



Original article

The virgin forests of the Synevyr National Nature Park, Ukraine: its current condition and biodiversity

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ABSTRACT

Among the protected sites of the Eastern Carpathians, the Synevyr National Nature Park (NNP) in the Zakarpattia region of Ukraine is one of the most valuable and was created to preserve its unique mountain beech and spruce forest communities. The importance of the conservation of typical natural virgin forest ecosystems of the Central European mountain system is emphasized. The aim of this article was to determine the state of the naturalness of virgin forests in the territory of Synevyr NNP, to analyse their syntaxonomy, and to establish the floristic and geobotanical characteristics of its virgin forests and to distinguish the existing biodiversity threats. It was established that the studied plots of beech and spruce forests within the territory of the Synevyr NNP have a distinct virgin nature based on their structure, forest valuation parameters, spontaneous dynamics and other features. Syntaxonomically the virgin forests of the park belong to two associations: *Symphyto cordati-Fagetum* Vida (1959) 1963 (alliance *Fagion sylvaticae* Luquet 1926, order *Fagetalia sylvaticae* Pawłowski 1928, class *Carpino-Fagetea sylvaticae* Jakucs ex Passarge 1968) and *Luzulo luzuloidis-Fagetum* (Du Rietz 1923) Markgraf 1932 (alliance *Luzulo-Fagion sylvaticae* Lohmeyer & Tx. in Tx. 1954, order *Luzulo-Fagetalia* Scamoni & Passarge 1959, class *Quercetea roboretanae* Br.-Bl. & Tx. ex Oberd. 1957). The natural and anthropogenic biodiversity threats of these virgin forests are summarized. The results of the research formed the basis for the inclusion of the beech virgin forests of Synevyr NNP as a UNESCO World Heritage Site in the list of objects on "Beech virgin forests and ancient forests of the Carpathians and other regions of Europe".

KEY WORDS: old-growth forest, beech forest, nature conservation, Carpathians

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1. Introduction

The preservation of typical natural ecosystems of the Central European Mountain System which have importance for the renaturalization of degraded landscapes and the sustainable use of biological resources is based on global and national trends (Carpathian Convention, decisions of the Krakow Conference of "Green Ridge of Central and Eastern Europe", the program of the Pan-European Ecological Network in Central and Eastern Europe, the Pan-European Strategy for Biodiversity and Landscape Conservation, and the Concept of Biodiversity Conservation of Ukraine) (USTYMENKO ET AL., 2012a).

The World Wildlife Fund (WWF) has recognized the Carpathian Mountains, located within the territory of seven European countries, as one of the 200 most important regions in the World in terms of their ecology and conservation (OLSON & DINERSTEIN, 2002). Therefore, the nature protection of this mountain system is a problem of international significance. In order to preserve the biodiversity and unique natural ecosystems and landscapes in the Carpathians more than 2000 reserves have been created including 38 national parks (KUCHARZYK, 2009), especially 18 national nature parks are in Ukraine (STOYKO ET AL., 2007). Two additional parks (Boykivshchyna and Korolivski Beskydy) were

established in the Ukrainian Carpathians in 2019. Among the protected areas of the Eastern Carpathians the Synevyr National Nature Park (NNP) was created to preserve its unique mountain ecosystems and its biological, phytocoenotic and landscape diversity, and it is one of the most valuable in terms of its landscape, ecology, biogeography and social aspects. The main task of the NNP is to preserve the character of this territory of beech and spruce forests, dominated by *Fagus sylvatica* and *Picea abies* respectively, and retain the natural composition and distinct virgin forest nature. Specific, and reliable information, about natural beech forests within the territory of Synevyr NNP was absent, and until recently it was considered that there were no virgin forests within the area (Chernyavsky, 2000, 2003; PARPAN, 2003; GAMOR, 2006; GAMOR ET AL., 2008, etc.).

Natural virgin forests are centres with a high concentration of biodiversity. They have important scientific significance (preservation of ecological information about their origin, coenotic structure, geographical distribution) and are important for biodiversity conservation and reproduction. The selection and preservation of virgin forests are based on detailed studies of the current state of their floristic and geobotanical structure.

The study and preservation of virgin forest ecosystems in the Carpathians was started between 1908–1913 when Hungarian foresters created two reserves for the conservation of beech-fir and spruce forests in the Uzh river basin on an area of 346,7 hectares (FÖLDVARY, 1933). Later similar reserves were established in the eastern part of the Transcarpathian region on the Hoverla and Pip Ivan Marmaroskyi mountains (STOYKO, 2013). The Czech botanist A. Zlatník studied the plant cover and the structure of soils of the virgin forests in the Beskids and Pip Ivan Marmaroskyi mountains in detail (ZLATNÍK, 1938) and with the collaboration of A. Hilitzer they proposed the conservation of 33 forest reserves (ZLATNÍK & HILITZER, 1932). A great contribution in the study of the virgin forests of the northern macroslopes of the Eastern Carpathians was made by Polish botanist Władysław Szafer who substantiated the conservation of the virgin fir-beech forest and included the participation of common yew (*Taxus baccata*) near the town of Kolomyia (now – Kniazhdvirskyi National Reserve) (SZAFAER, 1913) and the spruce virgin forest on Hoverla mountain (now situated within the territory of Karpatskyi NNP) (SZAFAER, 1929). Unfortunately, a lot of areas of virgin forests were destroyed in the second part of the twentieth century in the Carpathians due to anthropogenic activity. Now in the Eastern Carpathians within Ukraine virgin forests are preserved only on the territories of

national and regional reserves, such as: the Carpathian Biosphere Reserve, NNP Uzhanskyi, Synevyr and Zacharovanyi Kray (Zakarpattia region), Karpatskyi, Hutsulshchyna, Synyohora and Verkhovynskyi (Ivano-Frankivsk region), NNP Skolivski Beskidy and Regional Landscape Parks Nadsianskyi and Verkhniodniprovski Beskidy (Lviv region) and NNP Vyzhnytskyi (Chernivtsi region) (STOYKO, 2013).

The syntaxonomical diversity of the virgin forests within the territory of Synevyr NNP has not previously been specifically studied but several data about the syntaxonomy of beech and spruce forests in the Ukrainian Carpathians are available (BUDZHAK & ONYSHCHENKO, 2004; SOLOMAKHA ET AL., 2004, 2016; KLIMUK ET AL., 2006; ONYSHCHENKO, 2007, 2009; DERZHYPILSKY ET AL., 2011).

The aims of this article were to determine the naturalness of virgin beech and spruce forests within the territory of Synevyr NNP, to establish the syntaxonomic composition of these forest, to identify their floristic and geobotanical features and to establish the existing threats to their biodiversity.

2. Materials and methods

2.1. Study area

The territory of Synevyr NNP is situated in the upper part of the Tereblya River basin in the Mizhhirya and Khust districts of the Zakarpattia (Transcarpathia) region of Ukraine (Fig. 1). The area of the park is 42704 hectares.

According to the physical-geographical zoning of Ukraine (TOLSTOUKHOVA, 2006), the territory of the NNP belongs to two physical-geographical regions – Vododilno-Verkhovyna and Polonynsko-Chornohirska with elevations from 550 to 1719 (Strymba Mountain) metres a. s.l.

According to geobotanical zoning (RUDENKO, 2007) the research area belongs to the European Deciduous Forest region, Carpathian-Alpine Mountain province, Verkhovyna-Beskyd geobotanical district of oak, beech, fir and spruce forests and post-forest meadows.

According to geomorphological features the territory of the Synevyr NNP is characterized by the pronounced asymmetry of mountain range slopes, and the wide distribution of rocky sandstones and the slight presence of limestone. According to morphometric features it belongs to the dissected middle mountain relief with sharp vertical disintegration, deep transverse valleys, sharp ridges and peaks. Slopes with medium (15–30°) and major (more than 30°) steepness prevail within

this territory. Climatic conditions are temperate with a cool characteristic on upper altitudes only. The average annual temperature is 5.7°C, the maximum air temperature is 31°C (July), the minimum is -34°C (January). Atmospheric humidity is significant with an average annual precipitation of 1407 mm. Westerly and south-westerly winds predominate, and in winter it is mainly dry with cold northerly and north-easterly winds (SUBOTA & PUTRASHYK, 2019).



Fig. 1. The location of Synevyr National Nature Park within Ukraine

The native flora of the territory of the Synevyr NNP includes 890 vascular plant species from 398 genera and 104 families. Of these 133 species from 90 genera and 45 families are rare, specifically 48 species from the flora of the NNP are included in the Red Data Book of Ukraine (DIDUKH, 2009). The vegetation belongs to two mountain belts – forest and subalpine. The forest belt consists of four height-differentiated strips: beech forests dominated by *Fagus sylvatica* (500–750 m a. s.l.), spruce-fir-beech forests co-dominated by *Picea abies*, *Abies alba* and *Fagus sylvatica* (700–900 m), beech-fir-spruce forests (*Fagus sylvatica*, *Abies alba*, *Picea abies*, 900–1100) and spruce forests dominated by *Picea abies* (1100–1450). The subalpine belt is represented by krummholz and scrub vegetation dominated by *Pinus mugo* and *Duschekia alnobetula* with subalpine herbaceous and shrub communities (1450–1700 m).

2.2. Data and methods

Field methods for the geobotanical research were based on the selection of routes and the description of the forest vegetation within temporary plots. Optimal routes for the research were selected using forest valuation maps 1: 25000. Geobotanical relevés of virgin forests were carried out on plot

sizes of 25 x 25 m (625 m²), selected in homogeneous conditions with the preparation of the list of vascular plants and information was collected on the projected cover for all plant species. Geographical coordinates and altitude were recorded for the plots using GPS. Virgin beech communities were photographed. After the field research the data from the geobotanical relevés were analysed with the selection of associations of beech and spruce virgin forests. The main material for the syntaxonomy of beech virgin forests was 52 original relevés made by P.M. Ustymenko and D.V. Dubyna in 2012–2013. The database of relevés was created in TURBOVEG 2.79. Interpretation of phytosociological data was carried out by using a modified algorithm of the method of two-way indicator species analysis (TWINSPAN), included in the software package JUICE 7.0 (HILL, 1979; TICHÝ, 2002; ROLEČEK ET AL., 2009). The following scale for the plant species cover was used in syntaxonomical tables: + – <1%, 1 – 1–5%, 2 – 6–15%, 3 – 16–25%, 4 – 26–50%, 5 – >50%. The names of the vascular plant species are given according to the Ukrainian nomenclatural checklist (MOSYAKIN & FEDORONCHUK, 1999), names of bryophytes by BOIKO (2008), names of fungi and lichens by “Index Fungorum” website (<https://www.indexfungorum.org>).

3. Results and discussion

In recent articles from Ukraine (CHERNYAVSKY, 2000; BRANDLEY & DOVHANYCH, 2003; VOLOSHCHUK, 2004; STOYKO, 2005; STOYKO ET AL., 2007 etc.) virgin forests are treated as natural forest ecosystems formed spontaneously and include different age stages with close interconnections between their autotrophic and heterotrophic components and soils. Therefore, they are ecosystems in dynamic equilibrium since forests successfully support mechanisms for self-sustaining their high vitality. The naturalness of the forest should be confirmed by the absence of human impact in the past and currently (absolute absence of: stumps from felling, signs of grazing, forest meadows, campfires, trails, etc.), with absolute compliance of the species composition of natural flora with primary habitat conditions, and the presence of vertical and horizontal differentiation. In addition, there is a clear age diversity of the tree layer (from juvenile to senile individuals) and a constant differentiation of the vertical structure from several sublayers in the tree layer, a natural (not transformed) state of the pedosphere, presence of herb and moss cover, an absence of alien species and a presence of manifestations of natural death of trees at different stages of decay are typical characteristics of

virgin forests. The establishment of the forest history, the duration of its development and the presence, or absence, of buffer and transit zones around it are all mandatory features for the determination of virgin forests.

Despite the significant scale of transformation in mountain forests of Synevyr NNP several sites of beech virgin forests are still preserved (USTYMENKO ET AL., 2012b; USTYMENKO & DUBYNA, 2014). Their inaccessibility and lack of a network of forest roads for transporting wood have protected them from felling and preserved them. We found 12463 hectares of forests of natural origin within the territory of Synevyr NNP and 7415 hectares of them belong to natural beech forests. The authors studied them in Kvasovetsky, Synevyrsky, Kolochavsky, Vilshansky and Ostritsky environmental research departments (ERD; YAREMA & TYUKH, 2019).

Beech forests cover all mountain slopes in the southern part of the Synevyr NNP. They are common on the slopes of: Myrsha, Tyapysh, Krasna, Rivna, Strymba, Darvaika, Barvinok, Negrovets and Rizhok mountains. The study plots with distinct virgin character are mostly situated in the foothills of the mountain slopes within elevations of 800–1300 m a. s.l. These forests are distributed on 15–30° slopes (40–45° on several sites). The climatic conditions of mountain slopes contribute to the high vitality of *Fagus sylvatica* within this altitude zone. *Acer pseudoplatanus* is a constant companion of *Fagus sylvatica* in the tree layer. Beech forests have been found on brown soils formed of low-strength noncarbonate alluvial-deluvial deposits, underlain at a depth of 30–60 cm by a marl or even hard rock. A typical feature of the virgin forests within the territory of the NNP is a mosaic character of different phases of tree layer development (phase of restoration, formation of phytocoenotic structure, maturity and decay) and a combination of different age generations of trees. On a study plot trees with different thickness and height are present, which leads to the formation of multilayered communities. The most distributed communities have three sublayers within the tree layer formed by different beech generations. The oldest generation of *Fagus sylvatica* (160–200 years old) forms the first sublayer with 30–34 m high and 40–52 cm diameter at breast height trees. The medium generation (70–100 years) of beech with a slight admixture of *Acer pseudoplatanus* forms the second sublayer. The younger generation of beech trees form the third sublayer with several young trees of *Abies alba*.

The natural regeneration of *Fagus sylvatica* is quite sufficient. The young generation of *Acer pseudoplatanus*, *Abies alba* and *Picea abies* is sufficient

too, but in the adult phase only the first two species were found. The presence of a large amount of natural regeneration of *Fagus sylvatica* in combination with its high vitality is a determining element of the stability of these virgin forests.

High shading in virgin beech forests does not contribute to the spread of shrubs. Only a few plots were found on humid soils with a sporadic distribution of *Rubus hirtus* and *R. caesius*. This factor, with the presence of a thick litter layer (5–10 cm) does not allow the formation of a dense herb cover in these forests. Thus the floristic composition of these beech forests is poor (Fig. 2). One of the factors causing the inhibition of the development of the herb layer is the root system of *Fagus sylvatica*, which is localized in mountain conditions in the same horizon with the underground vegetative organs of herbaceous plants. Therefore, the typical vascular plant species of these beech forests are mainly long-rhizomatous perennials with numerous vegetative reproductive stems. The constant species of these virgin beech forests within the territory of Synevyr NNP are: *Dentaria glandulosa*, *D. bulbifera*, *Lunaria rediviva*, *Symphytum cordatum*, *Phegopteris connectilis*, *Polystichum aculeatum*, *P. braunii*, *Blechnum spicant*, *Helleborus purpurascens*, *Ranunculus platanifolius* and *Polygonatum verticillatum*. The floristic structure of these virgin beech forests is characterized by the complete absence of alien plants. Based on seasonal features of the light regime of beech forests, which favours the herbaceous plants before the appearance of leaves on the trees, spring ephemerals are common: *Anemone ranunculoides*, *A. nemorosa*, *Corydalis solida*, *C. cava*, *Galanthus nivalis*, *Leucojum vernalis*, *Dentaria glandulosa*. The herb layer of these virgin beech forests is marked by the presence of a large number of fern species: *Athyrium filix-femina*, *A. distentifolium*, *Blechnum spicant*, *Cystopteris fragilis*, *Dryopteris expansa*, *D. carthusiana*, *D. dilatata*, *D. filix-mas*, *Gymnocarpium dryopteris*, *Phegopteris connectilis*, *Phyllitis scolopendrium*, *Polystichum aculeatum*, *P. braunii*, and this also confirms the naturalness of these communities.

The biodiversity of virgin beech forest has great importance for their conservation. It includes nine species listed in “The Red Data Book of Ukraine” (DIDUKH, 2009): *Atropa belladonna*, *Galanthus nivalis*, *Huperzia selago*, *Leucojum vernalis*, *Lilium martagon*, *Lycopodium annotinum*, *Lunaria rediviva*, *Neottia nidus-avis* and *Platanthera bifolia*.

Moss cover in beech forests forms on soils, stones and trunks. Tree trunks are covered by lichens – *Phlyctis argena*, *Graphis scripta*, *Pseudevernia furfuracea*, *Hypogymnia physodes*, *Ramalina pollinaria*,

Parmelia sulcata, *Evernia prunastri*, *Platismatia glauca*, *Lobaria pulmonaria*, *Pertusaria albescens*.

A typical feature of these virgin beech forests is the high proportion of dead and rotten trees at different stages of decay. These include trunks which were broken at a height between 2 to 10 m. The share of dead wood in virgin forests is much (10–20 times) higher than in the surrounding forests. The dead wood of old and diseased trees form a favourable substrate for fungi. The most important wood-destroying fungi are: *Fomes fomentarius*, *Phelinus igniarius*, *Schizophyllum commune*. Fungal mycelia help to accumulate a large amount of nitrogen in dead wood, creating a good basis for plants of subsequent generations (BRANDLEY & DOVHANYCH, 2003). A significant amount of dead wood ensures the survival of a whole complex of xylobiotic organisms.



Fig. 2. Carpathian beech forest in Synevyr National Nature Park (photo by P.M. Ustymenko)

Syntaxonomically virgin beech forests are represented by communities of two associations. The most common within the territory of Synevyr NNP is *Symphyto cordati-Fagetum sylvaticae* Vida (1959) 1963 from the alliance *Fagion sylvaticae* Luquet 1926, the order *Fagetalia sylvaticae* Pawłowski 1928 and the class *Carpino-Fagetea sylvaticae* Jakucs ex Passarge 1968 (Table 1). The later synonym of this name is *Dentario glandulosae-Fagetum* W. Mat. ex Guzikowa et Kornaś 1969 (ONYSHCHENKO, 2009; DAVYDOV & SHEL'YAG-SOSONKO, 2019). It is the most distributed syntaxon of beech forests at altitudes 400–1200 m in the Eastern Carpathians within the territory of Ukraine (ONYSHCHENKO, 2009). Similar forest communities belonging to this association have also been described from the upper part of Chornyi Cheremosh river basin in Chernivtsi region (BUDZHAK & ONYSHCHENKO, 2004), NNP Skolivski Beskidy (SOLOMAKHA ET AL., 2004), Vyzhnytskyi (CHORNEY ET AL., 2005), Hutsultshchyna (DERZHYPILSKY ET AL., 2011) and

Karpatskyi (ONYSHCHENKO, 2009), the Nature Reserve Horhany (KLIMUK ET AL., 2006), Mala Uholka river basin in Karpatskyi Biosphere Reserve (ONYSHCHENKO, 2007); their floristic compositions are closely related to those of our relevés. Outside the territory of Ukraine the association *Symphyto cordati-Fagetum sylvaticae* is now known from Romania (VIDA, 1963; SANDA ET AL., 2008; GHEORGHE & BURESCU, 2012) so its area of distribution is situated only in the Eastern Carpathians. The second association of virgin beech forest is *Luzulo luzuloidis-Fagetum* (Du Rietz 1923) Markgraf 1932 which belongs to the alliance *Luzulo-Fagion sylvaticae* Lohmeyer & Tx. in Tx. 1954 from the order *Luzulo-Fagetalia* Scamoni & Passarge 1959 and the class *Quercetea robori-petraeae* Br.-Bl. & Tx. ex Oberd. 1957 have a local distribution and includes beech virgin forests as well as spruce ones (Table 2). This association, including acidophilous and acidic-tolerant mountain forests on rocky substrate, is widely distributed in Central Europe (Poland, Slovakia, Czech Republic) and the Carpathians (SLEZAK ET AL., 2016; ŚWIERKOSZ ET AL., 2018). In Ukraine it is known from Synevyr (SOLOMAKHA ET AL., 2016), and from the NNP Skolivski Beskidy (SOLOMAKHA ET AL., 2004), Vyzhnytskyi (CHORNEY ET AL., 2005) and Hutsultshchyna (DERZHYPILSKY ET AL., 2011). Unfortunately, previous research authors did not indicate an affiliation for the described relevés for virgin, or other forest types, so detailed research of the syntaxonomy of virgin forest is needed there.

The localization of virgin beech forests on high altitudes outside optimal areas in the Ukrainian Carpathians is their typical feature on the studied territory. Thus, in the compartment 2 of Kolochavsky ERD virgin beech forests were found at an altitude of 1330 m a. s.l. on the south-eastern slope with communities of the alliance *Alnion viridis* Schnyder 1930 and the association *Vaccinietum myrtilli* Szafer, Pawłowski et Kulczyński 1927.

According to our research results virgin beech ecosystems of Synevyr NNP with an area of 2865.04 hectares were included from 7 July 2017 in the list for “Ancient and Primeval Beech Forests of the Carpathians and Other Regions in Europe” as a UNESCO World Heritage Site (YAREMA ET AL., 2018).

Recently forest communities have been significantly affected by global climate change, which is manifested on the research territory as an increase of growing degree units and the length of the growing season, as well as increasing precipitation intervals (dry periods). These changes cause a massive drying of spruce forests, as planted as native (SHPARYK, 2018). The preservation of natural spruce forests in the Ukrainian Carpathians is also important now.

Table 1. Syntaxonomical characteristics of the association *Symphyto cordati-Fagetum sylvaticae* Vida (1959) 1963 (class *Carpino-Fagetea sylvaticae* Jakucs ex Passarge 1968)

Number of releve	1	2	3	4	5	6	7	8	9	10
Altitude, m	840	840	840	225	1050	1050	1220	1050	900	980
Tree layer cover, %	80	80	60	80	80	80	80	80	80	80
Shrub layer cover, %	5	-	60	5	-	-	-	20	20	20
Herb layer cover, %	10	50	5	5	20	20	30	30	25	30
Moss layer cover, %	-	-	-	-	-	-	-	-	-	-
Number of species	12	11	9	12	14	13	23	18	15	16
Diagnostic species of the association <i>Symphyto cordati-Fagetum</i> :										
<i>Acer pseudoplatanus</i>	1	1	1	1	+	+	+	1	1	-
<i>Rubus hirtus</i>	1	1	5	1	-	-	3	3	3	3
<i>Abies alba</i>	+	+	-	+	-	-	+	1	-	1
<i>Athyrium filix-femina</i>	-	-	1	-	+	+	+	+	-	+
<i>Oxalis acetosella</i>	-	-	-	-	+	+	+	+	+	+
<i>Dentaria glandulosa</i>	+	-	-	+	-	-	+	-	+	-
Diagnosis species of the class <i>Carpino-Fagetea sylvaticae</i> :										
<i>Fagus sylvatica</i>	5	5	5	5	5	5	5	5	5	-
<i>Dryopteris filix-mas</i>	+	+	+	+	-	-	+	-	+	+
<i>Dryopteris carthusiana</i>	+	1	-	+	-	-	-	-	+	-
<i>Anemone ranunculoides</i>	+	2	-	+	+	+	+	+	-	-
<i>Cystopteris fragilis</i>	-	-	-	-	-	-	+	+	+	+
<i>Galium odoratum</i>	1	1	-	+	-	-	-	-	-	-
<i>Fraxinus excelsior</i>	-	-	-	-	+	+	+	-	-	-
<i>Lamium galeobdolon</i>	-	-	-	-	3	1	-	+	-	-
<i>Lilium martagon</i>	-	-	-	-	+	+	-	+	-	-
<i>Paris quadrifolia</i>	-	-	-	-	+	+	-	+	-	-
<i>Sambucus nigra</i>	-	-	-	-	+	-	+	-	-	-
<i>Stellaria nemorum</i>	-	-	-	-	+	-	-	+	-	-
<i>Dentaria bulbifera</i>	-	-	-	-	-	-	+	-	-	+
Other species:										
<i>Picea abies</i>	1	+	-	+	1	1	-	1	+	1
<i>Gymnocarpium dryopteris</i>	+	+	+	+	-	-	+	+	+	-
<i>Dryopteris expansa</i>	-	-	-	-	+	+	+	+	-	+
<i>Betula pendula</i>	+	+	-	+	-	-	-	-	-	-
<i>Sorbus aucuparia</i>	-	-	+	-	-	-	+	+	+	+
<i>Blechnum spicant</i>	-	-	-	-	+	+	-	-	-	-
<i>Phegopteris connectilis</i>	-	-	-	-	-	-	+	-	-	+
<i>Polygonatum verticillatum</i>	-	-	-	-	-	-	+	-	-	+
<i>Luzula luzuloides</i>	-	-	-	-	-	-	+	+	+	-
<i>Calamagrostis arundinacea</i>	-	-	-	-	-	-	+	-	+	+
<i>Prenanthes purpurea</i>	-	-	-	-	-	-	+	-	-	+

Species with low frequency: *Circaea lutetiana* (3: +), *Corylus avellana* (10: +), *Dryopteris dilatata* (7: +), *Festuca altissima* (9: +), *Maianthemum bifolium* (9: +), *Mycelis muralis* (8: +), *Pinus sylvestris* (7: +), *Rubus idaeus* (3: +), *Stellaria holostea* (6: +).

Dates and locations of relevés: 1–4 – Kvasovetske ERD, compartment 14, 24 Jul 2012; 5–6 – Ostrytske ERD, compartment 29, 30 Jul 2012; 7 – Kolochavske ERD, compartment 11, 13 Jul 2013; 8 – Ostrytske ERD, compartment 29, 15 Jul 2013; 9 – Kvasovetske ERD, compartment 21, 15 Jul 2013; 10 – Kvasovetske ERD, compartment 15, 16 Jul 2013.

Table 2. Syntaxonomical characteristics of the association *Luzulo luzuloidis-Fagetum* (Du Rietz 1923) Markgraf 1932

Number of releve	1	2	3	4	5	6
Altitude, m	625	1350	1330	1330	1180	1140
Tree layer cover, %	70	70	80	80	70	70
Shrub layer cover, %	-	-	15	5	25	-
Herb layer cover, %	70	35	20	40	30	20
Moss layer cover, %	80	40	-	-	-	50
Number of species	16	15	23	22	21	26
Diagnostic species of the association <i>Luzulo luzuloidis-Fagetum</i> :						
<i>Vaccinium myrtillus</i>	5	1	1	4	1	2
<i>Luzula sylvatica</i>	+	+	+	+	+	2
<i>Dryopteris expansa</i>	+	4	+	+	+	+
<i>Huperzia selago</i>	+	+	-	-	-	+
Diagnostic species of the class <i>Quercetea robori-petraea</i> :						
<i>Calamagrostis arundinacea</i>	+	+	1	+	+	-
<i>Cystopteris fragilis</i>	+	+	+	+	+	+
<i>Oxalis acetosella</i>	+	1	1	+	+	+
<i>Sorbus aucuparia</i>	-	+	-	-	-	+
Other species:						
<i>Picea abies</i>	5	5	-	1	+	4
<i>Fagus sylvatica</i>	-	-	5	4	5	3
<i>Acer pseudoplatanus</i>	-	-	+	+	+	+
<i>Athyrium filix-femina</i>	-	-	+	+	+	+
<i>Maianthemum bifolium</i>	-	-	+	+	+	+
<i>Phegopteris connectilis</i>	-	-	+	+	+	+
<i>Pleurozium schreberi</i>	5	4	-	-	-	4
<i>Dicranum polysetum</i>	1	2	-	-	-	2
<i>Rubus caesius</i>	-	-	2	1	3	-
<i>Dryopteris dilatata</i>	-	-	+	+	+	-
<i>Lycopodium annotinum</i>	+	+	-	-	-	-
<i>Blechnum spicant</i>	+	-	-	-	-	+
<i>Dryopteris filix-mas</i>	-	-	+	+	-	-

Species with low frequency: *Abies alba* (6:3), *Anemone ranunculoides* (6:+), *Homogyne alpina* (6:+), *Lilium martagon* (3:+), *Polygonatum verticillatum* (6:+), *Prenanthes purpurea* (6:+).

Dates and locations of relevés: 1–2 – Synevyrskye ERD, compartment 20, 26 Jul 2012; 3–5 – Kolochevskye ERD, compartment 2, 26 Jul 2012; 6 – Synevyrskye ERD, compartment 4, 27 Jul 2012.

Spruce forests dominated by *Picea abies* were found on about 65% of the territory of the Synevyr NNP. Most of these forests are plantations and they are vulnerable to different factors. Natural spruce forests are now only distributed in the upper mountain forest belt. They stretch in continuous strips along the north-eastern and south-western macroslopes at an altitude of 900 to 1450 m a. s.l. (Sloboda, Roztoka, Krasny Zvir, Zelena Yavoryna, Pesya Rika, Fuleyovets, Berezovets, Kanchivsky, Studeny, Yavorovets forest tracts) and their preservation is only achievable by the lack of accessible roads which prevents their exploitation.

Studied plots of spruce forests with distinct virgin characters are now located mainly on the

foothills of mountain slopes within altitudes of 1000–1400 m a. s.l.

The climate and soil conditions contribute to the high vigour of *Picea abies* and the development of monodominant and mixed spruce forests. In pure virgin spruce forests the dominant tree layer was that of *Picea abies* with an age of 140–150 years, which was found at an elevation of 15–18 m and the trees had a diameter at breast height of 40–44 cm. Medium age and young trees in these communities are not rare. We also found dry and fallen trees at different decay stages and trunks were broken at a height of 4–6 m. The growth of spruce is reasonable, it formed the second sublayer in several plots. The undergrowth is not well formed, and single

trees of *Sorbus aucuparia* L. occur. The species that are characteristic of the mixed herb-shrub layer are: *Vaccinium myrtillus* (60–70% of projected cover), *Dryopteris expansa* (1–30%), *Blechnum spicant*, *Lycopodium annotinum*, *Calamagrostis arundinacea*, *Oxalis acetosella*, *Cystopteris fragilis*, *Luzula sylvatica*, *Huperzia selago*. The well-developed moss layer has a coverage of 75–80% and is formed mostly of *Pleurozium schreberi* and *Dicranum polysetum*.

The mixed virgin spruce forests have a tree layer with two sublayers. The first of these consists of *Picea abies* and *Abies alba* with an age of 60–70 to 120–130 years old, a height of 28–32 m and a diameter at breast height of 40–44 cm. The presence of single spruce trees aged 200–220 years was noted. The second tree sublayer is formed of *Fagus sylvatica* trees aged between 25–40 years with a height of 20–22 m. Juvenile individuals of *Fagus sylvatica* and *Picea abies* are common. The undergrowth is not well formed, and only solitary trees of *Sorbus aucuparia* were found. The herb-shrub layer is sparse, with a coverage of 20–25% and is formed of: *Vaccinium myrtillus* (5–10%), *Luzula sylvatica* (2–3%), *Huperzia selago*, *Dryopteris expansa*, *Oxalis acetosella*, *Cystopteris fragilis*, *Blechnum spicant*, *Anemone ranunculoides*, *Prenanthes purpurea*, *Athyrium filix-femina*, *Phegopteris connectilis*, *Maianthemum bifolium*, *Homogyne alpina*, *Polygonatum verticillatum*. The moss layer has a 40–50% projected cover and was formed of *Pleurozium schreberi*.

A typical feature of spruce virgin forests of the national park is the presence of dead, fallen and rotten tree roots at different stages of decay (Fig. 3). The trunks were broken at a height of between 2 to 5 m. The share of dead wood in virgin spruce forests was lower than in virgin beech forests, but higher than in the surrounding forests transformed by human activity.



Fig. 3. Acidophilous beech-spruce forest in Synevyr National Nature Park (photo by P.M. Ustymenko)

Current threats to the biodiversity of the virgin forests within the territory of the Synevyr NNP are caused by both natural and anthropogenic factors. Natural threats include falling dead trees, snowfall, and phytopathological dangers. Anthropogenic threats are caused by both direct (fires) and indirect factors. The existing network of forest roads makes previously inaccessible virgin plots available to forestry. A certain part of the forests is in contact with high mountain pastures or recreation areas where it is planned to build ski slopes with lifts and trails for extreme types of cycling and motorcycle racing (USTYMENKO ET AL., 2012b). Based on these facts the urgent task is to include all plots of the current virgin forests within an area of absolute protection within the territory of Synevyr NNP. It is necessary to provide a buffer strip (at least 200 m wide) in places where there is contact between virgin forest areas and recreational or economical zones. Further detailed floristic and geobotanical research of these communities is needed especially to map and monitor their dynamic features.

4. Conclusions

The natural beech and spruce forests found and studied by us within the territory of the Synevyr NNP have a virgin nature based on their structure, valuation parameters and spontaneous dynamics. The virgin forest ecosystems of Synevyr NNP should provide ecological models for forestry. There are natural (fallings of dead trees, snowfalls, phytopathological danger) and anthropogenic threats (direct human activity, network development of forest roads, recreation, fires) to the biodiversity within these forests. To preserve these habitats of virgin forests within the territory of Synevyr NNP we propose to include all the areas found in this research within a zone of absolute protection within the territory of the NNP. The urgent task is to conduct further research of these virgin forest ecosystems in the Ukrainian Carpathians. The results of our research have formed the basis for the inclusion of the virgin beech forests of Synevyr NNP in the list of sites of “Beech virgin forests and ancient forests of the Carpathians and other regions of Europe” as a UNESCO World Heritage Site (included on 7 July 2017 with an area of 2865.04 hectares).

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