Current biodiversity and hotspots in the primeval beech forest – Poloniny National Park, the Eastern Carpathians (Slovakia)

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Abstract. The research was carried out in the territory of the Bukovské vrchy hills, where natural beech forest stands contain an invaluable genetic reservoir of European beech and other species associated and dependent on these forest habitats. Present study is focused on the creation of local biodiversity hotspots. The structure of local biodiversity valuable areas is based on spatial distribution of indicator species of primeval beech forests and species of conservation interest. Field data on rare bryophytes, vascular plants, macrozoobentos and vertebrates were condensed into GIS layers. The new zonation of the Poloniny National Park was suggested. Spatial distribution of relevant species should be included in the new zonation which we believe will better ensure the protection of beech forests.

Key words: indicator species, hotspots, zonation, Bukovské vrchy Mts, Slovakia

Introduction

Despite an increase in conservation efforts, the state of biodiversity continues to decline (CBD 2010). Old-growth forests play a key role in sustaining biodiversity (Gibson et al. 2011), but also play an important role in climate change mitigation (Knohl et al. 2009). Despite the ecological importance of old-growth forests, globally, they are vanishing at an alarming rate, mainly due to deforestation, unsustainable logging practices, and fire (Achard et al. 2009). In central Europe, old-growth forests have survived mainly in remote and inaccessible mountain areas (Frank et al. 2009; Schulze et al. 2009), where logging of wood has been difficult and unprofitable. These are the areas where the first nature reserves have been established.

Beech forests in the Poloniny Mts represent an outstanding example of undisturbed, complex temperate forest and exhibit complete and comprehensive ecological patterns across a variety of environmental conditions. They contain an invaluable genetic reservoir of European beech and other species associated and dependent on this tree species. A significant component of the ecosystem is decaying wood, which is widely regarded as an important aspect of forest biodiversity forming key habitats for many species. Varied dead-wood features create additional habitat niches which increase habitat diversity (Speight 1989). For example, invertebrates, bryophytes, lichens, birds and mammals depend on or utilise dead wood as a source of food or shelter (Harmon et al. 1986; Esseen et al. 1997; Siitonen 2001). Birds like woodpeckers, owls, flycatchers and nuthatches dependent on dead wood (Tomiajóč and Wesołowski 2004). The amount of dead wood in the forest reserve provides ideal conditions for occurrence of a high number of wood-inhabiting fungi which are rare and threatened in many parts of Europe (Christensen et al. 2005). Dead wood is not only a substrate for vegetation, but its water holding ability contributes significantly to the maintenance of a humid climate in forests (Rambo and Muir 1998). Vast forests including large tracts of old-growth forest provide important habitat for populations of large mammals (Urus arctos, Canis lupus, Lynx lynx and Bison bonasus). An effective way to protect a large number of species is to map out biodiversity hotspots (Myers et al. 2000). The term ‘biodiversity hotspot’ was defined by Myers (1988) as an area where exceptional concentrations of endemic species are undergoing exceptional loss of habitat. Many authors consider hotspots to be areas with the highest species diversity, (Samson and Knopf 1993; Williams et al. 1996; Kerr 1997; Myers et al. 2000; Orme et al. 2005; Grenyer et al. 2006) or with endemic species (Kerr 1997; Orme et al. 2005), rare species (Prendergast et al. 1993; Williams et al. 1996; Grenyer et al. 2006), or threatened species (Dobson et al. 1997; Orme et al. 2005; Grenyer et al. 2006). Carpathians represents one of the major diversity hotspots in Europe (Bálint et al. 2011). On a regional scale, each are exhibiting higher species diversity, endemic or threatened species should be mapped. These places should be recognised as local “hotspots”, analogical to biodiversity hotspots in the world, and may be very important for the long-term survival of these threatened organisms and conservation of their habitat. Guidelines of the World Conservation Union (IUCN 1994, 2013) served as the basic documents not only for the creation of protected areas, but also for their management and
land use in these areas (Bishop et al. 2004). The first international system of landscape categorization was created in 1978 (IUCN 1978). This system was replaced in 1994 by the current categorization of protected areas (IUCN 1994), which is the starting point for the definition of six categories of nature and landscape protection and utilization. The subsequent work (Bridgewater et al. 1996; IUCN 1998; EUROPARC 2001; Phillips 2002; Bishop et al. 2004; IUCN 2004; Dudley 2008) shows how to apply the guidelines in certain specific geographical or other contexts. Zonation is generally regarded as a management tool (Dudley 2008) through which we can, in different parts of the large protected areas, follow different management objectives and restrict potential conflicts associated with the land use of these zones. Therefore, the zonation is the heart of many national parks (Syne 2010). If definitions of zones in protected areas are clear then further success depends on the role of authorities responsible for protected areas. This role usually differs between countries. In Slovakia, administration of national parks (or protected areas) occurs at an advisory level, while an administrator of national parks in Poland may be wholly responsible for management activities within their territory (Fall 2003).

The main motivation for our decision to address this topic is the conflict between nature conservation and economic profit. Slovak environmental organizations require that corporations limit, and in some cases stop, their activities in protected areas. This is also the case in Poland, where the national parks may be wholly responsible for management activities within their territory (Fall 2003).

The fundamental objective of this study was to define the core areas of high biodiversity in the primeval beech forest. For our purposes, we used epiphytic and epilithic bryophytes, herbaceous vascular plants and vertebrates, especially birds of the genus *Ficedula* to map the local biodiversity hotspots. The water quality of the most important streams inside the forest was evaluated by the measurements of water chemical composition and presence of some important taxa of macrozoobenthos.

### Material and Methods

#### Study area

Poloniny National Park is the easternmost large-scale protected area in Slovakia. It is located along the borders of three countries – Slovakia, Poland and Ukraine (Fig. 1). The park was established on October 1st, 1997 (Kramarik 1998). It covers an area of 29,805 hectares, with the specially protected area (buffer zone) amounting to 10,973 hectares. The most valuable parts of the national park are protected in seven national nature reserves (Stužica, Ruským), twelve natural reserves (Bahno, Borsučiny, Bazáň, Gazdoraň, Hlboke, Hrušok, Ruske, Stančia Slatina, Stružnická dolina, Šipkóva, Udava, Uličská Ostrá) and one natural monument (Ulička). In 1993, UNESCO’s Man and the Biosphere Programme declared it as the International East Carpathian Biosphere Reserve together with the adjacent Polish (Bieszczadski National Park, Ćmielowski-Wetliński Landscape Park and Dolina Sanu Landscape Park) and Ukrainian (Užansky Park, Nadsjanskyj Regional Landscape Park) regions, which made it the first trilateral biosphere reserve in the world (Burášvá and Němethová 2009). Poloniny National Park was awarded the prestigious European Council Diploma in 1998 (COE 2015). The National Park is a part of the Bukovské vrchy Mts., which consists mainly of coarse sandy flysh, greenish-grey and red claystone and fine sandstone. It is a moderately warm region, with less than 50 summer days annually on average with a daily maximum air temperature ≥ 25 °C and a July mean temperature 16 °C or more.

Reserves with strict protection (5th zone), B - Nature Reserves with management (4th zone), C - zone of National park (3rd zone) and D - buffer zone of National Park where are urban areas (2nd zone).

The National Park includes some of the most natural beech forest reserves in Europe. For example, long-term mycological research in Poloniny National Park revealed the occurrence of 1,244 fungal taxa (Kuthan et al. 1999). Some proposed indicators and ‘species of special interest’ appear to be common and abundant, e.g. *Ceriporiopsis gilvescens*, *Dentipellis fragilis*, *Pluteus umbrosus* (Adamčík et al. 2007).

In terms of the phytogeographical division of Slovakia, the area of Poloniny National Park is the only area where East Carpathian endemic species occur. They are represented by *Danthus barbatus* L. subsp. *compactus*, *Campanula abietina*, *Silene nutans* subsp. *dubia*, *Pestua saxatilis*, *Cirsium waldsteinii*, *Ranunculus carpicus*, *Melampyrum hertichii*, *Scorzonera rosea* or *Viola dacica* (Zemanek 1991; Dostál 1989).

The animal diversity of the region is documented by 5,981 species of invertebrates, including: 91 species of molluscs (Čežka et al. 2008); 234 species of mites and 403 species of other arachnids (Mašan and Švatoň 2003); 25 species of opiliones (Mihál et al. 2003); 71 species of mayflies and 42 species of stoneflies (Novikmeč et al. 2007); 1,472 species of beetles (Jászay 2001); 43 species of caddisflies (Novikmeč et al. 2007); and 819 species of butterflies (Paníga 2000).

#### Data collection

The research was carried out in spring, summer and autumn of 2012 as well as during spring and summer 2013. All observed species in the field were localized by GPS devices. The following information was collected from field research: field lists of herbaceous vascular plants, epiphytic and epilithic bryophytes, vertebrates (including amphibians), indicator species of birds as well as insects and macrozoobenthos. Emphasis was placed on species of conservation concern, i.e. red-listed, Red book and Natura 2000 species and indicators of primeval beech forests. Indicator species of primeval beech forests were selected through the assumption that old-growth forests are sources of biodiversity and have a high ecological value (Spies and Franklin 1996).

From the available literature, we excerpted species of bryophytes, which the authors considered as indicator species of old-growth forests (or unmanaged forests, or climax forest). In Table 1 is a list of species, which 11 authors (Andersson 1991; Gustafsson and Hallingbäck 1988; Maksimov et al. 2003; Ódor and Van Dort 2002, Trass et al. 1999;
The study area NP Poloniny and current zonation (N 49°02'07.90"; E 22°19'39.62") Zones according to Slovak Act 543/2002 are divided on the basis of the conservation status (five zones of protection): A - National Nature Reserves with strict protection (5th zone), B - Nature Reserves with management (4th zone), C - zone of National park (3rd zone) and D - buffer zone of National Park where are urban areas (2nd zone).

Vellak and Paal 1999; Hokkanen 2004; Ódor et al. 2005; Ohlson et al. 1997; Hodgest 1996; Söderström 2006) in Europe consider to be indicator species of old-growth forests (primeval) or natural forests. If less then four authors considered a species to be an indicator, it was excluded from this category.

In unmanaged natural forests the following species of bryophytes occur: Dicranum fuscescens, Dicranum majus, Harpagone flavoviridis, Herzogella seligeri, Homalia trichomanoides, Jungermannia leiantha, Lophozia occurr., Mnium stellare, Neckera pennata, Odontoschisma denudatum, Plagiothecium undulatum, Pseudobryum cinctiioides, Rhizomnium punctatum, Riccardia latifrons, Riccardia occurs, Scapania umbrosa, Sphagnum gigensohii, Sphagnum tenes, Trichocolea tomentella, Uloa crispa, Hylocomastium umbratum.

Herbaceous vascular plants were mapped in forest stands following the national classification of habitats (Stanová and Valachovič 2002) for beech and mixed beech forests. We focused on species of conservation interest (IUCN, Red Data Book, SR) us-

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ing the following categories: EN (endangered), NT (endangered near threatened), VU (vulnerable), CR (critically endangered), east carpathian endemits and occurrence subendemits. Localities were selected predominately within protected areas and the occurrence of species were recorded using GPS. Nomenclature of plant taxa follows Marhold and Hindák (Marhold and Hindák 1998).

In the case of vertebrates, we reviewed the occurrence of some species of mammals, amphibians, reptiles and birds, which are of conservational concern (Natura 2000). We focused particularly on the collared flycatcher (*Ficedula albicollis*) and red-breasted flycatcher (*Ficedula parva*), which are top bio-indicators of natural beech forest in the Poloniny region (Pčola 2012). Special attention was also focused on the yellow-bellied toad (*Bombina variegata*) and carpathian newt (*Triturus montandoni*) because of the ecological requirements of amphibians on their temporary occurrence, they may be useful to the design of corridors (from viewpoint of behavioural ecology) between protected sites.

Relative to the corridor design, we analysed the water quality in 17 streams (Stužická rieka, Kamenistý potok, Zbojský potok, Packov potok, Ráztkova, Hrabový potok, Javorník, Hlbočky potok, Ulička, Černegov potok, Smolník, Stružnica, Oľchovec, Černinský potok, Udava, Skorský potok, Pčolinka) (Table 2, Fig. 2c), where we collected samples and identified aquatic invertebrates (mayflies, stoneflies and caddisflies). Qualitative samples of macrozoobenthos were collected using a ‘kicking’ technique. Fig. 2. Landscape matrix; a) – hotspots of Bryophytes (+) and vascular plants (•); b) – hotspots of *Ficedula* spp. (+) and other vertebrates (•); c) – water quality sampling sites (+), aquatic invertebrates (•) (CE - Černinský brook; HR - Hrabavý brook; KA - Kamenistý brook; OL - Oľchovec brook; PA - Packov brook; PC - Pčolinka brook; RA - Ráztkova brook; SP - Skorský brook; SM - Smolník river; SR - Stružnica brook; ST - Stužická river; UD - Udava brook; UL - Ulička river; ZB - Zbojský brook; see Table 2); d) – current zonation (the most strictly protected zone A represent nature reserves inside of the national park); e) – areas of interest (red ) and old grown forest (blue).

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**Results and Discussion**

**Vegetation**

We have added species of European importance as well as redlisted species (Kubinska et al. 2001) to the selected species of bryophytes according to the methodological principles, if they have considered by some authors as indicator species (Fig. 2a). In the territory of the Bukovské vrchy hills there are only two species of European importance - *Buxbaumia viridis* and *Dicranum viride*, which is an indicator species identified by Trass et al. (1999) and Hodges (1996). Within the investigated territory, *Dicranum viride* was collected by Soldán (Šoltés and Bural 2012). *Neckera pennata* has been recorded as an indicator species by three authors, and as it is a redlisted bryophyte, it is considered to be an indicator species. The redlisted species *Porella coriacea*, has been recorded as an indicator by less than three authors, and in the investigated area it was recorded by Peciar (1987). *Orthotrichum gymnostomum*, was also found in the investigated area by Peciar (1987). *Orthotrichum pallens* was found in the investigated area by Platé (2007). *Anacamptodon splachnoides*, was found in the investigated area by Soldán (Duda and Váňa 1984; Šoltés and Bural 2012).

The number of epixylic species correlates with the diameter of lying trunks (Hradilek 1999). Baldwin and Bradfield (2005) examined the relationship between bryophyte diversity and the age of the stands. Bryophyte diversity sharply increased when the age of stands was over 300 years. Similar results have been obtained by Fenton and Bergeron (2008), who investigated correlation between bryophyte diversity and age of *Picea mariana*. The diversity reached its height at an age of 275 years. Gustafsson et al. (2004) have elaborated on a list of bryophytes, indicating that habitats of old, uneven aged stands with dead wood result in high diversity. The trunks and stumps have a different ecology. The trunks are more humid, with higher diversity of liverworts. In the managed forests, the stump diversity may even be higher (Rajandu et al. 2009).

Bryophyte biodiversity of managed and unmanaged forests has been compared by other authors (Table 1). Vellak and Paal (1999) compared bryophytes in managed and unmanaged forests in Estonia. Up to 50% of the species represented in the virgin forests in Estonia do not occur in younger forests. Thirty percent of the species in old unmanaged forests were liverworts, while in younger managed woods the liverworts accounted for 17% of bryophytes. Söderström (1998) found that in natural forests liverwort occurs more frequently, while in managed forests lichen of the genus *Cladonia* oc-
curred more frequently. This is because of decreased humidity and the lack of decaying wood in managed forests. Managed forests are younger, approximately evenly aged, and old trees and dead wood are missing; thus, the substrate for epiphytic flora is lacking (Södénström 2006). Ódar and Standaard (2001) when compared to the diversity of bryophytes in unmanaged and managed beech stands in Hungary.

Bryophytes in unmanaged stands showed a much greater diversity than in managed forests. To order to conservation biodiversity, it is essential for the bryophytes to protect isolated natural stands, and in particular the availability of dead wood. Gustafs scorn and Hallingback (1988) compared bryophytes of virgin forests and managed spruce forests in southwestern Sweden. Bryophytes of virgin forests are distinguished from bryophytes of managed forests, in particular, by the presence of liverwort species heralding the presence of thick trunks. Species such as Calypogeia suecica, Odontoschisma denudatum, Scapania umbrosa can be found in virgin forests. Andersson and Hytteborn (1991) researched species that occur in both managed forests and virgin forests, followed by species native only to virgin forests, and finally, species found only in unmanaged forests. Kush- nevskaya et al. (2007) compared the bryophytes of managed and semi-natural forests at an advanced stage of succession in the Northwest of Russia. Analysis of bryophytes found different liverworts in managed and semi-natural forests. Trass et al. (1999) did not consider hemerophobic species to be indicators in virgin forests, but they meet the ecological conditions in these forests. Ohlson et al. (1997) consider epigeic hydromorphic species (Pseudobryum cinchichoides, Rhizomnium pseu dopunctatum and others), as well as other species tied to dead wood, (Lepidozia reptans, Anastrophyllum helieranum, Tetraphis pelzczia, among others), to be indicators of natural swampy forests. Hokkainen (2004) defined the group of bryophytes found in unmanaged shady forests. In addition to the lignicole or epiphytic spe cies, a large part of the group is made up of epigeic bryophytes, particularly Sphagnum species such as Sphagnum fimbriatum, S. cinereohum, S. centrale and S. teres. Lesica et al. (1991) compared the abundance of liverworts in the climax forest and managed forests in Canada. They have shown that many species found their optimum in climax forests and are decreasing in managed forests. Hodgest (1996) consider three species of bryophytes, restricted to unmanaged old forests – Scapania massalongi (CR), Buxbaumia viridis (VV), Dicranum viride (NN) - to be endangered species in Europe. These bryophytes are referred to in Annex I of the Berne Convention and in Annex II of Habitats directive, and are important European species occurring in Slovakia.

Regarding vascular plants, an important floristic phenomenon in Poloniny is the presence of elements of Eastern Carpathian flora, including rare and endangered species (Fig. 2a). This was the reason for the classification of Poloniny as an “Important Plant Area “code - IPA EN 262 (Galvánek 2007). In the forest communities, we have recorded species belonging to the Dacian microelement (Hendrych and Hendrychová 1979), including Heleborus pur purascens and Aposeis foetida. The Dacian microelements are represented by species Dentaria glandulosa and Symphytum cordatum. Hádač and Terry (1989) also recorded these species, which are important for the preservation of the gene pool of Eastern elements in our flora. Heleborus pur purascens is also a species of conservation interest in the EN – endangered category. This species is restricted to the Bukovské vrchy Mts., and has been recorded at 35 sites – Ulic, valley Stužica, Ostrá, etc. (Čelovský et al. 1999). We observed this species in Starina and below Baranec hill. During the evaluated period, we identified the presence of: 5 species considered near threatened (NT); 13 species labelled vulnerable (VU); 3 endangered (EN) species; and 1 critically endangered (CR) species (2 carpathian subendemits – Ks and 2 east carpathian endemits). From the reclassified species list, we recorded Carex canescens (NT), Listera ovata (VV), Lyco podium annotinum (NT), Molinia caeno lavea (VV), Dactylorhiza fuchsii subsp. fuchsii (VV), Lilium martagon supsp. martagon (NT), Lathyrus laevigatus (EN), Acornutum mokavicum (VV), Centaurium ery thræa subsp. erythræa (NT), Scutellaria akissima (CR), Cephalanthera damasonum (VV), Platatera bibernia (VV), Gymnadenia conopsea (VV), Menyan thetes trifolata (EN), Dactylorhiza majalis subsp. ma jalis (VV), Carex lepidocarpa (NT), Epipactis palustr is (VV), Traunsteinella globosa (VV), Dianthus barbatus subsp. compactus (VV), Veratrum album subsp. album (VV), Gladiolus imbricatus (VV), Hel leborus purpurascens (East Carpathian endemite), Aposeis foetida (East Carpathian endemic), Den taria glandulosa (Carpathian subendemic) and Sym phytum cordatum (Carpathian subendemic).

Aquatic insect and water quality

In total, 53 localities were analysed in 2012 and 2013 in Poloniny National Park and adjacent areas (Fig. 2c). In 2012, 41 species (22 Ephemeroptera, 3 Ple coptera and 16 Trichoptera) of aquatic insect were recorded. In 2013, 18 species of Plecoptera, and 17 of Trichoptera were recorded. At some sampling sites, Dunsus bruneus, the Carpathian endemic species of Trichoptera was found. Only two known samples ex ist from Slovakia (Bítlík and Novíkmeč 1997; Novík meč et al. 2007), both from The Eastern Carpathians. From the Rhithrogena group, the Carpathian endemic species Rhithrogena goszánh was recorded. This species is an indicator of water purity (Mihaljević et al. 1998). As a result of a lack of “reliability” of deter mination features and due to poor vagility of mayflies and isolation by mountain ridges, the determination of genus is very difficult (Soldán andanda 1999). As is seen in Table 2 the water quality in the monitored flow is good. Higher levels of nitrates were occasionally found in Kamenistý brook, Stužica River and Zbojeky brook, Packov brook, Ulíčka River - probably caused by leaching from subsoil.

Changes in the physical-chemical characteristics of water quality are influenced not only by anthropogenic processes (Tymczyna et al. 2000; Ziemlinski et al. 2003), but also by natural processes such as hydrological conditions, topography and lithology, climate, precipitation inputs (Walina et al. 2003; Polkowska et al. 1999), and catchment area (Glimská-Lewczuk 2006), in combination with environmental influence.
### Table 2.
The physico-chemical properties of water samples. Legend: CE (Černinský brook), HR (Hrabavý brook), KA (Kamenistý brook), OL (Ochovcova brook), PA (Pacakov brook), PC (Podolinka brook), RA (Ráztoka brook), SP (Skorsky brook), SM (Smolník river), SR (Stružnica brook), ST (Stužická river), UD (Udava brook), UL (Ulička river), ZB (Zbojský brook), << below detection limit; >> above detection limit. Sampling sites are numbered downstream (see Fig. 2 C). Inventerbrate evaluation: * slight contamination; + medium contamination; +* high level of nitrate; * without contamination; + low level of nitrate; * Not recorded.

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Vertebrates

Transferring the data on flycatcher occurrence onto forestry maps shows the essential structure of suitable habitats for birds breeding in nest cavities (Fig. 2b). Moreover, we found nine species of mammals, five species of amphibians, four of reptiles. *Ursus arctos* was recorded at 14 locations, *Bison bonasus* at 6 localities, *Canis lupus* at 5 localities, *Castor fiber* at 2 locations and *Lynx lynx* at 1 location. Besides mammals and birds we have, for example, recorded 155 individuale of *Bombina variegata* at 61 locations and 34 individuals of *Triturus montandoni* at 29 different sites. Several studies show the difference in bird species richness between managed forests and old-growth forests (Boncina 2000; Müller et al. 2007). Dead wood evidently holds a key role for certain bird species like woodpeckers or flycatchers (Swallow et al. 1988). Any kind of wood use in beech forests as well as in other forests leads to a significant reduction of a whole series of specialised species, even if the natural tree species composition is not changed (Müller et al. 2007). The main difference between managed forests and old-growth forests is in the amount of coarse woody debris. Siitonen (2001) found that amount of dead wood in unmanaged boreal forests varied from 18% to 37% of the total wood volume.

In general, our results concerning the breeding of flycatchers in relation to old beech forest substantiate previous findings for many other European populations of these two species. The selection of the species is very useful to compose hotspot diversity maps in beech forest areas. The information in these maps is long-termed because pairs of flycatchers very often breed in the holes of the previous year or in the nearest one available. The map layer of occurrence of rare or highly-protected vertebrates enable us to design a map of potential ecological corridors (see Corsi et al. 2002). Amphibians are vagrants, especially during a nesting period, and their temporary occurrence may be very useful to design the corridors. This approach was very helpful to design the newly suggested zonation map of Poloniny National Park.

Hotspots and zonation

According to the philosophy of global biodiversity hotspots (Myers 2010), we created local biodiversity hotspots in our study area. Grant and Samways (2011) employed a similar definition of ‘micro-hotspots’ for identification of biodiversity hotspots of dragonflies in the Kogelberg Biosphere Reserve. Our hotspots (Fig. 2a-c) represent points with the presence of relevant species (indicator species and species of conservation interest) which were observed or collected in the field. Here we focus on these species, as the most prominent and readily recognizable form of biodiversity. Therefore, our approach may not be sufficient to fully capture all levels of biodiversity. To solve this issue, some authors (Onaindia et al. 2013, Peña et al. 2016) quantified different levels of biodiversity using variables such as plant richness, habitat quality and protection status. We used a simple method (in GIS) of overlaying maps of the hotspots with maps of forest stands (where forests older than 100 years were also included). Old-growth forests are sources of biodiversity and have a high ecological value (Spies and Franklin 1996; Brunet et al. 2010). Areas (forest stands) with a presence of relevant species were considered to be the areas of greatest interest in relation to nature conservation.

Hotspots and areas of interest should be one of the sources of suggested zonation. Most of the local hotspots should be included within zone A or zone B (see description of Fig. 1). Zone A represents category 1a (Strict Nature Reserve) according to the IUCN protected areas categories and zone B is category IV (Habitat/Species Management Area). Some hotspots occur outside these zones, e.g. *bryophyte Homalia trichomanoides* is an epiphyte of broadleaved trees. It often occurs in the woods in the residential areas of settlements, surviving on trees that are remnants of a former continuous forest.

In addition to forestry criteria regarding species composition, spatial and age structure, as well as the presence of indicator species should be incorporated into hotspots to determine suggested zonation. Odd, uneven-aged stands with high connectivity and the presence of hotspots should be included in zone A as it includes all the national nature reserves (Stužica, Havešová, Riaba skala, Rožok, Plaša, Stimák, Pod Ruským) in NP Poloniny. Compared to the current zonation (Fig. 2d), zone B is quite different. This zone should affect the degree to which a landscape is connected; influencing gene flow, local adaptation, extinction risk, colonization probability, and the potential for organisms to move as they cope with climate change. We think, zone B should be comprised of primarily old beech stands, but also beech stands influenced by clearcutting if situated close to zone A. We consider the successional stage of the forest ecosystem to be part of the virgin forest, as it originated through disturbance of the forest area and it is expected that it will be left to natural development. An important consequence of clearing by human activity is that continuous cover is broken down into isolated patches. If this activity continues, cleared areas may exceed a critical level, which means that landscapes will exhibit two phases; connected and disconnected. This is why we think that zone B should be extended and should link zone A together. Brunet et al. (2010), in a review of biodiversity in European beech forests, demonstrates that areas with predominant shelterwood management (in our study this is relevant for zone C and B) only have limited value for conservation of most species groups. Thus, the area of unmanaged reserves of beech forest needs to be larger. Zone C (IUCN category II - National Park), or the buffer zone, is intended to avert the effect of negative environmental or human influences. It links zones A and B, and increases their dynamics or conservation effects. Zone D (IUCN category V - Protected Landscape) consists of residential areas of settlements and cultural landscape. In principle, zonation models of protected sites in Europe are varied (Solár et al. 2015). Our zonation model is inspired by zoning in the National Park of Abruzzo, Italy (Singe 2004).
Biodiversity and hotspots in the primeval beech forest - Poloniny NP

Rare beech stands of this shared Slovakian-Polish-Ukrainian territory have become a subject of protection of World Heritage (Conference of Committee of the UNESCO World Heritage in New Zealand, Christchurch, June 28, 2007). However, at present, increasing economic pressure on timber harvest in beech forests are becoming obvious. Creation of world heritage boundaries has been considered with many small island enclaves, which assume that the phenomenon of fragmentation is adverse.

Acknowledgments

We thank Miroslav Buraľ, Zuzana Hrebová, Tomáš Vatycha and Natália Maximová for the help in the field data collection. The research was supported by project of Swiss Contribution and State Nature Conservancy of Slovakia (1551/2011) “Development of nature protection and protected areas in the Slovakian Carpathians”.

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Received 15 May 2017; accepted 16 September 2017.