.6.1998, 1100 m, SW, 2°, 40 m², 51. Gorjanci/Žumberak, Ravna Gora, 8.6. 1998, 990 m, SSW, 3°, 35 m², 52. Gorjanci/Žumberak, Ravna Gora, 8.6.1998, 1000 m, NW, 2°, 30 m², 53. Gorjanci/Žumberak, Ravna Gora, 8.6.1998, 1000 m, W, 3°, 20 m², 54. Gorjanci, Javorovica, 10.6.1998, 740m, W 20°, 20 m², 55. Gorjanci, Javorovica, 10.6.1998, 725 m, NNW, 5°, 25 m², 56. Gorjanci, Javorovica, 10.6.1998, 760 m, W, 2°, 30 m².

talía. In the research area, this community occurs relatively frequent in altitudes up to 500 m.

Origano-Campanuletum bononiensis ČARNI, FRANJÍČ, ŠILC & ŠKVOŘC, ass. nova (holotypus hoc loco, Tab. 1/27), was found all over the research area. The dominant species is *Campanula bononiensis* appearing also in the association Campanulo bononiesis-Vicetum tenuifoliae KRAUSCH in T. MÜLLER 1962. In the research area, *Vicia tenuifolia* does not appear in the stands. In addition to *Campanula bononiensis*, there are *Hypericum perforatum*, *Buphthalmum salicifolium*, *Teucrium chamaedrys*, to mention only the most common ones. The sites are dry and sunny. This community is one of the most heliophilic and thermophilic among all concerned. It forms wood margins of oak and beech forests. The holotype of the association is relevé 27 in the Table 1.

The Peucedanetum cervariae appears rarely in the region. It is more common in the central part of Europe where it is one of the most common fringe communities (MUCINA & KOLBEK 1993). It appears at lower altitudes and on sunny sites. Its floristic composition is rather poor and it is in contact with dry grasslands of the Brometalia. The most common species are: *Peucedanum cervaria*, *Teucrium chamaedrys*, *Centaurea jacea*, *Carex flacca* and *Briza media*. It appears at altitudes up to 400 m. At higher altitudes it is replaced by the Bupleuro-Laserpitietum latifolii and Laserpitietum sileris.

The Bupleuro longifolii-Laserpitietum latifolii is dominated by *Laserpitium latifolium*. The dominant *Laserpitium latifolium* belongs to the typical subspecies. At the border to the Pannonian basin, *Laserpitium latifolium* subsp. *asperum* (CR.) SCHÜBL. & MARTENS could also be expected. It is the characteristic species of the Arabidi turritae-Laserpitietum asperi MUCINA in MUCINA & KOLBEK 1993 that was described from the eastern part of Austria (Hainburg) and Slovakia (Tematin) (MUCINA & KOLBEK 1993). In the Alps, stands of the Trifolio-Laserpitietum latifolii are abundant in the upper montane belt (1200–1600) and have been classified within the Trifolion medii (MUCINA & KOLBEK 1993). The community under consideration is classified within the Geranion sanguinei. It is distributed at lower altitudes (600–1100). The species composition is typical for a Geranion sanguinei community including *Hypericum perforatum*, *Buphthalmum salicifolium*, *Carex montana* and many species of the Festuco-Brometea (e.g. *Bromus erectus*, *Carex flacca*, *Festuca rupicola*, *Thesium bavarum*, *Carlina acaulis* etc.). In comparison with the Laserpitietum sileris, this community is more sciophilous and it grows strictly in a narrow belt in the shadow of a forest canopy. This association was described from the Schwäbische Alb (MÜLLER 1978). There occur species like *Bupleurum longifolium* and *Knautia sylvatica* that are not found in the communities in Croatia. But the species composition corresponds to those from the

Schwäbische Alb. Taking into consideration this fact we decided to classify the community within the Bupleuro-Laserpitietum latifolii and to propose that it should be distinguished at a lower syntaxonomical level as a geographical race of *Knautia drymeia* that is a common species in the region.

Laserpitietum sileris was described in southeastern Bavaria from altitudes between 540–950 m on carbonate bedrock. The rendzina is not well developed and is poor in nutrients. The site properties are similar in Croatia. In comparison with Bupleuro-Laserpitietum latifolii distributed in the same region, the stands of Laserpitietum sileris are situated on sun-exposed sites on rendzina between 550 and 1100 m. In comparison with the communities in Bavaria, some differences in floristic composition can be recognised: *Calamagrostis varia* is a common species and there appear also *Erica herbacea*, *Sesleria varia*, etc. (SPRINGER 1987, 1990). It is considered that the floristic differences enable us to describe a geographical race of *Dianthus croaticus* that is a common species in the region.

4. 2 Ecological Conditions and Plant Functional Traits

The DCA analysis (Fig. 4) was applied using the plant functional types, and environmental and geographical variables were passively projected onto the diagram. So the distribution of relevés in the diagram is entirely dependant on plant functional traits composition. In the DCA diagram the distribution pattern of the communities is still similar to that in Fig. 3 and we can anticipate that the plant functional groups were well chosen and present the main difference between the vegetation types concerned.

In Fig. 4 two groups of plots (relevés) corresponding to alliances can be recognised: Trifolion medii (Trifolio-Agrimonetum and Trifolio-Melampyretum) in the direction of nutrient and moisture and Geranion sanguinei (Peucedanetum cervariae, Origano-Campanuletum, Laserpitietum sileris and Bupleuro-Laserpitietum latifolii) in the direction of pH.

It can be recognized that the axes representing moisture, nutrient and pH, that are responsible for site differentiation are more or less perpendicular to the axis continentality, temperature and altitude that built the main gradient. For estimating the correlation of continentality and temperature with species composition in the climatic gradient (that reflects also the phytogeographical gradient in the region) the regression was calculated. It shows a significant correlation (species composition vs. temperature $r^2 = 0.3958$, $p < 0.0000002$; species composition vs. continentality $r^2 = 0.2062$; $p < 0.0004$).

The diagram of the plant functional traits (Fig. 5) shows the importance of plant functional traits along the gradients. We suppose that we can filter micro site ecological conditions (moisture, nutrients, pH) (comp.

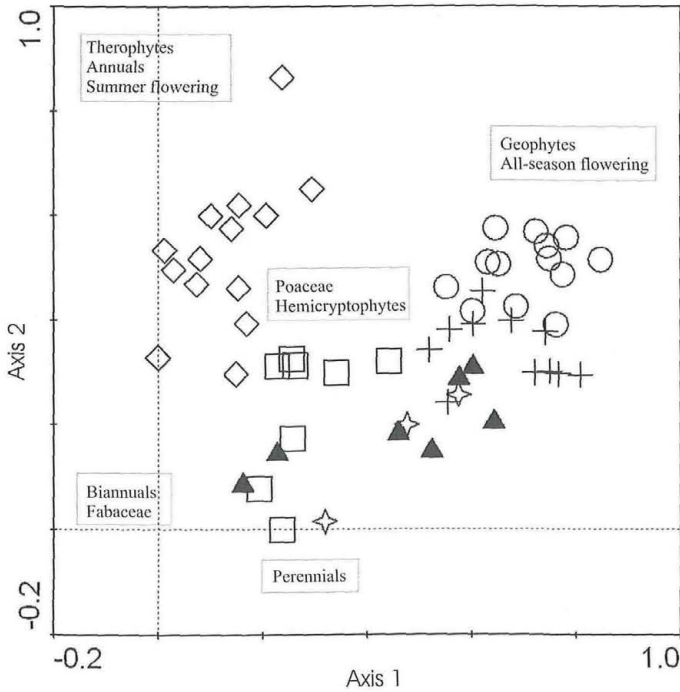


Fig. 5. DCA ordination of sites considering plant functional traits along the climatic (phytogeographical) gradient. Plant traits associated with different sectors of the ordination plane are displayed in boxes. Signs for associations see Fig 3.

Fig. 4) and a concentrate in a differentiation along the axes of the phytogeographical areas (Areas 1, 2, 3) and the climatic variables (continentality, temperature and altitude).

As we can see in the centre there are hemicryptophytic species and the species from the family *Poaceae*. Perennial species are also close to the central part of the diagram. These are the main characteristics of this vegetation type.

The annual and biannual species, which need at least two years of accumulation of nutrients for flowering, are more adapted to more severe conditions are therefore more common in the eastern part. The same reason also influences the increased presence of the species of the family *Fabaceae* that fix nitrogen and more easily survive the severe conditions. The species of the family *Fabaceae* are found in dry habitats poor in nitrogen and they appear abundantly in steppic zones of Eurasia (EHRENDORFER 1978). The geophytes are more common in the western part. Geophytes are more significant in more humid regions and therophytes in the more continental (arid) ones. We cannot correlate phanerophytes and chamaephytes to this gradient.

Concerning the phenological classes, there are species flowering throughout the year in the western, more humid part, and there is a peak of flowering in the high summer that corresponds to the *Ligustrum vulgare*-*Stachys sylvatica* and *Clematis vitalba*-*Galium sylvaticum* phases in the continental part (TREFFLICH & al. 2002). The reason is that the fringe communities appear especially in the intermittent sunlight conditions, but some stands are fully exposed to sun (VAN GILS 1977). Since in the eastern part the ecological conditions for development of this vegetation type are less propitious, it appears in a narrow belt on the wood margins, whereas in the western part, where the ecological niche of these communities is wider and they do not appear only strictly in a shadow of a forest canopy. So there appear species with various flowering periods, not only the species of forest fringes with a characteristic flowering period in the late summer (ČARNI 1999).

The research revealed the pattern of floristic, ecological and structural diversity of fringe communities in the northern part of Croatia. The communities differentiate on a small scale (site conditions), as well as on a large scale (climatic gradient). The vegetation is quite diverse and can be found in various habitats all over the region, as a consequence of the presence of diverse functional plant groups that can survive in various site conditions.

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