Thaiszia - J. Bot., Košice, 23 (1): 67-112, 2013
http://www.bz.upjs.sk/thaiszia

THAISZIA
JOURNAL OF
BOTANY

Mountain grasslands of high conservation value in the Eastern Carpathians: syntaxonomy, biodiversity, protection and management

A paper in honour of 95th birthday of Prof. Malynovski K. A. (1919–2005) – true pioneer in the study of grasslands of the Ukrainian Carpathians

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Kricsfalusy V.V. (2013): Mountain grasslands of high conservation value in the Eastern Carpathians: syntaxonomy, biodiversity, protection and management. – Thaiszia – J. Bot. 23 (1): 67–112. – ISSN 1210-0420.

Abstract: Mountain grasslands in the Eastern Carpathians within Ukraine are of high scientific and nature conservation value as well as of cultural and historical importance. They are home to a rich biodiversity, including many rare, endemic and relic plant species and plant communities, as well as those that are found at the periphery of their ranges.

This paper analyses data from mountain grasslands that contain significant concentrations of biodiversity in the region. We propose syntaxonomical revision of our previously-published classification of grassland communities, which contains some corrections and improvements. This study provides an assessment of 14 grassland communities, including their syntaxonomy, characterization, distribution, habitat, ecology, red-listed plants, dynamic trends, protection status, and conservation value. Phytogeographical analysis demonstrates that most plant associations have different levels of endemism, from local and regional to supra-regional.

This paper describes the patterns of distribution and the environmental affinity of mountain grassland communities, as well as the distribution and abundance of red-listed plant species. It analyses relationships between the size of the grassland patches, vegetation cover and species richness patterns for all taxonomic groups (vascular plants, bryophyte and lichen). This study assesses

the implications of the species richness patterns for the conservation status of grassland communities in the region. The major threats to mountain grasslands are considered to be changes in traditional land-use caused by overgrazing, abandonment, invasive species, afforestation, and climate change.

Conservation management for maintaining the structure and diversity of mountain grasslands is suggested. Promoting development of the forest and pasture economy, and integrating it with objectives for nature conservation, are key to the sustainable development of this region.

Keywords: grasslands, biodiversity, threats, conservation, management, natural heritage, sustainability.

Introduction

The Carpathian Mountain system is located in the very heart of the European continent and covers an area greater than the Alps. The system extends 1.500 km across seven European countries. The Eastern Carpathians occupy the central part of the Carpathians; they have played and continue to play an important role as a bridge linking the Western and Southern Carpathians. They have also acted as refuges for many plant species in the past, particularly during the ice ages, due to diverse geological bedrocks and rugged relief. This influenced a high natural diversity of its modern flora and vegetation.

The main part of the Eastern Carpathians lies in Ukraine and is often called the Ukrainian Carpathians (Fig. 1). Human influence in these highlands dates back to the 14–15th centuries, when Walachians started to migrate into the region from the Southern throughout the Eastern to the Western Carpathians. This process has a major impact on the culture of mountain settlements and eventually these immigrants assimilated with the local Slavic peoples. Many pastures were cleared within the forests up to the tree line and krummholz, forming an intermediate pasture zone or a specific landscape, called the *polonyny* (mountain grasslands). Natural alpine meadows located above the tree line survived mostly due to their inaccessibility. By the end of 17th century, this period ended, leaving a distinct polonyny landscape with the diverse cultural and natural heritage.

Because they were traditionally used as meadows and pastures over the centuries, the mountain grasslands changed. However, during the Soviet period, in the second half of the 20th century, mountain grasslands underwent drastic changes, due to heavy grazing. After the collapse of the Soviet system and disappearance of *kolkhoz* (large collective farms), the abandonment of pastoralism had a negative impact on overgrazed mountain grasslands. Today, the major threats to mountain grasslands are changes in traditional land-use, caused by overgrazing, abandonment, invasive species, and afforestation, as well as climate change. The impact of these forces on mountain grasslands is often so extensive as to cause irreversible changes in the species and the structure of the communities, even to the extinction of some grasslands, with spontaneous succession.

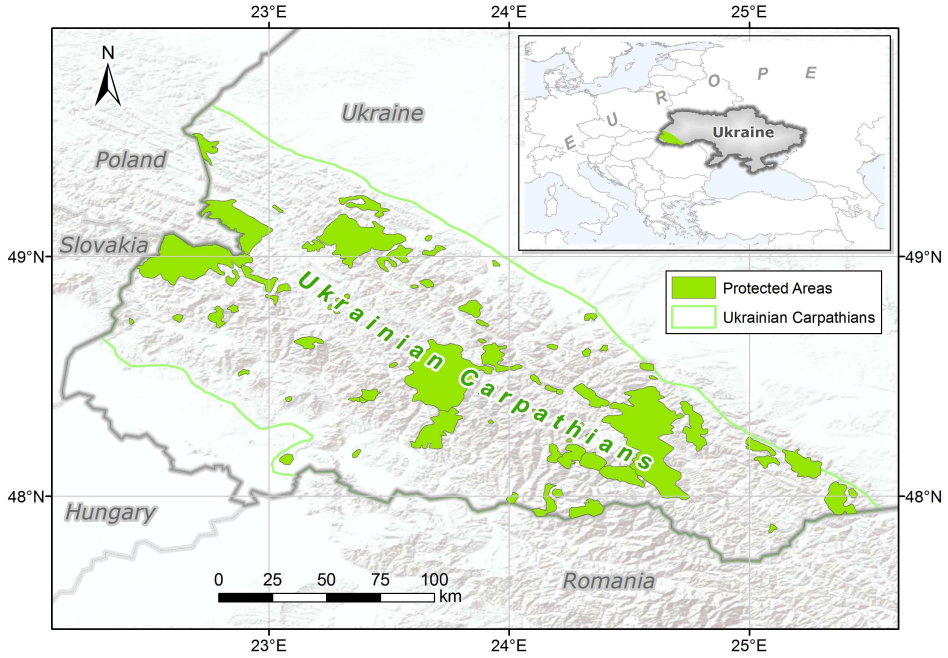


Fig. 1. Location of the Ukrainian Carpathians in Europe.

Conservation of the threatened plant species and plant communities as well as unique polonyny landscapes is of international importance. As human activities continue to threat mountain grasslands in the Ukrainian Carpathians, it is crutial to make full assessment of their conservation value. Hovewer the conservation of species and of the community diversity of the mountain grasslands are methodologically and practically a complex problem. Not only do grasslands need to be preserved in their original state, but elsewhere in the region, they also need to be restored. The aim of this paper is to distinguish mountain grasslands of high conservation value in the Ukrainian Carpathians, to document structure and diversity of these plant communities in the region, to evaluate their endangerment and to find mechanisms for conservation management.

Material and methods

Study area

The elevation of the Ukrainian Carpathians is just moderate: its highest peak is Mt. Hoverla (2061 m a.s.l.) and other summits exceeding 2000 m are located in the south-eastern part of the region. The predominant geological structure of the Ukrainian Carpathians, relatively young mountains formed during the Tertiary age, is Carpathian Flysh, which is composed of layers of alternating sandstone and shale with small areas of limestone and granite (TSARNENKO 1988).

The climate in the Ukrainian Carpathians is temperate continental. Winters are mild, with an average temperature in January of -5°C. Summers are warm, with an average temperature in July of +18°C. In the high mountain zone, the climate can be harsh, and it changes with elevation. Average temperatures are 3–5°C lower than in the pre-mountain zone. Snow covers the high mountain slopes for up to five months of the year.

Five climatic-vegetation belts are distinguished in the Ukrainian Carpathians (e.g. MALYNOVSKI 1980): the submountain (up to 300 m), the beech forest belt (250–1350 m), the spruce forest belt (700–1670 m), the subalpine belt (1300–1850 m), and the alpine belt (1850–2061 m). Mountain grasslands occur in the subalpine belt (tall herb mountain meadows and highland grasslands) and in the alpine belt (alpine grasslands).

Classification approach

For the purposes of this study, we use floristic classification of highland vegetation of the Ukrainian Carpathians, published earlier by MALYNOVSKI & KRICSFALUSY (2000, 2002). The classification was the first attempt to develop a typology of vegetation for this region based on the Braun-Blanquet method. Even gathering and analysis of data for that study was difficult task as different classification approaches were used which resulted in several vegetation schemes published in ten different languages. Overall, the mentioned classification served its ultimate goal well, enabling the access of western researchers to relevés for the plant communities described in the Ukrainian Carpathians and making possible their comparison with existing vegetation data in other European countries.

Because some of the described communities in the Ukrainian Carpathians were based on poorly documented relevés, their delineation and assignment to higher syntaxa remain ambiguous. Also, given the recent progress in studies on high-altitude vegetation of Europe, particularly of the Western Carpathians, it is possible to compare different classification schemes and described local associations. Although this paper does not seek to revise the whole floristic classification of highland vegetation of the Ukrainian Carpathians, we intend to propose a syntaxonomical revision of grassland communities in the region, particularly those of high conservation value. This paper contains some corrections and improvements of our previously-published classification (MALYNOVSKI & KRICSFALUSY 2000, 2002). Also, published in English this paper will enable western researchers a better understanding of the distinguished mountain grasslands of high conservation value in the Ukrainian Carpathians which was a linguistic challenge of the previous classification (ČESKÁ 2004).

The proposed classification in most cases is in line with the recent syntaxonomical revisions of the vegetation of the Western Carpathians (DÚBRAVCOVÁ et al. 2005; PETRÍK et al. 2005; KLIMENT & VALACHOVIČ 2007; KLIMENT et al. 2010) and of central Europe (MICHL et al. 2010), with some exceptions that will be discussed shortly. The nomenclature of the plant taxa follows the checklist of TASENKEVICH (1998), except for the treatment of a few species (DVOŘÁKOVÁ 2003; THE PLANT LIST 2010).

Categories and protection status

Depending on the current state and degree of threat to grassland communities in the Ukrainian Carpathians, we classified them into three categories: EN – Endangered: usually 5 or fewer occurrences with very small community size; or, because of some factor(s), making the community especially threatened; VU – Vulnerable: usually between 5 and 20 occurrences with small community size, in some occurrences; or, because of some factor(s), making the community threatened; LR – Low Risk: typical community with above 20 occurrences; or that may have fewer occurrences, but with a large community size; may be susceptible to large-scale disturbances.

Rationale for the selection of "red-listed plants" is based on their presence in the IUCN – Red List of threatened species (IUCN 2011); ERL – European Red List of vascular plants (BILZ et al. 2011); B – Bern Convention (COUNCIL OF EUROPE 1979); H5 – Annex V of Habitat Directive of European Union (EUROPEAN COMMISSION 2007); RDBU – Red Data Book of Ukraine (RDBU 2009), and the Red List of Transcarpathia (KRICSFALUSY et al. 1999). We have also considered the endemic status of plant species based on the analysis conducted by KRICSFALUSY & BUDNIKOV (2002).

Rationale for the selection of plant communities is based on their presence in the GDBU – Green Data Book of Ukraine (GDBU 2009), and the Red List of Transcarpathia (KRICSFALUSY et al. 1999). We have also taken into consideration the relic or endemic status of grassland communities, their distribution range (if it is a peripheral community or not), as well as the presence and role of red-listed plants in community composition.

Conservation assessment

Conservation assessment of mountain grasslands in the Ukrainian Carpathians has three main objectives: 1) to contribute to regional conservation planning through provision of a baseline dataset, reporting the status of the grasslands of high conservation value; 2) to identify those habitats needing to be conserved, to prevent extinctions and to ensure that grasslands reach and maintain a favourable conservation status; and 3) to identify the major threats and to propose mitigating measures and conservation actions to address them.

Description of grassland communities has been done according to the following unified scheme: syntaxonomy, characterization, distribution (including mapping), habitat, ecology, red-listed plants, trends, protection status, and conservation value. Habitat affinities of study grassland communities were identified using typology of Natura 2000 (INTERPRETATION MANUAL OF EUROPEAN UNION HABITATS 2007).

Data collection and analysis

For the purposes of this study, we used relevés of grassland communities from floristic classification of highland vegetation of the Ukrainian Carpathians, published earlier by MALYNOVSKI & KRICSFALUSY (2000, 2002). We counted the presence of all vascular plant species, bryophytes and lichens within the 3–16 (4 m^2) sample plots and total number of species for each of 129 study sites. We

calculated species richness (*r*) and frequency (*Fr*) for each taxonomic group (vascular plants, bryophytes, and lichens) and diversity indeces – the Shannon index (*H*) and Simpson index (*D*) for 14 study communities. The Shannon index is defined as $H = -\sum Pi[\ln Pi]$) and the Simpson index is determined as $D = 1/\sum[Pi^2]$, according to BEGON et al. (1986). We used analysis of variance (ANOVA) for comparing means of the Shannon index and the Simpson index across all study communities.

To investigate the correlation between parameters, regression analysis incorporating Pearson's co-efficient of correlation *R* was applied. To model the effects of the patch size and vegetation cover on patterns of total species richness and species richness of the different taxonomic groups (vascular plants, bryophytes, and lichens) multiple linear regressions were performed. F-tests were used to estimate statistically significant differences. To visualize data in 3-dimensional space we used 3D XYZ Graphs program. 3D Surface Plots were generated applying Least Squares methods. For statistical analyses the Statistica version 9 software was used (STATSOFT 2009).

Results and Discussion

Description of grassland communities (Tab. 1; Figs. 2–7)

1. Association *Gentiano punctatae-Festucetum picturatae*

Syntaxonomy: In the Ukrainian Carpathians this community was described as *Gnaphalium supinum-Festuca picta*, *Gnaphalium supinum-Luzula spadiceae*, *Meum mutellina-Potentilla aurea* (DEYL 1940), and *Gnaphalietum festucosum pictae* (MALYNOVSKI 1980). This association also occurs in the Western Carpathians (KRAJINA 1933; KLIMENT & VALACHOVIČ 2007) and in the Eastern Carpathians, within Romania (BORZA 1934; PUŞCARU et al. 1956; COLDEA et al. 1997).

Distribution: The community is found in Chornohora, the Maramorosh Mts., Svydovets, Gorgany, and Borzhava at an altitude of 1650–1920 m. It occupies small spots from 40 to 100 m^2 and rarely exceeds area of 200 m^2.

Habitat: Natura 2000 – 6150. Siliceous alpine and boreal grasslands.

Ecology: The community tends to occupy small gravel and moist soils. It is widespread in the upper part of subalpine belt and also occurs in alpine belts on very steep slopes of 20–45°, mostly with north-eastern exposure

Characterisation: The structure of the community is two-layered: the first layer is comprised of grasses and the second of forbs; total cover ranges between 60–95%. The community is dominated by *Festuca picturata,* whereas *Omalotheca supina*, *Anthoxanthum alpinum, Potentilla aurea, Carex sempervirens,* and *Vaccinium myrtillus* have lesser cover. Mosses and lichens include *Hylocomium splendens*, *Pogonatum alpinum, Cetraria islandica* and some other species. The community possesses a rich floristic composition (100 vascular plants and 10 cryptogams).

Tab. 1. Conspectus of the grassland communities of high conservation value in the Ukrainian Carpathians

1. *Salicetea herbaceae* Br.-Bl. 1948
- 1.1. *Salicetalia herbaceae* Br.-Bl. in Br.-Bl. et Jenny 1926
  - 1.1.1. *Festucion picturatae* Krajina 1933 corr. Dúbravcová 2007
    - *Gentiano punctatae-Festucetum picturatae* (Krajina 1933) Dúbravcová in Kliment et al. 2010

2. *Caricetea curvulae* Br.-Bl. 1948
- 2.1. *Caricetalia curvulae* Br.-Bl. in Br.-Bl. et Jenny 1926
  - 2.1.1. *Caricion curvulae* Br.-Bl. 1925
    - *Primulo minimae-Caricetum curvulae* Br.-Bl. 1926 et Oberd. 1957

3. *Carici rupestris-Kobresietea bellardii* Ohba 1974
- 3.1. *Oxytropido-Elynetalia* Oberdorfer ex Albrecht 1969
  - 3.1.1. *Festucion versicoloris* Krajina 1933
    - *Saxifrago paniculatae-Festucetum versicoloris* (Walas 1933) Pawłowski 1935

4. *Elyno-Seslerietea* Br.-Bl. 1948
- 4.1. *Seslerietalia caerulae* Br.-Bl. in Br.-Bl. et Jenny 1926
  - 4.1.1. *Festuco saxatilis-Seslerion bielzii* (Pawłowski et Walalas 1949) Coldea 1984
    - *Senecio carpaticae-Seslerietum bielzii* Kricsfalusy et Malynovsky 2000
    - *Thymo pulcherrimi-Festucetum amethystinae* Kricsfalusy et Malynovsky 2000
    - *Festucetum saxatilis* Domin 1933
      - *F. s. typicum*
      - *F. s. thymetosum alpestris* Pawłowski et Walas 1949

5. *Nardetea strictae* Rivas Goday et Borja Carbonell 1961
- 5.1. *Nardetalia strictae* Oberdorfer ex Preising 1949
  - 5.1.1. *Nardion strictae* Br.-Bl. 1926
    - *Soldanello hungaricae-Nardetum strictae* Kricsfalusy et Malynovsky 2000
      - *S.-N. gentianetosum* Kricsfalusy et Malynovsky 2000
      - *S.-N. narcissetosum* Kricsfalusy et Malynovsky 2000
    - *Carici nigrae-Nardetum strictae* (Krajina 1933) Kliment 2007

6. *Mulgedio-Aconitetea* Hadač et Klika in Klika 1948
- 6.1. *Adenostyletalia* Br.-Bl. 1931
  - 6.1.1. *Adenostylion alliariae* Br.-Bl. 1926
    - *Ranunculo platanifolii-Adenostyletum alliariae* (Krajina 1933) Dúbravcová et Hadač ex Kočí 2001
    - *Pulmonario filarszkyanae-Alnetum viridis* Pawłowski et Walas 1949
- 6.2. *Calamagrostietalia villosae* Pawłowski et al. 1928
  - 6.2.1. *Calamagrostion villosae* Pawłowski et al. 1928
    - *Hyperico alpigeni-Calamagrostietum villosae* Pawłowski et Walas 1949
    - *Poo chaixii-Deschampsietum caespitosae* Pawłowski et Walas 1949
    - *Phleo alpini-Deschampsietum caespitosae* (Krajina 1933) Coldea 1983
  - 6.2.2. *Festucion carpaticae* Bělohlávková et Fišerová 1989
    - *Festucetum carpaticae* Domin 1925

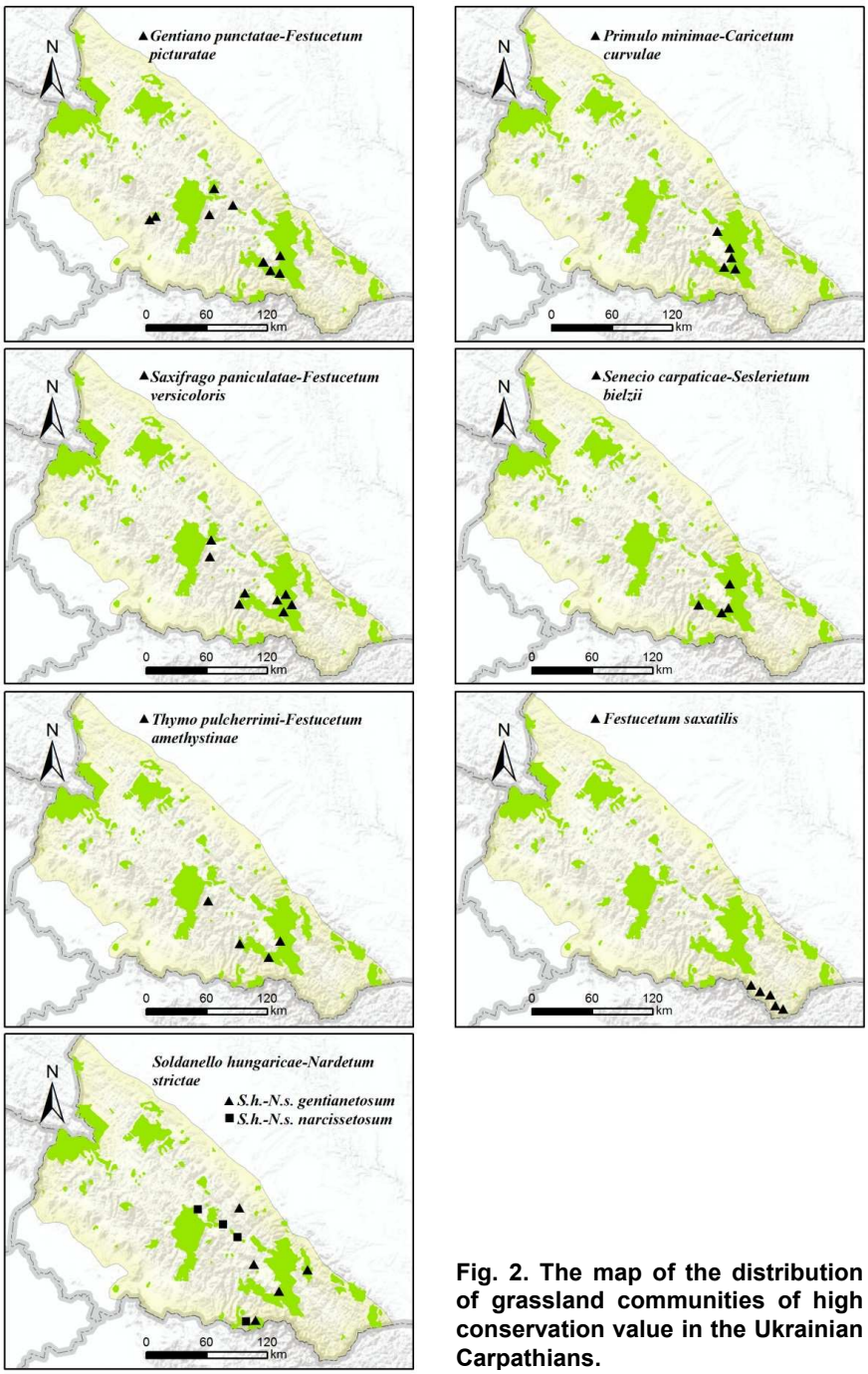


Fig. 2. The map of the distribution of grassland communities of high conservation value in the Ukrainian Carpathians.

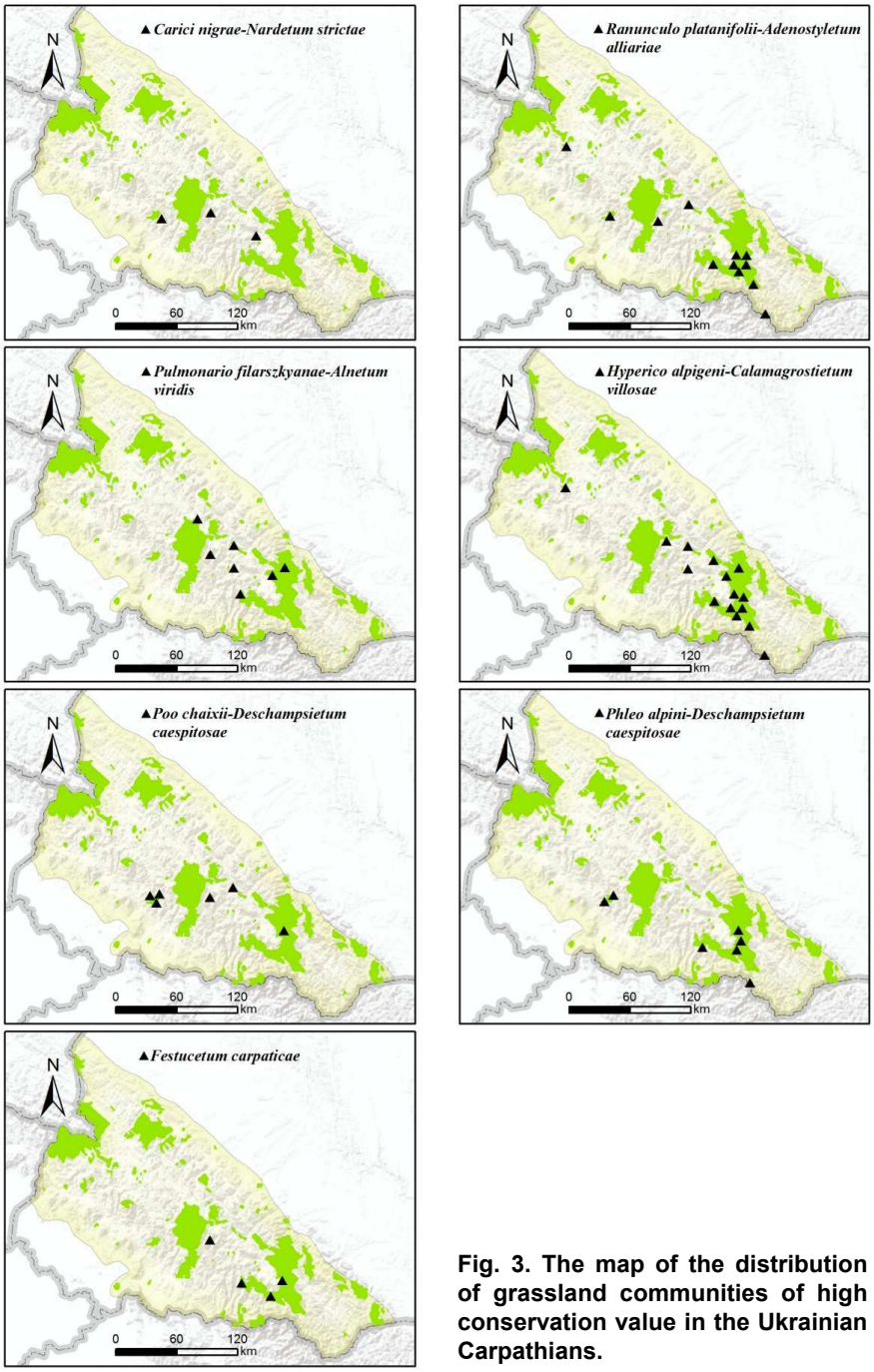


Fig. 3. The map of the distribution of grassland communities of high conservation value in the Ukrainian Carpathians.

Red-listed plants: B – *Campanula patula* subsp*. abietina, Poa deylii*; **RDBU** – *Aconitum anthora, Anemone narcissiflora, Campanula rotundifolia* subsp. *kladniana, Coeloglossum viride, Gentiana laciniata, Gentiana punctata, Gymnadenia conopsea, Primula minima, Pulsatilla alba, Ranunculus thora, Rhodiola rosea, Rhododendron myrtifolium,* and *Salix herbacea.*

Trends: Due to grazing, the community is declining.

Protection status: VU. Protected in Carpathian Biosphere Reserve and Carpathian National Nature Park.

Conservation value: This community is endemic to the Carpathians and has limited distribution in the Ukrainian Carpathians. It contains many red-listed plants, and endemic and peripheral species. The community needs legal protection and should be included in the GDBU.

2. Association *Primulo minimae-Caricetum curvulae*

Syntaxonomy: This community was described in the Ukrainian Carpathians as *Caricetum curvulae* (DEYL 1940; BRADIS & ZAPIATOVA 1954; MALYNOVSKI 1980), *Curvuletum* (KOMENDAR 1964), and *Caricetum curvula* as a pasture type (SWEDERSKI & SZAFRAN 1931). The closest community was delineated in the Southern Carpathians as *Caricetum curvulae bucegicum* (PUŞCARU et al. 1956).

Distribution: The community is spread only in Chornohora and the Maramorosh Mts. on the top of mountain ranges at an altitude of 1950–2060 m. It forms medium size growths (up to 100 m^2), occasionally covering larger areas of 200–400 m^2. Often habitats survive on little spots only (10–40 m^2).

Habitat: Natura 2000 – 6150. Siliceous alpine and boreal grasslands.

Ecology: The community occupies quite moderate slopes of 2–10^o, and rarely occurs on relief areas of 15–20^o. The community tends to occupy small gravel and turf alpine soils with pH 3,8–4,1 with a depth of 30 cm (DEYL 1940).

Characterisation: Typically, the community forms two-layered vegetation cover with a height of 15–20 cm; the first layer is formed by *Carex curvula*, *C. sempervirens*, *Sesleria bielzii*, and *Festuca airoides*; the second is comprised of leaf rosettes and forbs' basal leaves, lichens and mosses. *Carex curvula* mostly forms monodominant communities with both sparse and dense vegetation, the cover of which reaches 90–100%, including the dominant species that occupies 60–80% of the area. Species such as *Sesleria bielzii, Festuca airoides*, *Vaccinium myrtillus,* and *Cetraria islandica* make up to 2–5% of the cover. A total of 35 species of vascular plants and 36 cryptogams were recorded in the community.

Red-listed plants: RDBU – *Huperzia selago, Loiseleuria procumbens, Oreochloa disticha*, *Primula minima, Pulsatilla alba, Rhododendron myrtifolium,* and *Salix herbacea.*

Trends: In the alpine belt, this association is a climax community that might be altered by overgrazing. In such cases, short-tussock communities with the dominance of *Festuca airoides*, *Juncus trifidus* or *Carex curvula* are being formed there instead of *Primulo minimae-Caricetum curvulae* community.

Protection status: VU; **GDBU** – R. Protected in Carpathian Biosphere Reserve and Carpathian National Nature Park.

Conservation value: One of the community dominants, *Primula minima*, is a rare species included in the RDBU (2009). The community has a narrow distribution in the Ukrainian Carpathians. It contains several red-listed plants and peripheral species.

3. Association *Saxifrago paniculatae-Festucetum versicoloris*

Syntaxonomy: In the Ukrainian Carpathians, this community was described as *Festucetum versicoloris muscosum* (DEYL 1940) and *Festucetum versicoloris* (MALYNOVSKI 1980). Similar communities were delineated by BELDIE (1967) in the Southern Carpathians as *Seslerio-Festucetum versicoloris* (syn. *Festucetum versicoloris* according to PUŞCARU et al. 1956).

Mainly due to the presence of elements typical of the *Elyno-Seslerietea* and the *Caricetea curvulae,* the classification of *Saxifrago paniculatae-Festucetum versicoloris* remains disputable, according to PETRIK et al. (2006). The authors proposed to use the name *Festucetum versicoloris* Domin 1929 for the communities with dominance of *Festuca versicolor,* and with the presence of *Oxytropis* species. However, due to differences between ecology and floristic composition of the stands in the Ukrainian Carpathians, and the one in the Western Carpathians, we prefer to retain the name *Saxifrago paniculatae-Festucetum versicoloris,* used in our earlier classification (MALYNOVSKI & KRICSFALUSY 2000, 2002). Given limitations of the data available and transitional character of this community, more investigations are needed to clarify their syntaxonomical position.

Distribution: The community has limited occurrence in the subalpine belt of the Ukrainian Carpathians. It occurs mainly in the eastern part of the region, mainly in Svydovets and Chornohora, at an altitude of 1650–1800 m. It occupies medium-sized areas of 50–100 m^2 but sometimes covers up to 200 m^2.

Habitat: Natura 2000 – 6170. Alpine and subalpine calcareous grasslands.

Ecology: The community tends to occupy rocky substrates on the dry, southern, very steep slopes of 27–55°. It has formed on shallow soils (up to 20 cm) with pH 5, 7–7,8. Alkaline soils are optimal for the development of the community. Increased acidity results in decline of vascular plants and depletion of floristic composition, and also encourages moss growth.

Characterisation: Vertical structure of the vegetation is two-layered. The first layer (up to 40 cm) is comprised of *Festuca versicolor*, *Calamagrostis villosa*, *Deschampsia caespitosa,* and other tall grasses and forbs. The second, scarce, layer (up to 15–20 cm), is comprised of short forbs. The total vegetation cover is of medium range (55–80%). It is comprised of large fescue tussocks, which take up slightly more than half of the area. Inter-tussock are spaces often filled with forbs or fragments of rocks. This community is of high biodiversity value, as it includes 90 vascular plants and one species of cryptogams.

Red-listed plants: ERL – *Astragalus australis* subsp. *krajinae, Primula elatior* subsp. *poloninensis;* **B** – *Campanula patula* subsp. *abietina;* **RDBU** – *Anemone narcissiflora, Aquilegia nigricans, Aster alpinus, Astragalus australis* subsp. *krajinae, Campanula rotundifolia* subsp. *kladniana, Coeloglossum viride, Draba aizoides, Gentiana laciniata, Hedysarum hedysaroides, Huperzia selago, Leontopodium alpinum, Minuartia pauciflora* (syn. *M. verna* subsp. *gerardii;* see DVOŘÁKOVÁ (2003)*, Pulsatilla alba, Rhodiola rosea, Salix herbacea,* and *Selaginella selaginoides.*

Trends: This community does not have agricultural importance, because it occupies very small areas which are not suitable for the grazing of sheep. In the areas suitable for grazing, the community changes to dense tussock coenenoses and degrades to gravelly substrates on steep slopes.

Protection status: VU. Protected in Carpathian Biosphere Reserve.

Conservation value: This community is a Carpathian endemic with limited distribution in the Ukrainian Carpathians. It represents a rare habitat and is a relic of the xerothermic period. The community is very rich in red-listed plants, endemic, and relic species. It needs legal protection and should be included in the GDBU.

4. Association *Senecio carpaticae-Seslerietum bielzii*

Syntaxonomy: This association was described in the Ukrainian Carpathians by MALYNOVSKI (1980) as *Seslerietum coerulans*. Similar communities with dominance of *Sesleria tatrae* occurs in the Western Carpathians (SZAFER et al. 1923; DOMIN 1929), and with dominance of *S. haynaldiana* and *S. heufleriana* in the Southern Carpathians Carpathians (PUŞCARU et al. 1956; COLDEA 1991; COLDEA et al. 1997).

Distribution: Until now, this community has been known only in the alpine belt of Chornohora and Svydovets at an altitude of 1800–2000 m. The community occupies areas of medium size, around 100 m^2, and can sometimes reach a larger area of up to 200–400 m^2.

Habitat: Natura 2000 – 6170. Alpine and subalpine calcareous grasslands.

Ecology: The community forms on northern and south-western slopes of 5–30° on alpine humus and very gravelly soils which have three weakly defined horizons with pH 5,2–6,8.

Characterisation: The structure of the vegetation cover is two-layered. *Sesleria bielzii* is spread diffusely in small patches, and gaps between these are filled with tussocks of different grasses and other species of forbs and mosses. In the first layer (up to 18–25 cm) *Sesleria bielzii*, *Carex sempervirens*, *Festuca airoides*, and *Deschampsia caespitosa* occur. The second layer is formed by *Soldanella hungarica* subsp. *major*, *Homogyne alpina*, *Pulsatilla alba* and other forbs, together with mosses and lichens. The vegetation is comprised of *Sesleria bielzii* with cover of 25–50%. *Hylocomium splendens*, *Polytrichum strictum,* and *Thamnolia vermicularis* occur in the moss-lichen layer. Due to the wide ecological amplitude of *Sesleria bielzii,* the floristic composition of the community is quite rich in calcareous as well as acidophilus plants. Most

Fig. 4. Silicious alpine grasslands in the Maramorosh Mts., the Ukrainian Carpathians.

Fig. 5. Calcareous alpine and subalpine grasslands in Svydovets, the Ukrainian Carpathians.

species of this community belong to the arctic-alpine and alpine elements of flora. A total of 35 species of vascular plants and 4 cryptogams were found.

Red-listed plants: RDBU – *Campanula rotundifolia* subsp. *kladniana, Doronicum clusii* subsp. *villosum, Huperzia selago, Loiseleuria procumbens, Primula minima, Pulsatilla alba, Rhodiola rosea, Rhododendron myrtifolium,* and *Senecio abrotanifolius* subsp. *carpaticus.*

Trends: It changes to dense-tussock coenenoses and degrades to gravelly substrates on the steep slopes.

Protection status: EN. Protected in Carpathian Biosphere Reserve.

Conservation value: One of the community dominants, *Senecio abrotanifolius* subsp. *carpaticus*, is a rare species included in the RDBU (2009). This community is an East Carpathian endemic with very narrow distribution in the Ukrainian Carpathians. The community represents a rare habitat and contains many red-listed plants. It needs legal protection and should be included in the GDBU.

5. Association *Thymo pulcherrimi-Festucetum amethystinae*

Syntaxonomy: This community was earlier described by MALYNOVSKI & KRICSFALUSY (2000, 2002) as *Th.p.-F.a. typicum* Kricsfalusy et Malynovski 2000. Similar ecological features and floristic composition make it close to *Diantho tenuifolii-Festucetum amethystinae,* reported from the Southern Carpathians (COLDEA 1991). Other vicariant association occur in the Balkans: *Hypochaeri-Festucetum amethystinae* and *Koelerio-Festucetum amethystinae* (HORVAT et al. 1974).

Distribution: This community occurs in Chornohora, Svydovets, Chyvchyny and Hrynyavy at the altitude of 1675–1900 m. It occupies medium-sized areas of 50–100 m^2, and sometimes can cover up to 200 m^2.

Habitat: This is a diverse community that might be assigned to the Natura 2000 – 6170. Alpine and subalpine calcareous grasslands.

Ecology: The community forms on the steep southern and eastern hills (35–55°), on limestone rocks in depressions, in clefts between rocks and in places of accumulated detrital material. The soils are rocky with detritus that has major lime inclusions of dark-grey colour. The soils are moist and range from slightly acidic to slightly alkaline (pH 5,4–8,2). Fluctuation in the acidity of soils often causes changes in the floristic composition of the community. When acidity rises the presence of calcareous species decreases, and with the decline of acidity, the number of acidophilus species increases.

Characterisation: The structure of comparatively low vegetation cover (25–30 cm) is two-layered or three-layered. It is formed by *Festuca amethystina* subsp. *amethystina* which takes up to 25–70% of the area and sometimes forms solid cover. Often components are *Carex sempervirens*, *Campanula rotundifolia* subsp. *kladniana, Anthoxantum alpinum, Thymus pulcherrimus* subsp. *pulcherrimus*, and other plants. The ground layer is comprised *of Festuca airoides*, *Avenula versicolor* and many small forbs, such as *Saxifraga paniculata, Bartsia alpina, Rhodiola rosea* and other species. The total cover

of the community varies from 50 to 75%. The moss cushions often include *Polytricum formosum*, *Radula complanata*, *Rhytidiadelphus* spp. and other species. A total of 81 vascular plants and 9 cryptogams are spotted in its composition. Alpine and mountain plant species form the floristic core of the community.

Red-listed plants: IUCN – *Achillea shurii, Aconitum firmum* subsp. *firmum*; **ERL** –*Heracleum carpaticum; Astragalus australis* subsp. *krajinae, Primula elatior* subsp. *poloninensis;* **H5** – *Arnica montana*; **RDBU** – *Aconitum anthora, Agrostis rupestris, Anemone narcissiflora, Aquilegia nigricans, Aster alpinus, Campanula rotundifolia* subsp. *kladniana, Gentiana laciniata, Huperzia selago, Minuartia pauciflora, Primula minima, Pulsatilla alba, Ranunculus thora, Rhodiola rosea, Rhododendron myrtifolium, Salix retusa* subsp. *retusa,* and *Selaginella selaginoides.*

Trends: The community was more widespread in the subalpine belt in the past, but now survives only in places which are inaccessible for grazing.

Protection status: EN; **GDBU** – R. Protected in Carpathian Biosphere Reserve.

Conservation value: This community is an Eastern Carpathian endemic with limited distribution in the Ukrainian Carpathians. The community represents a rare habitat and it is a relic of xerothermic period with many red-listed plants, peripheral, and endemic species.

6. Association *Festucetum saxatilis*

Syntaxonomy: This association was described by DOMIN (1933) for the first time in the Southern Carpathians. It is also reported from the Ukrainian Carpathians by PAWŁOWSKI & WALAS (1949). The authors divided the association into two subassociations: *F. s. typicum* and *F. s. thymetosum alpestris*. The latter is dominated by *Thymus pulcherrimus* subsp. *pulcherrimus*.

Distribution: The community is found mainly on the eastern and southern slopes, at an altitude of 1400–1740 m in Chyvchyny and Hrynyavy, and in the Maramorosh Mts., at an altitude of 1800 m. It occupies areas of medium size from 30–50 m^2 to 100–200 m^2, and some places reach up to 300–500 m^2.

Habitat: Natura 2000 – 6170. Alpine and subalpine calcareous grasslands.

Ecology: The community is formed on small and shallow (depth of 40 cm) gravel soils, and among outcrops of limestone on very steep slopes (20–50°) of mostly south-eastern, and, more rarely, south-western exposure. The soil acidity ranges from slightly acidic to alkaline (pH 6,3–8,6).

Characterisation: The structure of the community is complicated – three- and four-layered. The vegetation cover is dominated by *Festuca rupicola* subsp. *saxatilis*, covering 56–60% of the area. *Thymus pulcherrimus* subsp. *pulcherrimus*, *Festuca carpatica*, *F. airoides*, *Carex sempervirens*, and *Acinos alpinus* subsp. *baumgartenii*, account for a high percentage of the cover. The vegetation is unevenly spread in patches in gaps and on gravel deposits. The total cover of the community is 60–100%. Floristic composition of the community is variable, as it depends upon edaphic factors and especially on

the degree of development of gravelly soils and the presence of rock outcrops. Some species from the *Asplenietea trichomanis* class (*Trisetum alpestre*, *Saxifraga luteoviridis*, and *Asplenium ruta-muraria*) dominate in more rocky places. *Thymus pulcherrimus* subsp. *pulcherrimus* grows here in dense clumps, as well. Warm conditions with rich soils promote intensive plant growth. A total of 72 species of vascular plants and 8 cryptogams were found here.

Red-listed plants: RDBU – *Aconitum anthora, Botrychium lunaria, Festuca rupicola* subsp. *saxatilis, Gymnadenia conopsea, Jovibarba hirta* subsp. *glabrescens, Lilium martagon,* and *Saxifraga luteoviridis.*

Trends: This community, similar to the previous association, used to be present over larger areas in the past. Nowadays, it survives only in places which cannot be accessed for grazing. Under grazing, the community changes to dense tussock coenenoses dominated by *Carex curvula* and *Sesleria bielzii*.

Protection status: VU; **GDBU** – R. Protected in Carpathian Biosphere Reserve and Carpathian National Nature Park.

Conservation value: One of the community dominants, *Festuca rupicola* subsp. *saxatilis*, is a rare species included in the RDBU (2009). This community is an East-South Carpathian endemic with very narrow distribution in the Ukrainian Carpathians. It represents a rare habitat and is rich in red-listed plants, relic, and endemic species.

7. Association *Soldanello hungaricae-Nardetum strictae*

Syntaxonomy: The association was described for the first time by MALYNOVSKI & KRICSFALUSY (2000, 2002). This community is large in size, complex and very diverse. It is comprised of a few subassociations, some of which, particularly affected by humans, might be included in the alliances *Nardo-Agrostion tenuis* Silinger 1933 and *Violion caninae* Schwickerath 1944. However this needs a special study and a proper revision thus is not dealt directly in this paper.

S.h.-N.s. gentianetosum

Syntaxonomy: The community was delineated in the Ukrainian Carpathians by BRADIS and ZAPIATOVA (1954), and later by MALYNOVSKI (1980) as the *Nardetum gentianosum luteae* association.

Distribution: This community occurs in Chornohora, Svydovets, Gorgany and the Maramorosh Mts. at an altitude of 1300–1500 m. It occupies areas of medium size (100–200 m^2) except for Mt. Sheshul in Chornohora, where the community forms huge growths over a few dozen hectares.

Habitat: Natura 2000 – 6230*. Species-rich *Nardus* grasslands on siliceous substrates in mountain areas.

Ecology: It is found on south and east facing steep slopes up to 25^o.

Characterisation: The community structure is multi-layered. The first layer (height 35 cm to 1 m) is made up of *Gentiana lutea* and tall grasses – *Deschampsia caespitosa* and *Poa chaixii*. The second layer is more dense (height 10–35 cm) and is formed by *Festuca rubra*, *Apera spica-venti*,

Anthoxanthum alpinum and *Gentiana lutea*'s lower stem and basal leaves. The third layer (height 5–10 cm) is formed by forbs, dominated by mountainous species *Soldanella hungarica* subsp. *major*, *Homogyne alpina*, and *Hieracium aurantiacum* subsp. *aurantiacum*. The fourth, ground layer is composed of mosses and lichens, rosettes of small forbs and seedling recruitment of *Gentiana lutea*. In addition to *Nardus stricta* and *Gentiana lutea*, the cover of which reaches of 50% and 15–20% respectively, the representatives of native mountainous flora also dominate here--e.g. *Festuca picturata*, *Gentiana aslepiadea*, and *Vaccinium myrtillus* cover 2–3% of the area. *Arnica montana*, *Festuca airoides*, *Carex sempervirens*, and some other species have lower cover, whereas mosses and lichens are also common (*Cetraria islandica*, *Hylocomium splendens*, *Pleurozium schreberi,* etc.). A total 40 species of vascular plants and 6 cryptogams were found.

Red-listed plants: B – *Campanula patula* subsp. *abietina*; **H5** – *Arnica montana*, *Gentiana lutea;* **RDBU** – *Campanula rotundifolia* subsp. *kladniana*, *Gentiana lutea, G. punctata, Rhododendron myrtifolium.*

Trends: In the process of pastoral degradation, *Gentiana lutea* gradually disappears from the vegetation and is replaced with dense tussock grasses.

Protection status: VU; **GDBU** – R. Protected in Carpathian Biosphere Reserve and Carpathian National Nature Park.

Conservation value: One of the community dominants, *Gentiana lutea*, is a rare species included in the RDBU (2009). This community is an East-South Carpathian endemic, and it is rare in the Ukrainian Carpathians and contains some red-listed plants. It also has important agricultural functions, including the provision of rhizomes, as well as the seeds of *G. lutea,* which is a valuable medicinal plant.

S.h.-N.s. narcissetosum

Syntaxonomy: The community was described in the Ukrainian Carpathians as the *Nardus stricta+Narcissus angustifolius* association (KOMENDAR 1964) and later as *Nardetum narcissetosum angustifolii* by KRICSFALUSY (KRICSFALUSY & KOMENDAR 1990).

Distribution: The community occurs only in the highland belt of Svydovets and the Maramosh Mts., at an altitude of 1200–1600 m, on medium-sized areas of 100–200 m^2.

Habitat: Natura 2000 – 6230*. Species-rich *Nardus* grasslands on siliceous substrates in mountain areas.

Ecology: This community forms on gentle mountain slopes of 10–18^o, with different exposure. It prefers mountain-meadow, brown, gravel soils, with a depth of 20–30 cm and a well-developed layer of litter and a humus horizon, with pH 3,4.

Characterisation: The community appearance is determined by the presence of *Narcissus poeticus* subsp. *angustifolius*, which forms white mosaic carpets during the blooming period. The total vegetation cover reaches 100%. The structure of vegetation is three-layered: the first layer is created by generative

shoots of *Nardus stricta*, *Festuca rubra*, *Agrostis capillaris*, and also *Narcissus poeticus* subsp. *angustifolius;* the second by leaves and stems of forbs; and the third, ground layer by mosses and lichens (*Hylocomium splendens*, *Mnium* sp., *Polytrichum commune,* etc.). The most common species in this community are *Narcissus poeticus* subsp. *angustifolius*, *Poa chaixii,* and *Phleum alpinum*. A total 37 species of vascular plants and 3 cryptogams were recorded in the community.

Red-listed plants: B – *Narcissus poeticus* subsp. *angustifolius*; **RDBU** – *Campanula rotundifolia* subsp. *kladniana*, *Crocus vernus* subsp. *vernus, Diphasiastrum alpinum, Narcissus poeticus* subsp. *angustifolius.*

Trends: In the case of intensive grazing, the community transforms into secondary tussock grass conenoses with some forbs, from which *Narcissus poeticus* subsp. *angustifolius* completely disappears over time.

Protection status: VU; **GDBU** – R. Protected in Carpathian Biosphere Reserve.

Conservation value: One of the community dominants, *Narcissus poeticus* subsp. *angustifolius*, is a rare species included in the RDBU (2009). This community is an East-South Carpathian endemic. It is rare in the Ukrainian Carpathians.

8. Association *Carici nigrae-Nardetum strictae*

Syntaxonomy: The community was delineated in the Ukrainian Carpathians by MALYNOVSKI (1980) as *Nardetum sphagnosum* and described by MALYNOVSKI & KRICSFALUSY (2000, 2002) as *S.h.-N.s. sphagnetosum* Kricsfalusy et Malynovski 2000. The similar association occurs in the Western Carpathians (KLIMENT 2007).

Distribution: The community is spread in the lower part of the subalpine belt, in most of the Ukrainian Carpathians mountain massifs, at an altitude of 1200–1600 m., on medium sized areas about 100 m^2.

Habitat: Natura 2000 – 6230*. Species-rich *Nardus* grasslands on siliceous substrates in mountain areas.

Ecology: The communities are spread in depressions of relief next to spring sources, on stream shores, glacial lakes, lowlands with close groundwater, and on slopes of various exposure and of steepness from 1–5 ^{o} to 15–18 ^{o}. Coenoses look like narrow strips along stream shores and around overgrown lakes. The soils are weak and turf-like. Soil moisture is higher than 80% during the whole vegetation season, with pH 3,5–4,5.

Characterisation: Vegetation cover is low and has typically has a three-layered structure. The first layer is sparse and is created by grasses and tall forbs: *Nardus stricta*, *Anthoxanthum alpinum*, and *Deschampsia caespitose.* The second layer is formed by *Vaccinium vitis-idaea*, *Homogyne alpina*, *Soldanella hungarica* subsp. *major* and other forbs. The third, ground layer is formed by *Sphagnum* spp. and other mosses. The last layer looks like a carpet only on lowering of the relief. The cover of *Nardus stricta* does not exceed 50%, and *Sphagnum fuscum*, *Sph. acutifolium*, and *Sph. girgensohnii* do not exceed 30%. *Deschampsia caespitosa* and *Carex nigra* occupy up to 5–10% of the

area. The community is characterized by the dominance of boreal species in its composition, the heavy presence of the *Sphagnum* mosses, low soil richness and excessive moisture of the substrate. Floristic composition of the community includes more than 60 vascular plants and 12 species of mosses.

Red-listed plants: RDBU – *Coeloglossum viride, Dactylorhiza cordigera, Gentiana laciniata, Pinguicula vulgaris,* and *Swertia perennis* (incl. *S. alpestris*).

Trends: This primary community, as a result of grazing and drainage, transforms into secondary, moist *Nardus* grasslands.

Protection status: LR. Protected in Carpathian Biosphere Reserve, Carpathian National Nature Park, Synevyr National Nature Park, and Gorgany Nature Reserve.

Conservation value: This community is a West-East Carpathian endemic. As a relic of the post-glacial period and a refuge of many rare plant species, this community needs legal protection and should be included into GDBU.

9. Association *Ranunculo platanifolii-Adenostyletum alliariae*

Syntaxonomy: There are two ecological groups of associations described by DEYL (1940) in the Ukrainian Carpathians: mezophytic (*Adenostyletum alliariae*) and eutrophic (*Adenostyles alliariae-Rumex alpinus, Cirsium pauciflorum-Adenostyles alliariae,* and *Cirsium pauciflorum-Rumex alpinus*). MALYNOVSKI & KRICSFALUSY (2000, 2002) consider them as variants of *Ranunculo platanifolii-Adenostyletum alliariae* association. Similar communities from the Southern and Eastern Carpatians in Romania were described as *Adenostylo-Doronicum austriaci* (COLDEA et al. 1997).

Distribution: The community is mostly spread in Svydovets, Chornohora, the Maramorosh Mts., Chyvchyny and Hrynyavy, and in Beskyd. It occupies the ecotone zone on the tree line, formed by beech forest. Usually, this community forms small patches (4–10 m^2) and sometimes reaches a larger size (20–40 m^2).

Habitat: Natura 2000 – 6430. Hygrophilous tall-herb fringe communities of plains and of montane to alpine levels.

Ecology: The community forms along streams, in hollows between rocks, on steep (20–45°) humid slopes of different exposure. Soils are shallow, of black color, and are rich in organic matter, with a pH of 5,1–5,8. The soil is comprised of merely a humus horizon on alluvial limestones, or on the rocks.

Characterisation: The vegetation cover is dominated by tall-herb species, which creates overgrowth, with a height of 1.5–2.0 m, and occupies 90–100% of the surface. The vegetation layers are not clearly determined. The first layer is dominated by *Adenostyles alliariae* (25–80%). In addition, *Cirsium waldsteinii* (up to 20%), *Filipendula ulmaria*, *Dactylis glomerata*, and *Aconitum* spp. also occur. The second layer is formed by *Doronicum austriacum*, *Cicerbita alpina*, *Rumex alpestris* subsp. *carpaticus* and some other species; the third layer is represented by the shadow tolerant *Epilobium alpestre* and *Poa nemoralis*; the fourth, ground layer, is formed by *Chrysosplenium alternifolium*, *Aposeris*

foetida, and *Viola biflora*. Sparse moss cushions scattered through this layer include *Brachythecium*, *Rhytidiadelphus*, *Eurhynchium* and other species. This is one of the richest plant communities, there were 120 vascular plants and 6 cryptogams recorded.

Red-listed plants: IUCN – *Heracleum carpaticum;* **ERL** – *Heracleum carpaticum, Primula elatior* subsp. *poloninensis,* and *Pulmonaria filarszkyana;* **B** – *Campanula patula* subsp. *abietina;* **RDBU** – *Gentiana punctata, Lilium martagon.*

Trends: As a result of grazing, the association transforms into coenoses with *Calamagrostis* spp. on relatively dry soils, and with *Deschampsia caespitosa*, in moister areas.

Protection status: VU. Protected in Carpathian Biosphere Reserve, Carpathian National Nature Park, and Uzhansky National Nature Park.

Conservation value: The floristic core of the community is formed by a number of Carpathian endemic species and red-listed plants. This community is an East-South Carpathian endemic. It needs legal protection and should be included in the GDBU.

10. Association *Pulmonario filarszkyanae-Alnetum viridis*

Syntaxonomy: The association was described in the Ukrainian Carpathians as *Alnus viridis-Senecio nemorensis* (DEYL 1940), *Pulmonarieto-Alnetum* (PAWŁOWSKI & WALAS 1949), *Alnetum senecio fuchsii-pulmonario filarszkyana* (KOMENDAR 1966), and *Duschekietum pulmonario-seneciosum* (MALYNOVSKI 1980).

Distribution: The community is widespread in Chornohora, Svydovets, Chyvchyny and Hrynyavy, and the Maramorosh Mts., at an altitude of 1370–1750 m. It occupies areas of medium size (100–200 m^2), but can sometimes extend over one ha.

Habitat: Natura 2000 – 6430. Hygrophilous, tall-herb fringe communities of plains and of montane to alpine levels.

Ecology: The community is widespread on steep slopes of over 25^o, mostly of northern exposure, on walls of glacial cirques. It may occur on slopes of southern or eastern exposure. The community tends to occupy well-developed humus rich brown soils with high humidity in the upper horizons.

Characterisation: The vegetation structure is multi-layered. In primary krummholz communities, the first, shrub layer, is 2.5–3.0 m tall and is formed by *Alnus alnobetula;* the second layer consists of tall-forb species (*Adenostyles alliariae, Calamagrostis arundinacea,* etc.). The third layer is made up of *Senecio nemorensis* and *Pulmonaria filarszkyana* and small forbs. The fourth, ground layer is well developed and is dominated by different species of mosses (*Polytrichum, Dicranum,* etc.). A total of 76 vascular plants and 30 cryptogams were found in the community.

Within the association, a number of variants are delineated. The most interesting among them is the *Narcissus poeticus* subsp. *angustifolius* variant, delineated by KRICSFALUSY (MALYNOVSKI & KRICSFALUSY 2000, 2002). It was

Fig. 6. Species rich siliceous *Nardus* grasslands of mountain areas in Chornohora, the Ukrainian Carpathians.

Fig. 7. Tall-herb grasslands of mountain to alpine levels the Maramorosh Mts., the Ukrainian Carpathians.

described in Svydovets at an altitude of 1300–1450 m on steep slopes (up to 35°). Krummholz of *Alnus alnobetula* are short (1–1.5 m), and the stand is sparse, with a density of only 50%. As a result of the low shrub cover, the herbaceous layer is dense (up to 90%). *Narcissus poeticus* subsp. *angustifolius* grows here in large clumps because this species reproduces very well vegetatively.

Red-listed plants: IUCN – *Heracleum carpaticum;* **ERL** – *Heracleum carpaticum, Primula elatior* subsp. *poloninensis, Pulmonaria filarszkyana,* and *Sempervivum montanum* subsp. *carpaticum;* **B** – *Campanula patula* subsp. *abietina, Narcissus poeticus* subsp. *angustifolius;* **RDBU:** *Campanula rotundifolia* subsp. *kladniana, Crocus vernus* subsp. *vernus, Gentiana punctata, Narcissus poeticus* subsp. *angustifolius,* and *Sempervivum montanum* subsp. *carpaticum.*

Trends: Under anthropogenic impact (grazing, burning, and cutting), the community transforms, through a few consequent stages, into dense tussock coenoses, mostly with *Deschampsia caespitosa*.

Protection status: VU. Protected in Carpathian Biosphere Reserve and Carpathian National Nature Park.

Conservation value: One of the community dominants, *Pulmonaria filarszkyana*, is a rare species included in the European Red List of vascular plants (2010). The association is an East Carpathian endemic and includes many red-listed plants and endemic species. The community has important water-protection and anti-erosion significance. Therefore, the association needs legal protection and should be included in the GDBU.

11. Association *Hyperico alpigeni-Calamagrostietum villosae*

Syntaxonomy: The association was described in the Ukrainian Carpathians for the first time by PAWŁOWSKI & WALAS (1949). This name has recently been adapted for the communities from the Southern and Eastern Carpathians, in Romania (COLDEA et al. 1997). Other names for these communities include *Calamagrostis villosa* type (SWEDERSKI & SZAFRAN 1931) and *Calamagrostietum villosae* (MALYNOVSKI 1980).

Distribution: The community occurs in the subalpine belt and in the lower part of the alpine belt in Chornohora, Chyvchyny and Hrynyavy, Gorgany, and the Maramorosh Mts., at an altitude of 1500–1900 m. It covers areas of medium size (100–200 m^2) and can sometimes cover up to 400 m^2.

Habitat: Natura 2000 – 6430. Hygrophilous tall-herb fringe communities of plains and of montane to alpine levels.

Ecology: The community is widespread on steep rocks, in pits and depressions, in glacial cirques, and on slopes of different steepness (20–40^o) and exposure. It forms on the siliceous bedrocks, on well drained brown soils with a high degree of mineralization and a weakly developed humus horizon, with pH 3,9–5,3.

Characterisation: The structure of the community is complex and multi-layered. The first layer is formed by *Calamagrostis villosa*, *C. arundinacea,*

Deschampsia caespitosa, *Festuca carpatica* and other tall-grasses and forbs; the second is comprised of dense grasses (*Fesrtuca picturata*, *F. rubra*, *Agrostis alpina*, and *Luzula luzuloides*) and small forbs (*Thymus pulcherrimus* subsp. *pulcherrimus*, *Soldanella hugarica* subsp. *major,* etc.). The third, ground layer is sparse and is formed by mosses (*Cetraria islandica, Rhytidiadelphus squarrosus*). This is one of the richest plant communities with 129 vascular plants and 52 cryptogams reported.

Trends: Intensive grazing has a severe impact on the community: it changes with coenenoses of dense tussock grasses, such as *Deschampsia caespitosa* and *Nardus stricta* in the subalpine belt, and *Festuca airoides* in the alpine belt.

Red-listed plants: IUCN – *Heracleum carpaticum;* **ERL** – *Heracleum carpaticum, Primula elatior* subsp. *poloninensis,* and *Ranunculus malinovskii;* **B** – *Campanula patula* subsp. *abietina;* **H5** – *Arnica montana;* **RDBU** – *Campanula rotundifolia* subsp. *kladniana, Coeloglossum viride, Cystopteris sudetica, Gentiana punctata, Gymnadenia conopsea, Lilium martagon, Pulsatilla alba, Rhodiola rosea,* and *Rhododendron myrtifolium.* Data on occurrence of *Lloydia serotina* in this community (MALYNOVSKI 1980) needs confirmation with additional studies.

Protection status: VU. Protected in Carpathian Biosphere Reserve and Carpathian National Nature Park.

Conservation value: This community is an endemic to the Eastern Carpathians. It includes many red-listed plants and endemic species. The community needs legal protection and should be included in the GDBU.

12. Association *Poo chaixii-Deschampsietum caespitosae*

Syntaxonomy: The association was described for the first time in the Ukrainian Carpathians by PAWŁOWSKI & WALAS (1949). This community was often treated under different names, such as *Deschampsietum caespitosae* (DEYL 1940), *Deschampsietum poosum chaixii*, *Deschampsietum agrostiosum*, *Deschampsietum calamagrostiosum*, *Deschampsietum helictotrichosum*, *Deschampsietum anthoxanthosum*, *Deschampsietum festucosum supinae* (YERMACHENKO 1962), and *Deschampsietum festucoso-pictae herbosum* (MALYNOVSKI 1980).

Distribution: The community is formed in the upper parts of subalpine and alpine belts of the Ukrainian Carpathians at an altitude of 1300–1900 m. It covers areas of medium size (100–200 m^2) and can sometimes cover up to 300 m^2.

Habitat: Natura 2000 – 6430. Hygrophilous tall-herb fringe communities of plains and of montane to alpine levels.

Ecology: The community is widespread on moderate (5–20 ^{o}) and very steep (25–50^o) slopes of southern and western exposure. These chionophilios pastures tend to grow in deep, well-mineralized, wet humus-rich acidic soils with a pH of 4,3–5,9.

Characterisation: Communities are characterized by a complex, multi-layered structure. In most instances, there are four layers. The first layer is sparse (60–120 cm) and is formed by *Deschampsia caespitosa*, *Calamagrostis arundinacea*, *Luzula luzuloides*, and *Avenula pubescens.* The second layer (20–60 cm) consists of *Festuca picturata*, *Anthoxanthum alpinum* and other species. Most forbs are concentrated in the third layer (10–20 cm), formed by *Thymus pulcherrimus* subsp. *pulcherrimus*, *Homogyne alpina*, *Soldanella hugarica* subsp. *major* and many other species. The fourth, ground layer consists of mosses, lichens, and small forbs. A total of 77 vascular plants and 19 cryptogams were recorded in the community. The core of its floristic composition is formed by mountainous and alpine elements of flora.

There are many brightly coloured forbs in the community which create an exotic look, during the flowering period. Within them the *Narcissus poeticus* subsp. *angustifolius* variant was described by KRICSFALUSY in Svydovets (MALYNOVSKI & KRICSFALUSY 2000, 2002).

Trends: Under the impact of intense grazing, the community changes to poor-structured coenenoses of dense tussock grasses dominated by *Deschampsia caespitosa* or *Nardus stricta* in the subalpine belt, and by *Festuca airoides*, in the alpine belt.

Red-listed plants: B – *Campanula patula* subsp. *abietina, Narcissus poeticus* subsp*. angustifolius;* **RDBU** – *Campanula rotundifolia* subsp. *kladniana, Coeloglossum viride, Crocus vernus* subsp*. vernus, Diphasiastrum alpinum,* and *Narcissus poeticus* subsp. *angustifolius.*

Protection status: LR. Protected in Carpathian Biosphere Reserve and Carpathian National Nature Park, and Uzhansky National Nature Park.

Conservation value: The community is rare and endemic to the Western and Eastern Carpathians. Also, it contains many red-listed plants and peripheral species. The community needs legal protection and should be included in the GDBU.

13. Association *Phleo alpini-Deschampsietum caespitosae*

Syntaxonomy: This association was reported from the Ukrainian Carpathians by MALYNOVSKI & KRICSFALUSY (2000, 2002).

Distribution: This community occurs in the subalpine belt in all mountain massifs of the Ukrainian Carpathians, at an altitude of 1300–1800 m, on areas of medium size (100–200 m^2), but can sometimes extend to 400 m^2.

Habitat: Natura 2000 – 6430. Hygrophilous tall-herb fringe communities of plains and of montane to alpine levels.

Ecology: The community grows mostly on moderate slopes from 5–10° to 40° of south-eastern and south-western exposures. This chinophilous community occur on moist brown soils with some humus and a pH of 4,3–5,9.

Characterisation: Similar to the previous association, the community is characterized by a multi-layered structure. The first, sparse layer is about 1 m tall and it is formed by *Deschampsia caespitosa*, *Luzula luzuloides*, and *Phleum alpinum.* The second layer is 50 cm tall and consists of *Festuca*

picturata, *F. rubra,* and *Anthoxanthum alpinum*. Forbs are concentrated in the third layer (20 cm), formed by *Homogyne alpina*, *Potentilla aurea, Soldanella hugarica* subsp. *major* and many other species. The fourth, ground layer is formed by mosses, lichens, and small forbs. The overall vegetation cover ranges from 50–100%. The community is rich in species of different ecological groups and life forms. *Deschampsia caespitosa, Phleum alpinum, Homogyne alpina, Potentilla aurea, Ligusticum mutellina* and a few other species are most often found among them. However, high density is found only with *Deschampsia caespitosa, Luzula luzuloides, Festuca picturata* and *F. rubra* and some mosses (*Polytrichum* spp.). The floristic composition of the community is rich; it includes 96 vascular plants and 6 cryptogams.

Trends: Due to grazing of vegetation in the subalpine belt, the community can change to coenoses dominated by *Nardus stricta.*

Red-listed plants: B – *Campanula patula* subsp. *abietina;* **RDBU** – *Campanula rotundifolia* subsp. *kladniana, Coeloglossum viride, Crocus vernus* subsp. *vernus,* and *Festuca rupicola* subsp. *saxatilis.*

Protection status: LR. Protected in Carpathian Biosphere Reserve, Carpathian National Nature Park, and Uzhansky National Nature Park.

Conservation value: The community is endemic to the Carpathians and contains rare plant species. It needs legal protection and should be included in the GDBU.

14. Association *Festucetum carpaticae*

Syntaxonomy: This association was reported for the Ukrainian Carpathians as *Festucetum carpaticae* by DOMIN (1930) and DEYL (1940), and later as *Festucetum carpaticae herbosum* by MALYNOVSKI (1980). The community was delineated in the earlier version of our classification (MALYNOVSKI & KRICSFALUSY 2000, 2002) as *Th.p.-F.a. festucetosum carpaticae* Kricsfalusy et Malynovski 2000.

Distribution: This community occurs in the subalpine belt in Chornohora, Chyvchyny and Hrynyavy, the Maramorosh Mts., and Svydovets, at an altitude of 1300–1750 m. It occupies areas of medium size from 40–50 m^2 to 100–200 m^2.

Habitat: Natura 2000 – 6430. Hygrophilous tall-herb fringe communities of plains and of montane to alpine levels.

Ecology: The community grows mostly on steep slopes from 35° to 55° of eastern, south-eastern, and southern exposures. This is species rich chionophilous community on moist carbonate soils.

Characterisation: *Festuca carpatica* defines the structure of the vegetation cover, which is three-layered. The first layer, at a height of 70–80 cm, is created by *Calamagrostis arundinacea*, *Centaurea phrygia* subsp. *carpatica*, *Achillea stricta*, *Leucanthemopsis alpina* and other plants. The second, main layer, at a height of 40–50 cm, is formed by *Festuca carpatica.* Many other tall-grass species such as *Astrantia major*, *Leucanthemum subalpinum*, *Phyteuma orbiculare*, *Potentilla aurea*, *Heracleum carpaticum* also occur

there. The third layer is comprised of many small forbs, such as *Gentiana*, *Ranunculus oreophilus* and other species. The total cover of the community varies from 70 to 90%. The moss cushions often include *Brachythecium albicans*, *Hylocomium splendens* and other species. A total of 86 vascular plants and 6 cryptogams are spotted in its composition. Mountain plant species form the floristic core of the community.

Red-listed plants: IUCN – *Heracleum carpaticum;* **ERL** – *Heracleum carpaticum, Primula elatior* subsp. *poloninensis;* **B** – *Campanula patula* subsp. *abietina;* **H5** – *Arnica montana*;

RDBU – *Anemone narcissiflora, Gentiana laciniata.*

Trends: The community used to be more widespread in the subalpine belt, however its area has shrank under grazing impact. The community has good recovery potential.

Protection status: VU; **GDBU** – R. Protected in Carpathian Biosphere Reserve.

Conservation value: This community is a Carpathian endemic, with limited distribution in the Ukrainian Carpathians.

Distribution of grasslands

Altitudinal distribution of mountain grasslands in the study area is shown in Fig. 8. The mountain grassland communities occur in the subalpine and alpine belt, at an altitude of 1300–2060 m. There is only the lower alpine belt in the Ukrainian Carpathians which differentiates this mountain massif from the Southern and Western Carpathians, where the upper alpine or nival belt is well-developed.

Chionophilous communities of the *Salicetea herbaceae* class are spread throughout the Ukrainian Carpathians in the alpine belt of Chornohora, the Maramorosh Mts. and Svydovets, where adverse climatic conditions predominate. There is a short vegetative period, acidic subtrates on the silicate bedrocks, high humidity, as a result of the lengthy snow cover, and constant ground water flow. The *Gentiano punctatae-Festucetum picturatae* association is endemic to the Carpathians. The majority of its localities have already transformed into dense secondary tussock communities due to overgrazing.

Only in the alpine belt, on the top of mountains and mountain ranges, the communities of *Caricetea curvulae* class are widespread. The *Primulo minimae-Caricetum curvulae* association takes a special place within this class. The latter one is widespread on silicate bedrocks and acidic soils. Being typical for the highlands of Central Europe, this association is found in the Ukrainian Carpathians only in a few places in the Maramorosh Mts. and Chornohora, where its north-eastern border lies. Most communities of the *Elyno-Seslerietea* class are rare in the Ukrainian Carpathians. This is a large class of syntaxa, to which the union *Festuco saxatilis-Seslerion bielzii* belongs. Four of five associations belong to rare communities, which are spread on the carbonate bedrocks, in the eastern part of the mountains. Most diagnostic species belong to alpine and arctic-alpine elements of flora. Two communities of this class, *Senecio carpaticae-Seslerietum bielzii* and *Thymo pulcherrimi-Festucetum*

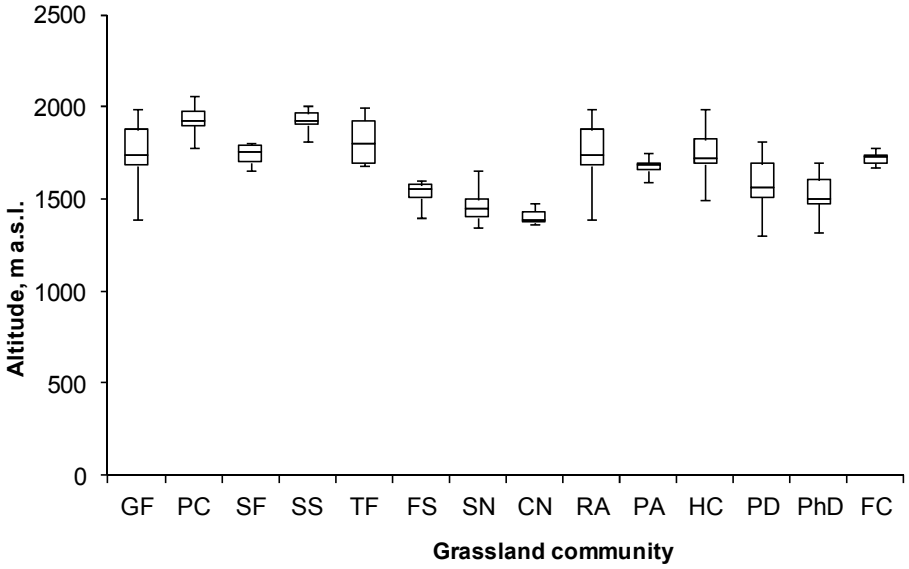


Fig. 8. Box plot diagram of the altitudinal distribution of grassland communities of high conservation value in the Ukrainian Carpathians:
GF – *Gentiano punctatae-Festucetum picturatae*, PC – *Primulo minimae-Caricetum curvulae*, SF – *Saxifrago paniculatae-Festucetum versicoloris*, SS – *Senecio carpaticae-Seslerietum bielzii*, TF – *Thymo pulcherrimi-Festucetum amethystinae*, FS – *Festucetum saxatilis*, SN – *Soldanello hungaricae-Nardetum strictae*, CN – *Carici nigrae-Nardetum strictae*, RA – *Ranunculo platanifolii-Adenostyletum alliariae*, PA – *Pulmonario filarszkyanae-Alnetum viridis*, HC – *Hyperico alpigeni-Calamagrostietum villosae*, PD – *Poo chaixii-Deschampsietum caespitosae*, PhD – *Phleo alpini-Deschampsietum caespitosae*, FC – *Festucetum carpaticae.*

amethystinae, are endemic to the Eastern Carpathians. Besides this the *Festucetum saxatilis* association is endemic to the Eastern and Southern Carpathians, and the *Festucetum versicoloris* to the Carpathians. There are many rare and endemic plant species in the composition of these communities.

The primary communities of the *Nardetea strictae* class survived mainly in the subalpine belt. The secondary communities of this class can stand intensive grazing and are spread on the highlands, due to morphologic characteristics, and intensive seed and vegetative reproduction, as well as the ability of some plants to produce poison. The *Soldanello hungaricae-Nardetum strictae* association is endemic to the Eastern and Southern Carpathians. The *Carici nigrae-Nardetum strictae* communities are spread in depressions of relief, next to spring sources, on stream shores and glacial lakes. This association is endemic to the Western and Eastern Carpathians.

The *Mulgedio-Aconitetea* class is represented by a series of endemic communities of different levels, from local and regional to supra-regional. These communities are mainly comprised of tall-grass and tall-forb plant species. Associations such as *Pulmonario filarszkyanae-Alnetum viridis* and *Hyperico*

apligeni-Calamagrostietum villosae are endemic to the Eastern Carpathians, while *Poo chaixii-Deschampsietum caespitosae* is endemic to the Western and Eastern Carpathians and *Ranunculo platanifolii-Adenostyletum alliariae* to the Southern and Eastern Carpathians. Another two communities, *Phleo alpini-Deschampsietum caespitosae* and *Festucetum carpaticae,* are endemic to the Carpathians.

Phytogeographical analyses of grassland communities unveiled that all of them but *Primulo minimae-Caricetum curvulae* are endemic at different levels: East Carpathian (5 associations), East-South Carpathian (2), West-East Carpathian (2), and Pan Carpathian (4) (Fig. 9). The East Carpathian endemic group is the richest one, closely followed by the Pan Carpathian.

Comparison of highland vegetation of the Ukrainian Carpathians with the Southern and Western Carpathians revealed that the latter two mountain systems have richer and more diverse communities than the Ukrainian Carpathians (MALYNOVSKI & KRICSFALUSY 2000, 2002). We hypothesized that this can be explained by their larger size, higher elevation and topographical differentiation, and more diverse composition of soil-forming rocks and soils, as well as the history of the vegetation (MALYNOVSKI & KRICSFALUSY 2000, 2002). Recently ŠIBÍKOVÁ et al. (2010) supported this hypothesis, suggesting that, after the ice age, the extremely broken high-mountain relief, various geological bedrocks and soils, and specific microclimates resulted in experimental habitat heterogeneity. That heterogeneity, on the one hand, provided refuges for relic species, and, on the other hand, created suitable conditions for speciation and hence became centers of endemism.

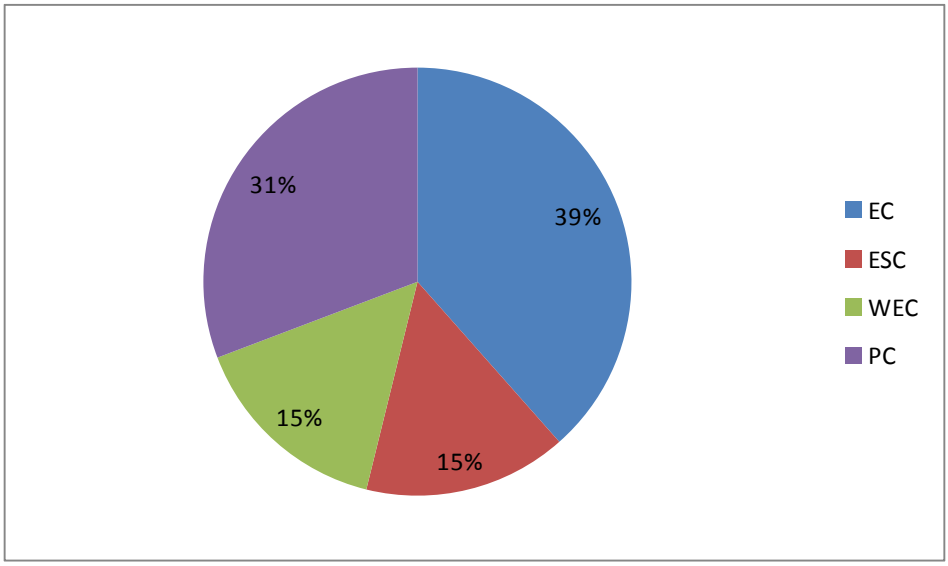


Fig. 9. Proportion of the endemic grassland communities of high conservation value in the Ukrainian Carpathians: EC – East Carpathian, ESC – East-South Carpathian, WEC – West-East Carpathian (WEC), PC – Pan Carpathian.

Diversity of grasslands

The analysis of habitat richness shows that the hygrophilous tall-herb fringe communities possess the highest number of plant associations (6), followed by the alpine and subalpine calcareous grasslands (4) (Tab. 2). The lowest number of of plant associations (2) is recorded in the siliceous alpine and boreal grasslands, and in the species-rich *Nardus* grasslands. The latter one can be partly explained by the very broad size of the association *Soldanello hungaricae-Nardetum strictae*, which, in fact, includes five subassociations that potentially might be delineated as separate associations. Overall, hygrophilous tall-herb fringe communities possess the highest richness of both plant associations and plant species (see further below).

Tab. 2. Occurrence of vascular plants in habitats and grassland communities of high conservation value in the Ukrainian Carpathians

Habitat (Natura 2000)	Alliance	Association	Nr of all vascular plants	Nr of red-listed plants
Siliceous alpine and boreal grasslands	*Festucion picturatae*	*Gentiano punctatae-Festucetum picturatae*	110	15
	Caricion curvulae	*Primulo minimae-Caricetum curvulae*	71	7
Alpine and subalpine calcareous grasslands	*Festucion versicoloris*	*Saxifrago paniculatae-Festucetum versicoloris*	91	18
	Festuco saxatilis-Seslerion bielzii	*Senecio carpaticae-Seslerietum bielzii*	39	9
		Thymo pulcherrimi-Festucetum amethystinae	138	21
		Festucetum saxatilis	82	7
Species-rich *Nardus* grasslands on siliceous substrates in mountain areas	*Nardion strictae*	*Soldanello hungaricae-Nardetum strictae*	88	9
		Carici nigrae-Nardetum strictae	72	5
Hygrophilous tall-herb fringe communities of plains and of montane to alpine levels	*Adenostylion alliariae*	*Ranunculo platanifolii-Adenostyletum alliariae*	126	6
		Pulmonario filarszkyanae-Alnetum viridis	106	9
	Calamagrostion villosae	*Hyperico alpigeni-Calamagrostietum villosae*	181	14
		Poo chaixii-Deschampsietum caespitosae	96	6
		Phleo alpini-Deschampsietum caespitosae	103	5
	Festucion carpaticae	*Festucetum carpaticae*	90	6

In total, 516 plant species which belong to three taxonomic groups (372 vascular plants, 89 bryophytes, and 55 lichens) were identified in the 129 sites, within the 14 study grassland communities. In terms of total number of species present in each community (species occurrence), *Hyperico alpigeni-Calamagrostietum villosae*, *Thymo pulcherrimi-Festucetum amethystinae*, and *Ranunculo platanifolii-Adenostyletum alliariae* make the top three associations (Tab. 2, Fig. 10). These associations also contain the highest vascular plant number. *Hyperico alpigeni-Calamagrostietum villosae, Pulmonario filarszkyanae-Alnetum viridis* and *Poo chaixii-Deschampsietum caespitosae* are among the the richest communities, in the number of bryophytes and lichens (Fig. 6). These differences in species richness could be due to the unique ecological conditions prevailing in each vegetation type. For example, five out of six communities, which have the highest richness that exceeds 100 species, belong to the *Mulgedio-Aconitetea* class. These communities occur on nutrient-rich and moist soils, from montane to alpine belt. They have a large pool of constant species, and their habitat conditions are quite similar. Also, these associations support the largest numbers of endemic species among all studied grassland communities.

In terms of red-listed vascular plant occurence, *Thymo pulcherrimi-Festucetum amethystinae* (*r* = 21), *Festucetum versicoloris* (*r* = 18) and *Gentiano punctatae-Festucetum picturatae* (*r* = 15) make the top three associations (Tab. 3; Fig. 11). They are closely followed by *Hyperico apligeni-Calamagrostietum villosae* (*r* = 14). The distribution of red-listed plants within vegetation communities is generally uneven. Of the total 51 red-listed plants documented (Tab. 3), only 9 species (17.7%) occur in more than one third of all associations (*Fr* ≥ 0.36). Such species as *Campanula patula* subsp*. abietina* and *C. rotundifolia* subsp. *kladniana* (*Fr* = 0.64), *Coeloglossum viride, Primula elatior* subsp*. poloninensis, Pulsatilla alba,* and *Rhododendron myrtifolium* (*Fr* = 0.43) are the most common red-listed plants in the composition of mountain grasslands.

Under a different level of international protection are 13 vascular plant species (note that some of them are included in more than one list): 3 are on the IUCN Red List of threatened species (2010), 6 are on the European Red List of vascular plants (BILZ et al. 2011), 3 are included in the Bern Convention (1979), and 2 are in the Annex V of Habitat Directive of European Union (European Commission 2007). The highest number of red-listed plants, which totals 42 species, is included in the Red Data Book of Ukraine (2009).

Beyond counting species occurrence and the distribution of red-listed plants, we also analysed relationships between the size of the grassland communities, vegetation cover and species richness patterns. Calculating means of species richness based on the data obtained from the 129 study sites (a total of (3)5–12(16) plots were established per each site), allowed us to document high grassland diversity that varies from 18.86 to 32.60 species. These data are compatable with the diversity of species-rich grasslands videly reported from Europe which have on average about 30 plant species and are a bit lower than higher average for species-rich mown grasslands which totals 38 species in the Romanian part of the Eastern Capathians (CSERGŐ & DEMETER 2012).

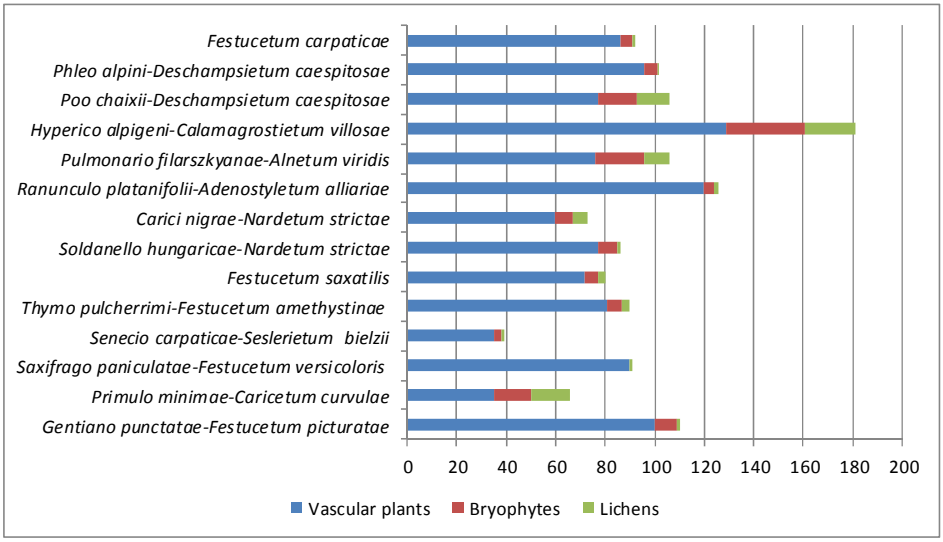


Fig. 10. Occurrence of different species groups in grassland communities of high conservation value in the Ukrainian Carpathians: horizontal axis – number of species, vertical axis – plant association.

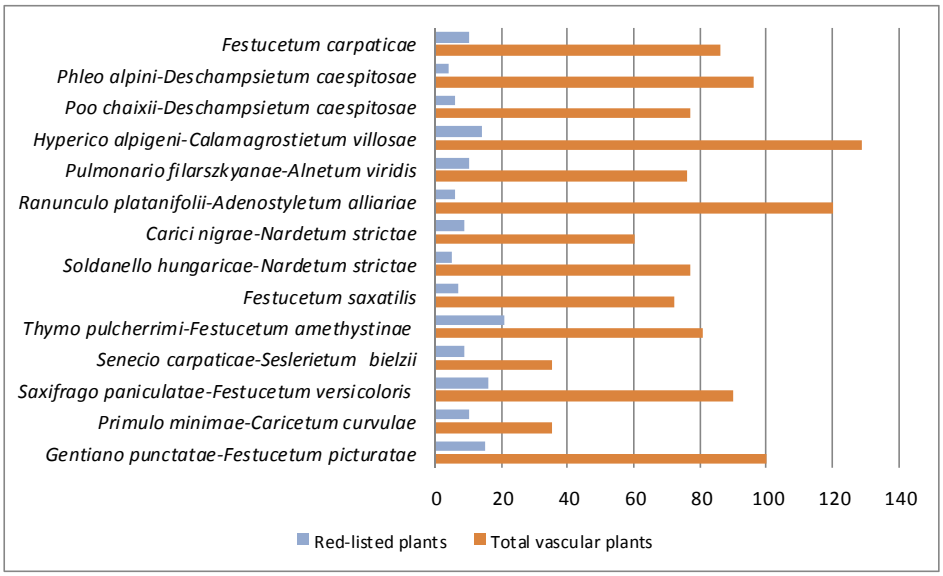


Fig. 11. Occurrence of red-listed vascular plants in grassland communities of high conservation value in the Ukrainian Carpathians: horizontal axis – number of species, vertical axis – plant association.

Tab. 3. Occurrence of red-listed vascular plants in grassland communities of high conservation value in the Ukrainian Carpathians

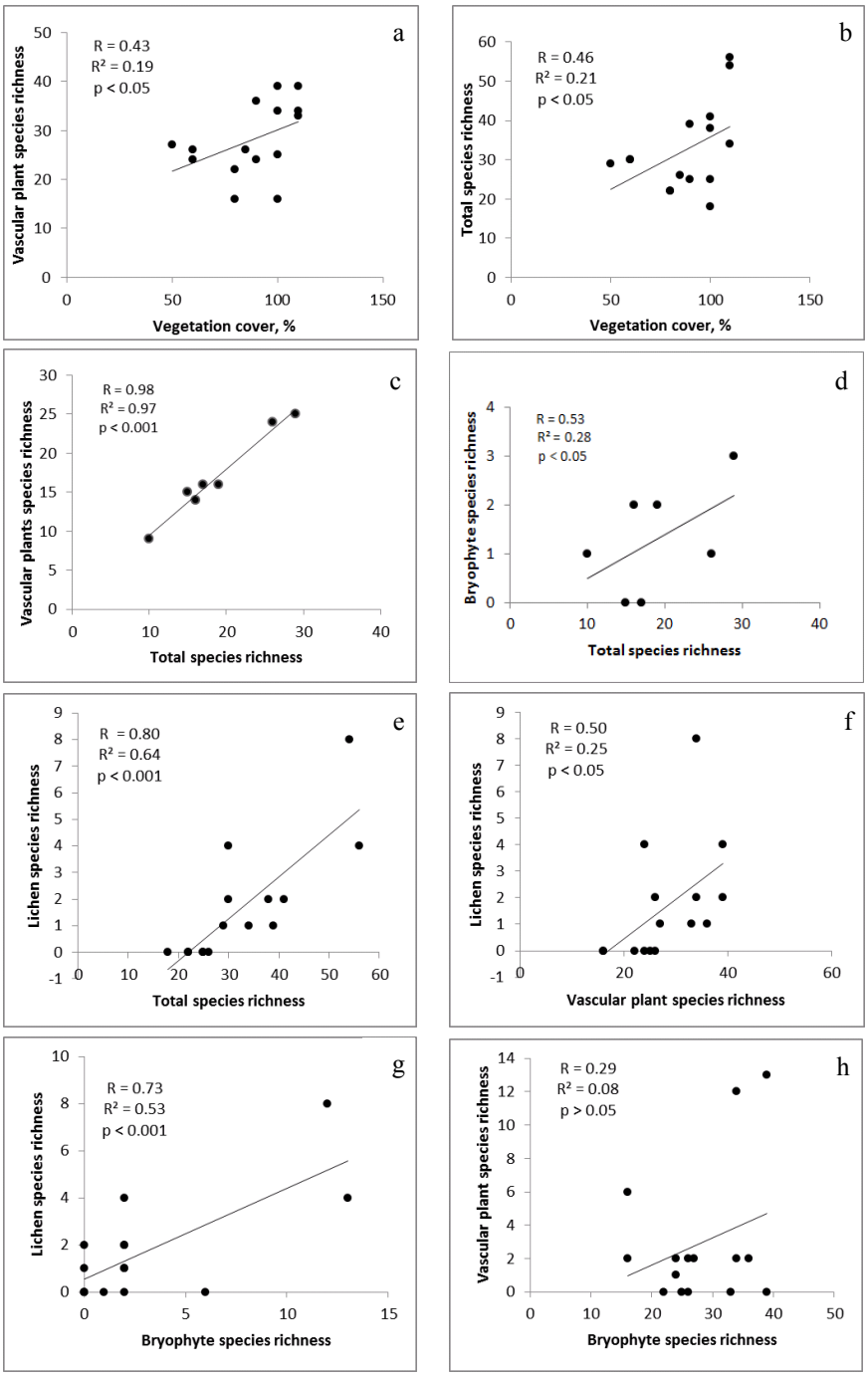
Red-listed vascular plants	GF	PC	SF	SS	TF	FS	SN	CN	RA	PA	HC	PD	PhD	FC	*Fr*
Achillea shurii					+										0.07
Aconitum anthora	+				+	+									0.21
Aconitum firmum subsp. *firmum*					+										0.07
Agrostis rupestris					+										0.07
Anemone narcissiflora	+		+		+									+	0.29
Aquilegia nigricans			+		+										0.14
Arnica montana					+		+				+			+	0.29
Aster alpinus			+		+										0.14
Astragalus australis subsp. *krajinae*			+		+										0.14
Botrychium lunaria						+									0.07
Campanula patula subsp. *abietina*	+		+				+		+	+	+	+	+	+	0.64
Campanula rotundifolia subsp. *kladniana*	+		+	+	+		+			+	+	+	+		0.64
Coeloglossum viride	+		+					+			+	+	+		0.43
Crocus vernus subsp. *vernus*							+			+		+	+		0.29
Cystopteris sudetica											+				0.07
Dactylorhiza cordigera								+							0.07
Diphasiastrum alpinum							+					+			0.14
Doronicum clusii subsp. *villosum*				+											0.07
Draba aizoides			+												0.07
Festuca rupicola subsp. *saxatilis*						+							+		0.14
Gentiana laciniata	+		+		+			+						+	0.36
Gentiana lutea							+								0.07
Gentiana punctata	+						+		+	+	+				0.36
Gymnadenia conopsea	+					+					+				0.21
Hedysarum hedysaroides			+												0.07
Heracleum carpaticum									+	+	+			+	0.29
Huperzia selago		+	+	+	+										0.29
Jovibarba hirta subsp. *glabrescens*						+									0.07
Leontopodium alpinum			+												0.07
Lilium martagon						+			+		+				0.21
Loiseleuria procumbens		+		+											0.14
Minuartia pauciflora			+		+										0.14
Narcissus poeticus subsp. *angustifolius*							+			+		+			0.21
Oreochloa disticha		+													0.07
Pinguicula vulgaris								+							0.07
Poa deylii	+														0.07

Tab. 3. - cont.

Red-listed vascular plants	GF	PC	SF	SS	TF	FS	SN	CN	RA	PA	HC	PD	PhD	FC	*Fr*
Primula elatior subsp. *poloninensis*			+		+				+	+	+			+	0.43
Primula minima	+	+		+	+										0.29
Pulmonaria filarszkyana									+	+					0.14
Pulsatilla alba	+	+	+	+	+						+				0.43
Ranunculus malinovskii											+				0.07
Ranunculus thora	+				+										0.14
Rhodiola rosea	+		+	+	+						+				0.36
Rhododendron myrtifolium	+	+		+	+		+				+				0.43
Salix herbacea	+	+	+												0.21
Salix retusa subsp. *retusa*					+										0.07
Saxifraga luteoviridis						+									0.07
Selaginella selaginoides			+		+										0.14
Sempervivum montanum subsp. *carpaticum*										+					0.07
Senecio abrotanifolius subsp. *carpaticus*				+											0.07
Swertia perennis (inc. *S. alpestris*)								+							0.07
r	**15**	**7**	**18**	**9**	**21**	**7**	**9**	**5**	**6**	**9**	**14**	**6**	**5**	**6**	

GF – *Gentiano punctatae-Festucetum picturatae,* PC – *Primulo minimae-Caricetum curvulae,* SF – *Saxifrago paniculatae-Festucetum versicoloris,* SS – *Senecio carpaticae-Seslerietum bielzii,* TF – *Thymo pulcherrimi-Festucetum amethystinae,* FS – *Festucetum saxatilis,* SN – *Soldanello hungaricae-Nardetum strictae,* CN – *Carici nigrae-Nardetum strictae,* RA – *Ranunculo platanifolii-Adenostyletum alliariae,* PA – *Pulmonario filarszkyanae-Alnetum viridis,* HC – *Hyperico alpigeni-Calamagrostietum villosae,* PD – *Poo chaixii-Deschampsietum caespitosae,* PhD – *Phleo alpini-Deschampsietum caespitosae,* FC – *Festucetum carpaticae; Fr* – Species frequency, *r* – Species richness.

Overall, we observed a multimodal relationship between species richness (vascular plants, bryophytes, and lichens) and biotic and abiotic environmental variables in the study communities. Results of these analyses are illustrated on the example of the *Hyperico alpigeni-Calamagrostietum villosae* and *Senecio carpaticae-Seslerietum bielzii* communities where these relatioships are most evident (Fig. 12). Total species richness (Pearson's co-efficient of correlation varies from $R = 0.36$ to $R = 0.55$) and vascular plant species richness ($R = 0.37$ to $R = 0.49$) linearly enhanced with increasing vegetation cover. In most communities there are strong relationships between total species richness and the species richness of vascular plants ($R = 0.55$ to $R = 0.99$), bryophytes ($R = 0.53$ to $R = 0.99$) and lichens ($R = 0.50$ to $R = 0.95$). Also, the species richness of vascular plants and lichens ($R = 0.33$ to $R = 0.90$) as well as the species richness of bryophytes and lichens ($R = 0.32$ to $R = 0.94$) showed positive correlations. The relationships between the species richness of vascular plants and bryophytes are less evident, however they were positively related in some study grassland communities ($R = 0.40$ to $R = 0.78$).


a
R = 0.43
R² = 0.19
p < 0.05
Vascular plant species richness
Vegetation cover, %
b
R = 0.46
R² = 0.21
p < 0.05
Total species richness
Vegetation cover, %
c
R = 0.98
R² = 0.97
p < 0.001
Vascular plants species richness
Total species richness
d
R = 0.53
R² = 0.28
p < 0.05
Bryophyte species richness
Total species richness
e
R = 0.80
R² = 0.64
p < 0.001
Lichen species richness
Total species richness
f
R = 0.50
R² = 0.25
p < 0.05
Lichen species richness
Vascular plant species richness
g
R = 0.73
R² = 0.53
p < 0.001
Lichen species richness
Bryophyte species richness
h
R = 0.29
R² = 0.08
p > 0.05
Vascular plant species richness
Bryophyte species richness

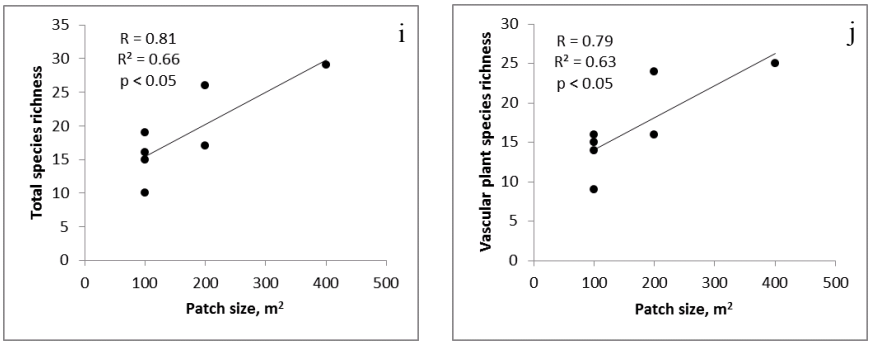
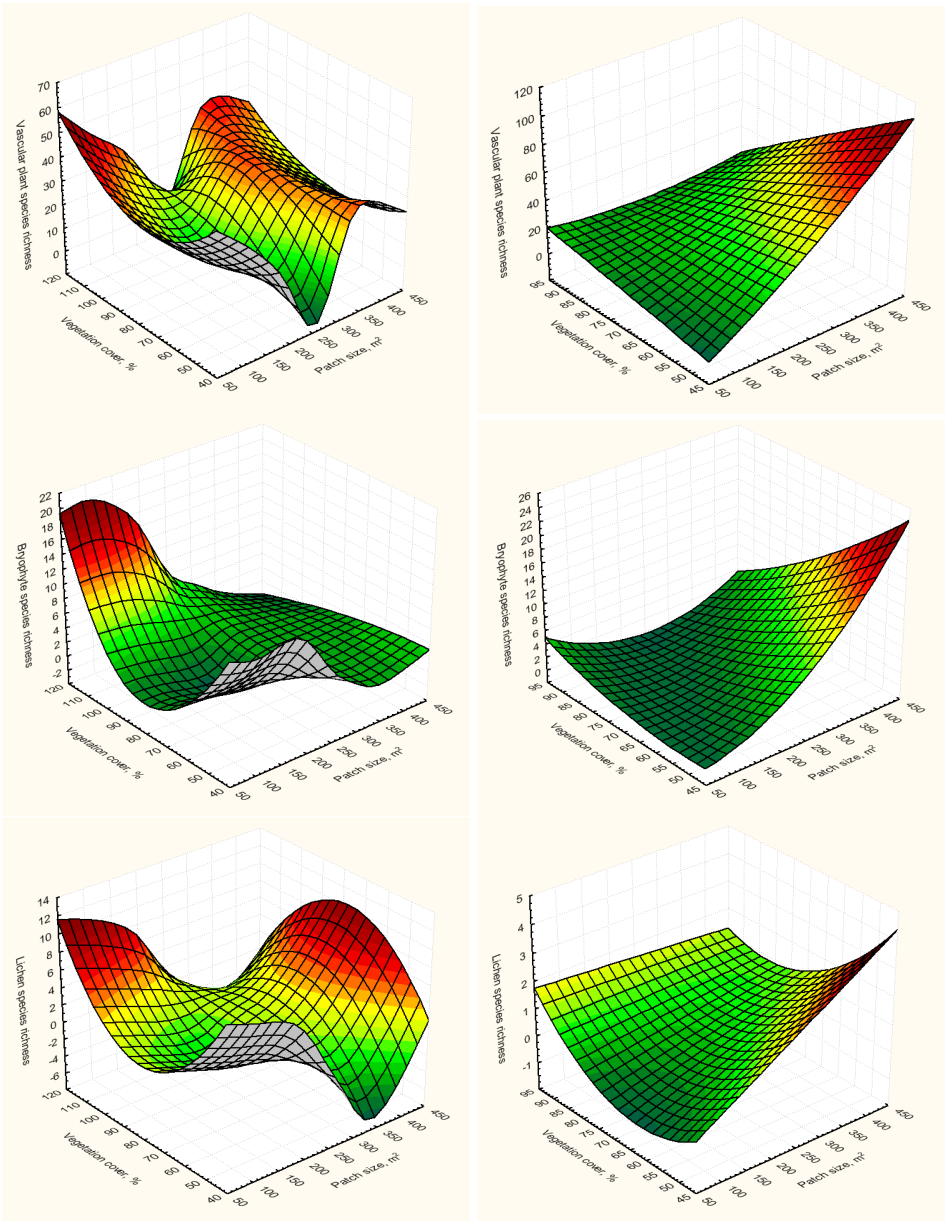


Fig. 12. Relationships between the species richness patterns, vegetation cover and patch size in the model grassland communities in the Ukrainian Carpathians: *Hyperico alpigeni-Calamagrostietum villosae* – a, b, e, f, g, h; *Senecio carpaticae-Seslerietum bielzii* – c, d, i, j.

In more than a half of the grassland communities, the patch size significantly enhanced total species richness (R = 0.34 to R = 0.84) and vascular plant species richness (R = 0.40 to R = 0.79). In contrast, it was not important for bryophyte and lichen species richness, and in some cases they were even negatively related. It is interesting enough that the patch size does not affect total species richness and species richness of study taxonomic groups (i.e. vascular plants, bryophytes, and lichens) in all 6 grassland communities that belong to the *Mulgedio-Aconitetea* class (Fig. 13A). Although there are some smaller picks which deserve additional analysis, overall it demonstrates that in some cases the local environment and quality of the habitat have a stronger effect on the species distribution than spatial habitat configuration. These findings, together with the data on total species richness in the *Mulgedio-Aconitetea* class analysed above, allow us to conclude that for the distribution of plant species in hygrophilous tall-herb grasslands which occur on nutrient-rich and moist soils, habitat configuration *per se* may be less important than habitat quality.

Different responses of plant species richness to biotic and abiotic environmental factors are illustrated in Fig. 13 on the examples of the *Hyperico alpigeni-Calamagrostietum villosae* community (*Mulgedio-Aconitetea* class) and *Senecio carpaticae-Seslerietum bielzii* community (*Elyno-Seslerietea* class). In contrast to the species richness patterns described above for the communities of the *Mulgedio-Aconitetea* class (Fig. 13A), in communities of the *Elyno-Seslerietea* class (Fig. 13B) patch size generally enhanced vascular plants, bryophytes, and lichens species richness.

To summarize, our results suggest that responses of plant species richness to biotic and abiotic environmental factors differ, depending on type of grassland community and specific taxonomic group (vascular plants, bryophytes or lichens). However, these relationships are also depending on the combination of biotic and abiotic environmental factors which in particular habitats may be even more important.



A B

Fig. 13. Responses of species richness (vascular plants, bryophytes, and lichens) to biotic (vegetation cover) and abiotic (patch size) factors in different grassland communities in the Ukrainian Carpathians: A – *Hyperico alpigeni-Calamagrostietum villosae* (*Mulgedio-Aconitetea* class) and B – *Senecio carpaticae-Seslerietum bielzii* (*Elyno-Seslerietea* class)

Two diversity indices were calculated for each of 129 sites, because the indices have different meanings of equality. Then the mean values of both indeces were calculated for each community. The analysis of variance showed that both the Shannon diversity index (*H*) and the Simpson's diversity index (*D*) did not differ very much between sites as a whole (Tab. 5). To identify which communities differ from one another we calculated the least significant difference (*LSD* = 5%) between the mean values of both indeces. We found that *Thymo pulcherrimi-Festucetum amethystinae* is the most different community in terms of diversity indeces.

The Shannon diversity index (*H*) had the greatest values in the *Thymo pulcherrimi-Festucetum amethystinae* (*H* = 3.24), *Hyperico alpigeni-Calamagrostietum villosae* (*H* = 3.18), and *Phleo alpini-Deschampsietum caespitosae* (*H* = 3.16) communities (Tab. 4, Fig. 14). The Simpson's diversity

Tab. 4. Total species richness (vascular plants, bryophytes, and lichens) and diversity indeces in grassland communities of high conservation value in the Ukrainian Carpathians

Association	Total species richness (4 m^2)			Shannon index (H)	Simpson's index (D)
	Mean	Min	Max		
Gentiano punctatae-Festucetum picturatae	22.67	12	43	2.81	13.14
Primulo minimae-Caricetum curvulae	26.91	14	54	2.78	13.16
Saxifrago paniculatae-Festucetum versicoloris	21.20	7	37	2.71	12.05
Senecio carpaticae-Seslerietum bielzii	18.86	10	29	2.46	8.83
Thymo pulcherrimi-Festucetum amethystinae	31.86	20	43	3.24	20.21
Festucetum saxatilis	29.00	16	48	3.03	17.86
Soldanello hungaricae-Nardetum strictae	24.20	11	34	2.85	13.63
Carici nigrae-Nardetum strictae	20.00	12	33	2.69	12.56
Ranunculo platanifolii-Adenostyletum alliariae	26.19	16	46	2.95	14.90
Pulmonario filarszkyanae-Alnetum viridis	23.00	11	31	2.74	10.67
Hyperico alpigeni-Calamagrostietum villosae	32.60	18	56	3.18	17.16
Poo chaixii-Deschampsietum caespitosae	23.20	16	45	2.81	13.17
Phleo alpini-Deschampsietum caespitosae	30.86	17	46	3.16	17.61
Festucetum carpaticae	27.00	23	33	3.07	14.62

Tab. 5. Results of analysis of variance (ANOVA) for comparing diversity indeces in grassland communities of high conservation value in the Ukrainian Carpathians

ANOVA for Shannon Index						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.39	13	0.41	2.71	0.01	1.80
Within Groups	17.89	117	0.15			
Total	23.28	130				
ANOVA for Simpson's Index						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1045.59	13	80.43	2.21	0.01	1.80
Within Groups	4254.71	117	36.37			
Total	5300.30	130				

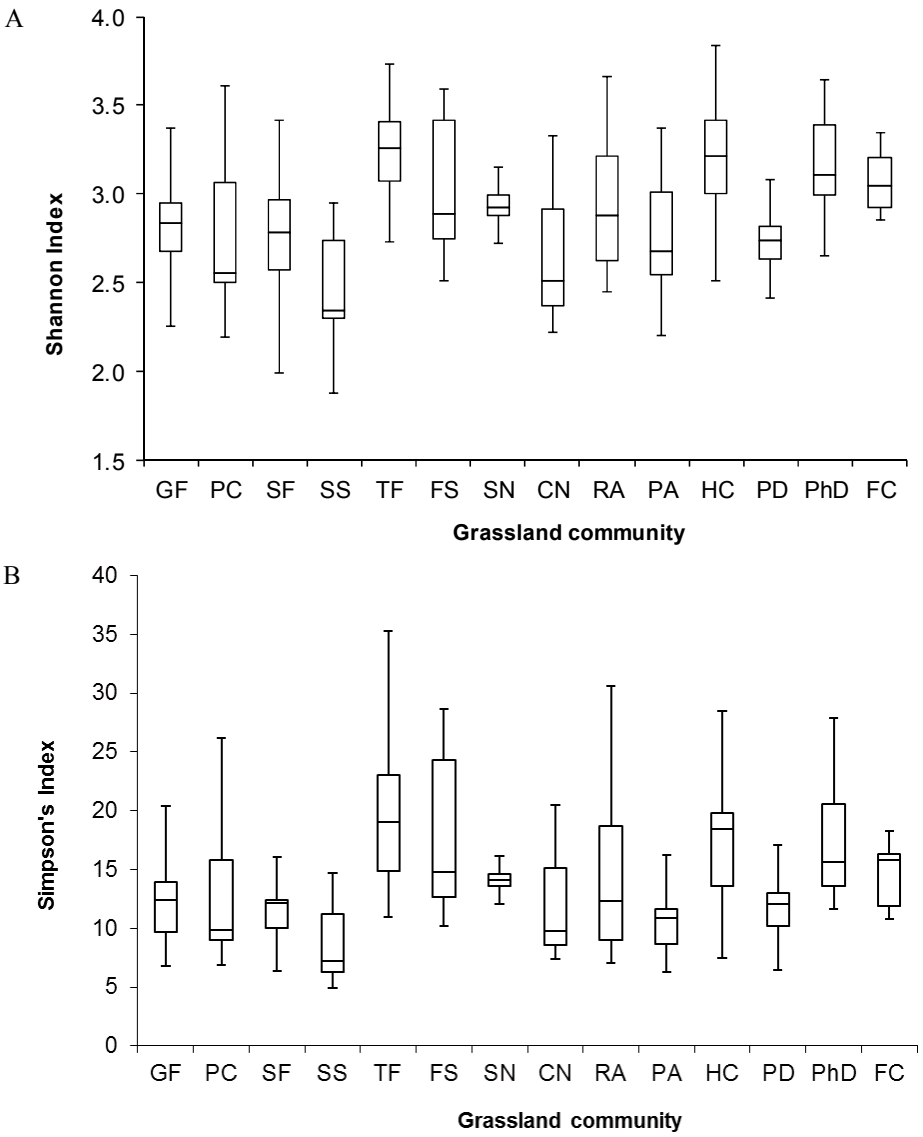


Fig. 14. Box plot diagrams of the diversity (A – Shannon index, B –Simpson's indexes) of grassland communities of high conservation value in the Ukrainian Carpathians: GF – *Gentiano punctatae-Festucetum picturatae*, PC – *Primulo minimae-Caricetum curvulae*, SF – *Saxifrago paniculatae-Festucetum versicoloris*, SS – *Senecio carpaticae-Seslerietum bielzii*, TF – *Thymo pulcherrimi-Festucetum amethystinae*, FS – *Festucetum saxatilis*, SN – *Soldanello hungaricae-Nardetum strictae*, CN – *Carici nigrae-Nardetum strictae*, RA – *Ranunculo platanifolii-Adenostyletum alliariae*, PA – *Pulmonario filarszkyanae-Alnetum viridis*, HC – *Hyperico alpigeni-Calamagrostietum villosae*, PD – *Poo chaixii-Deschampsietum caespitosae*, PhD – *Phleo alpini-Deschampsietum caespitosae*, FC – *Festucetum carpaticae*

index (*D*) significantly differed between some sites. It reached the greatest values in the *Thymo pulcherrimi-Festucetum amethystinae* (*D* = 20.21), *Festucetum saxatilis* (*D* = 17.86), and *Phleo alpini-Deschampsietum caespitosae* (*D* = 17.61) communities. Overall, based on the diversity indices calculated the tall-herb grassland communities of the *Mulgedio-Aconitetea* class attained the greatest values of diversity.

Conservation value of grasslands

Efficient maintenance of biodiversity requires it conservation at all structural levels from genes to ecosystems, including species and communities as the key elements. Assessing the conservation status of species for policy and planning has been greatly advanced since the 1980s (see review by MACE et al. 2008). Development and implementation of comparable standards for communities has begun only recently (e.g., NICHOLSON et al 2008; RODRIGUES et al. 2010). When used with species red lists, it could provide the most informative indicator of the status of biological diversity, however to achieve this, multiple scientific challenges must be met (RODRIGUES et al. 2010).

To estimate conservation value of the mountain grassland communities in the Ukrainian Carpathians we assessed them based on biotic and abiotic factors, but also took into account other features such as historical changes, cultural importance and practical needs. Scarcity of data and subjectivity of judjement are two major limitations of this assessment. Further steps are needed to provide detailed community documentation which can substantionally improve expert judgement.

The conducted conservation assessment showed that the mountain grassland communities can contribute effectively to landscape diversity because they have high levels of both local species richness (alpha diversity) and regional or spatial variation in community composition (beta diversity). These communities include diverse suite of mountain and alpine species, and they can serve as refugia in landscapes where primary vegetation is degraded or destroyed by human impact.

This study demonstrates that mountain grasslands in the Ukrainian Carpathians are valuable resource for the conservation of biodiversity because they contain high levels of local species richness including many rare, endemic and relic plant species and plant communities, as well as those that are found at the periphery of their ranges. Grassland communities in these habitats represent unique combinations of plant species which would be lost after degradation.

This study will also help to assess the relative conservation value of different sites to maximize local and regional diversity. Identified patterns of the grassland diversity make it important to protect greater number of their habitats, rather than greater size of areas, and to make them a higher priority in landscapes altered by human activities. Conservation planning which includes all diverse types of grasslands will contribute substantially to the preservation and sustainable management of natural resources in the Ukrainian Carpathians.

Threats to grasslands

Historically, primary mountain grasslands of the Ukrainian Carpathians were significantly transformed, due to climatic changes in the Holocene (hologenetic changes) as reported by TOLPA (1928) and KOZIJ (1934), livelihood of the communities (endogenetic changes), and human settlement in the region, which started at the turn of 14th century. Human settlement continued during the 15 and 16th centuries, and was followed by intense, pastoral practices (anthropogenic changes). Due to anthropogenic impact, major dynamic changes in the vegetation occurred, such as the spreading of herbaceous communities and the shrinking of the area occupied by forests, krummholz, and shrubs, the disappearance of some plant species and communities, the invasion of antropochoric species and the establishment of ruderal communities. Currently, the major threats to mountain grasslands are changes in traditional land use, caused by overgrazing, abandonment, invasive species, afforestation, and climate change.

Overgrazing: Intensive grazing of sheep, combined with other livestock (cows and horses) in many places, caused pastoral degradation to a catastrophic degree and substantial changes in the vegetation cover of the subalpine and alpine belts of the Ukrainian Carpathians. In particular, this is manifested in the decrease of the upper tree line, the decrease in the area of primary communities of the highlands (shrubs, mountain meadows and highland grasslands), and the increase in the areas of secondary shrublands and dense tussock communities.

The majority of the highlands' communities belong to the primary types, which used to cover the entire region of the Ukrainian Carpathians. Today, they remain only in small areas, in the eastern part of the mountains, in sparsely populated areas, or on steep slopes (25–40^0), inaccessible for grazing. Non guided pastoralism in highlands on steep slopes caused strong negative soil erosion which creates substantial landscape level threat of land use to primary vegetation.

All primary communities are characterized by a rich, floristic composition (mainly consisting of mountainous, alpine, and arctic-alpine plant species). At first, primary communities are invaded with sparse grasses, and afterwards, by dense tussock grasses, which, through a number of consequent stages, form secondary communities. Expansion of dense tussock grasses occurs where primary vegetation is being destroyed, due to intensive grazing. Today, the secondary communities occupy more than half of the highland area.

Instead of tall-grass communities with *Adenostyles alliaria* and *Cirsium waldstenii,* short living grass-forb, grass, and forb communities developed. Under grazing impact and through a number of transitional stages, they change to communities with a dominance of *Nardus stricta* or *Deschampsia caespitosa* in the subalpine belt, and by *Festuca airoides* and moss-lichen coenoses on the border of the alpine belt. The grazing impact on the vegetation cover on rocky slopes is small, because the conditions of the relief are unfavourable. Because of that, such communities as *Primulo minimae-Caricetum curvulae* and *Saxifrago paniculatae-Festucetum versicoloris* have lowest vulnerability to grazing.

Abandonment: This process occurs in all places where anthropogenic impact weakened. Many pastures on the mountain slopes were abandoned and are now densely covered by alder shrubs. It is interesting to note that the expansion of *Alnus alnobetula* into grassland communities is observed not only in mountain massifs with abandoned pastures or in places with light grazing, but also in the places with moderate grazing pressure. Alder shrubs are spreading very quickly in the subalpine belt, when grazing stops, much faster than the forest. *Alnus alnobetula* reproduces by seeds everywhere, often overgrowing entire places, particularly on the north-facing slopes. Decreasing grazing and the resulting increased litter-production may affect original species composition in the primary mountain grasslands, because it leads to humus accumulation, which stimulates the spread of generalists, and may cause the local extinction of some native grassland species.

Following the end of grazing, some pastures can develop into a certain type of mountain grasslands, but only when these communities are present nearby and can serve as a source for re-colonisation. Most tall-herb grassland communities of the *Mulgedio-Aconitetea* class have a good recovery potential.

Invasive species: Native mountain grasslands in the region have been altered significantly. Many unusual plants appeared in their composition, including boreal, nemoral, and arid species. The role of weeds intensified as a result of their introduction by humans. Species such as *Sinapis alba, Cirsium arvense, Scleranthus annuus, Anagallis arvensis, Carduus acanthoides, Knautia arvensis, Veronica arvensis, V. persica, Urtica dioica, U. urens, Rumex acetosella, Chelidonium majus, Capsella bursa-pastoris, Lepidotheca suaveolens* and many others belong to anthropochoric species, the origin of which is certain.

The overgrazed areas are always the starting point for colonisation by invasive alien species. In many places in the pastures, ruderal communities have developed and taken over the native grasslands. They occupy from 1or 2 to 50% of the areas of separate pastures and lead to further penetration of the invasive components of flora and fauna into the highlands (KRICSFALUSY & MALYNOVSKI 2003). These coenoses become the first stage of the naturalization of the ruderal flora, which spread to other high mountain communities. Spreading pastoral vegetation has created many secondary communities, with inconsistent floral composition and diverse combinations of dominant species. These impacts have particular importance for species-rich *Nardus* grasslands on siliceous substrates in mountain areas.

Afforestation: During the previous century, mainly in the 1950s–90s, the Soviet state forest companies afforested vast areas of polonyny grasslands and krummholz in the Ukrainian Carpathians to increase their environmental protection (KRICSFALUSY et al. 2004). As a result of these activities, for instance, the general area of mountain grasslands decreased approximately 15% and the altitude of the tree line became higher by 4% on average, within the study area in Svydovets (KRICSFALUSY et al. 2008). However, afforestation continues, even after this aim has been achieved. Planting on mountain grasslands causes

serious damage from the points of view of both economic value and conservation. Active management of polonyny grasslands needs a careful selection of representative grassland areas with prevention of afforestation.

Climate change: In terms of vegetation dynamics, two opposite trends are observed in the Ukrainian Carpathians – the expansion of primary communities, moving to the forest tree-line formed by *Fagus sylvatica* and *Picea abies*; as well as krummholz, formed by *Alnus alnobetula, Juniperus communis* subsp. *nana* and *Pinus mugho.* These processes are caused on one hand by previous climate warming, and, on the other hand, by progressive reduction of the tree-line, krummholz and primary grasslands resulting from anthropogenic impact (mainly pasture and grazing, cutting, and burning) (KRICSFALUSY et al. 2008).

Climate change will likely cause the current tree-line to advance upward, which might lead to a shrinking of the area currently occupied by some mountain grassland communities, particularly of the *Mulgedio-Aconitetea* class. According to the recent studies (GOTTFRIED et al. 2012), species losses are most pronounce on the lower summits, where plants are expected to suffer earlier from water deficiency than at higher elevations.

Climate change will largely affects mountain grassland biodiversity, by reducing available land area for these communities and for its associated native plants. The plant species moving uphill, due to climate change, can in the long term potentially out-compete rare species or those adapted to the cold. GOTTFRIED et al. (2012) have recently found that newly appearing plants in European mountain systems are predominantly more widespread species from lower elevations and will pose increasing competition pressure on the rarer cold-loving high-mountain species.

Management of grasslands

Because most of the mountain grasslands in the Ukrainian Carpathians were under intense grazing, they stabilized over the last centuries. Management is needed to maintain these secondary grassland communities and the diversity of their associated plant species. Mountain grasslands in the region, like in many other parts of Europe (VEEN et al. 2009), have stabilized to such an extent that, without appropriate management, natural succession leads to the formation of scrubs and woodlands, or at least to the invasion of expansive grasses and alien plant species.

Mountain grasslands in the Ukrainian Carpathians are mostly semi-natural habitats, where high biological diversity is maintained alongside human activities. Active management of these secondary grassland communities is required at least periodically to prevent afforestation and to stop the spread of invasive alien species. The only meaningful solution is to reestablish traditional land use, by conservation grazing or mowing. Moderate grazing is an option to manage and to maintain the vegetation structure and plant diversity of mountain grasslands. Using sheep would be an effective and simple measure to counteract the undesired scrub encroachment.

The primary highlands´communities in the Ukrainian Carpathians remain only in small areas, on the steep slopes inaccessible for grasing. Conservation of this unique vegetation is possible only in representative areas, not in whole polonyny grasslands. Non-intervention can be allowed in locations where the objective is to allow natural succession, i.e. in strictly protected areas – the Carpathian Biosphere Reserve and core zones of several national nature parks. In non-strictly protected areas planting on mountain grasslands is appropriate only on steep slopes with strong soil erosion. It is necessary to harmonise the requirement for grassland conservation and anti-erosion activities. Overall, grassland management can be substantially improved by implementation of more effective policies that regulate protected areas and involvement of local communities through different incentives programs.

Towards a sustainable future

In this region, spectacular scenery, a clean environment, rich wildlife, and cultural uniqueness are all assets that favour ecotourism as a means of balancing biodiversity conservation with community livelihoods. Local communities can enjoy long-term benefits from the income generated, when ecotourism mutually supports the conservation of biodiversity and of community livelihoods.

Another aspect of sustainability is the history of the traditional use of mountain grasslands, as meadows and pastures, during the centuries which had heavy impact on the grassland ecology and their species richness. Some of these traditional methods are very important for conservation management of grasslands and for restoring grassland habitat. These traditional practices are not only an element of cultural history, but also, when used as effective management tools, can provide income for local communities who shape polonyny landscape through their day-to-day activities. It's becoming more and more evident that the preservation of the cultural heritage of the region cannot be separated from the protection of nature.

Promoting development of the forest and pasture economy, and integrating it with objectives for nature conservation is necessary in the Ukrainian Carpathians. Revitalizing a traditional forest and pasture economy is one of the keys for the sustainable development of this region.

Acknowledgements

We are grateful to S. Daviduik, R. Kish, M. Li, and O. Zbyranyk for assistance in preparing manuscript. We thank J. Šibík for his helpful advice on an earlier version of this paper. Special thanks to the anonymous reviewers for their valuable comments on this paper.

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Received: December 12th 2012
Revised: May 31st 2013
Accepted: June 3rd 2013