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Pinus cembra communities in the Tatras – comments to the study of Zięba et al.

Zirbengesellschaften in der Tatra – Bemerkungen über die Studie von Zięba et al.

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Abstract

In Tuexenia, vol. 38, Zięba et al. published an extensive syntaxonomical study of Arolla pine (*Pinus cembra*) forests, based on 108 relevés from both Poland and Slovakia. The authors stated that only a few works have been dedicated to the Arolla pine forests of the Tatras, and that calcicolous communities have not been studied previously. However, only Polish authors were cited, and studies on Arolla pine forest communities from Slovakia were neglected. In total, 141 relevés of (mixed) Arolla pine communities were published between the years 1932–2016 from the Slovakian part of the Tatras. The present article briefly introduces the respective literature sources and refers to an alternative syntaxonomical synthesis of Arolla pine communities recently published: simultaneously, the relevés of Zięba et al. are reclassified. Missing literature sources are reflected in the use of the incorrect altitudinal value for the "theoretical tree line" (1,550 m a.s.l.) as well as in the controversial evaluation of documented Arolla pine stands as "relict forests", although traces of spontaneous secondary succession are detectable on most of the sites due to historical anthropogenic disturbances. The problematic issues are shortly discussed, based on available literature and documented field data.

Keywords: phytosociology, *Pinus cembra*, Slovakia, syntaxonomy, upper forest line, vegetation, Western Carpathians

1. Introduction

European Arolla pine (*Pinus cembra*) communities belong to a lesser-studied type of vegetation. The most probable reason is their location in the high-mountain altitudes, often on hardly-accessible sites, resulting in more difficult field research conditions compared to prevailing forest vegetation types. Therefore, all studies producing original phytosociological data on these special woodlands are truly welcome.

One of these welcomed works was recently published in Tuexenia by Zięba et al. (2018), who studied the syntaxonomy of *P. cembra* communities in the Tatras (Western Carpathians). While the amount of the field- as well as office-work needed for their publication was impressive, the study suffers considerably from an insufficient study of the literature published on the topic.

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The authors stated that only a few phytosociological studies on Arolla pine woodlands of the Tatras were published until the present time, among them PAWŁOWSKI et al. (1928), MYCZKOWSKI & LESIŃSKI (1974) and WOJTERSKA et al. (2004). They also presumed that calcicolous Arolla pine woodlands were not documented before their own study. However, all relevant studies published in the territory of Slovakia were neglected, beginning with DOSTÁL (1932) and ending with several papers published after 2010, including the lectotypification of the association described by Polish authors – *Cembro-Piceetum* Myczkowski & Lesiński 1974 (KUČERA 2010). Communities on carbonates were already documented by BARANČOK (2002) and KANKA (2008) (cf. KUČERA 2012).

One of the results preceding the planned monograph *Plant Communities of Slovakia. Forest and Shrub Vegetation* (Valachovič et al., in prep.) was a comprehensive syntaxonomical survey of Arolla pine phytocoenoses from the Tatras (KUČERA 2017). It included an evaluation of the Arolla pine relevés from almost all of the published articles and studies on the subject; some papers were published after that dataset was established, and I was not aware of the survey of WOJTERSKA et al. (2004) containing a synoptic table of the recorded relevés and one single relevé.

The aim of this paper is to present a survey of geobotanical studies published about *P. cembra* communities in Slovakia which were missing in the study of ZIĘBA et al. (2018). An updated syntaxonomical classification along with reclassification of the relevés of Zięba et al., considerations on the statements about the upper forest line and relict character of Arolla pine woodlands and methods used by the authors are also given.

2. Material and methods

The present syntaxonomical evaluation of the Arolla pine woodlands follows the study of KUČERA (2017). The recorded coordinates (WGS-84) were obtained with Magellan SporTrak Pro GPS unit (2004) and later a GPSMAP® 60CSx. Altitudinal elevations (Table 2) were revised according to the detailed maps available at Národný geoportál (http://geoportal.gov.sk/narodny-geoportal; accessed 2018-12-19). Nomenclature of the vascular plants, bryophytes and lichens follows the lists of KUBINSKÁ & JANOVICOVÁ (1998), MARHOLD et al. (1998) and GUTTOVÁ et al. (2013), respectively; otherwise the name is accompanied with author citation. Syntaxonomical nomenclatural rules are applied according to ICPN (WEBER et al. 2000).

3. Results and discussion

3.1 Literature with phytosociological data on Arolla pine communities from the Slovak part of the Tatras

The study of PAWŁOWSKI et al. (1928) from the Polish part of the High Tatras was the first to include a relevé of an Arolla pine woodland from the whole mountain range. Several years later, DOSTÁL (1932) published a paper on the Arolla pine distribution in the Západné Tatry Mts (cf. SVOBODA 1939) – the western part of the Tatras – accompanied by the first phytosociological relevé of an Arolla pine community from Slovakia.

Shortly thereafter, KRAJINA (1933a, b) published his famous geobotanical study on the vegetation of the valley Mlynická Dolina in the High Tatras. He recorded several relevés with Arolla pines; however, they mostly represented successional stages of the anthropogenically disturbed vegetation. Further studies were discontinued due to the serious economic situation of the state before World War II and following adverse political changes. Dostál's field studies in the Západné Tatry Mts were discontinued, and the author published only a short overview on forest vegetation types of the mountain range, following the syntaxonomical schemes of Sillinger, Krajina and Szafer et al. (DOSTÁL 1935).

The next relevés documenting Arolla pine communities were not published until SAMEK et al. (1957), who elaborated on forest communities in the northern part of the High Tatras. They were followed by ZLATNÍK (1970), who published data from the easternmost part of the Západné Tatry as well as from two other localities of the High Tatras. HORÁK (1971) studied vegetation of the upper forest line and upper krummholz line in the Západné Tatry. ŠOLTÉS (1976) also documented forest phytocoenoses with Arolla pine.

Two forest relevés with Arolla pine were published by ŠOMŠÁK et al. (1981) from the southern margin of the eastern part of the High Tatras. Under the lead of Prof. L. Šomšák and Dr. E. Majzlanová, a series of four Master's theses from the border region of the Západné Tatry and High Tatras was elaborated in the years 1985–1987 (Kobzáková, Naďová, Moravčíková, Rajcová). Only a minor part of the documented relevés of Arolla pine woodlands was immediately published, e.g. *Pinus cembra* phytocoenoses from the Krížna Dolina in the easternmost part of the Západné Tatry (VIDLIČKOVÁ 1989). The rest were included in the survey on the Norway spruce syntaxa of Slovakia (KUČERA 2012, p. 198–204).

KUBÍČEK et al. (1992) as well as VOLOŠČUK (1996) recorded, respectively, one relevé in the Furkotská Dolina (western part of the High Tatras); the latter within a series of specialized long-term forestry studies of the Tatras' forests (cf. KORPEĽ 1992, VOŠKO 1996, VOLOŠČUK 2012 etc.).

BARANČOK & VARŠAVOVÁ (1995) published a study of the Arolla pine woodlands in the Bielovodská Dolina in the northern part of the High Tatras, followed by a brief overview of Arolla pine communities studied by the author in the eastern part of the Tatras (BARANČOK 2002, with synoptic tables). KUKLA et al. (2002) also studied vegetation in the Bielovodská Dolina.

KANKA (2008) published a comprehensive study of the forests of the Belianske Tatry Mts., where he differentiated two community types determined or co-dominated by Arolla pine. KUČERA (2010) lectotypified forest communities of the Norway spruce dominated syntaxa, which were at the time commonly used in the Slovak Republic. Later KUČERA (2012) published a monograph on the distribution and communities of the Norway spruce altitudinal vegetation zone in the Western Carpathians, including a comprehensive syntaxonomical evaluation of Norway spruce as well as Arolla pine communities.

More recently, JASÍK et al. (2014) and JASÍK & DÍTĚ (2016) published relevés of special habitats where Arolla pine grows with *Linnaea borealis* – an extremely rare species in the Tatras and in all of Slovakia. VALACHOVIČ (2014) published relevés of the Arolla pine forest above the lake Popradské Pleso (Mengusovská Dolina, central part of the High Tatras) with brief comparison to previously published relevés.

The most recent work from Slovakia is a comprehensive syntaxonomical study of Arolla pine and mixed Arolla pine woodlands (KUČERA 2017, 2018). In total 143 phytosociological relevés were retrieved from or inserted to the Slovak phytosciological database (*Centrálna databáza fytocenologických zápisov*, http://ibot.sav.sk/cdf/index.html; HEGEDÜŠOVÁ 2007) (relevés of Jasík and coll. were not included in the database at the time) from the aforementioned Slovakian works, and six relevés from Poland published by PAWŁOWSKI et al. (1928) and MYCZKOWSKI & LESIŃSKI (1974) were added. Consequently, 110 relevés were selected for statistical evaluation. That syntaxonomical synthesis resulted in the differentiation of six Arolla pine communities classified in the following manner:

Piceetalia excelsae Pawłowski ex Pawłowski et al. 1928
Homogyno alpinae-Pinion cembrae P. Kučera 2017
1. *Homogyno alpinae-Pinetum cembrae* P. Kučera 2017
2. *Prenantho purpureae-Pinetum cembrae* P. Kučera 2017
3. *Mylio taylorii-Pinetum cembrae* P. Kučera 2017
4. *Cembro-Piceetum* Myczkowski et Lesiński 1974

Athyrio filicis-feminae-Piceetalia Hadač ex Hadač et al. 1969
Calamagrostio variae-Pinion cembrae P. Kučera 2017
5. *Seslerio tatrae-Pinetum cembrae* P. Kučera 2017
6. *Cystopterido montanae-Pinetum cembrae* P. Kučera 2017

3.2 Syntaxonomical notes on recently published relevés of Polish authors

In the frame of KUČERA's (2017) syntaxonomical scheme, where phytocoenoses from the Tatras and the Alps were considered phytogeographically independent units (Kučera in Valachovič et al., in prep.), the Arolla pine woodlands documented by WOJTERSKA et al. (2004) belong to the alliance *Homogyno alpinae-Pinion cembrae*. The authors classified *Pinus cembra* stands as *Larici-Pinetum cembrae* Ellenberg et Klötzli 1974, nom. cons. propos. (ut "*Larici-Pinetum cembrae* (Pallmann et Hafter 1933) Ellenberg 1963"; cf. KUČERA 2017) and described, albeit invalidly, a new subassociation *Larici-Pinetum cembrae sphagnetosum* WOJTERSKA et al. 2004, nom. inval. (ICPN Art. 3g, WEBER 2000). Their original relevé, presented as the nomenclatural type of the subassociation, clearly belongs to the association *Mylio taylori-Pinetum cembrae*.

The rest of the relevés (6) of this subassociation were not published, only a constancy table is available. However, species composition and frequencies indicate the affiliation of the most of the relevés with the association *Mylio taylori-Pinetum cembrae.*

Sixteen relevés classified by WOJTERSKA et al. (2004) as "*Larici-Pinetum cembrae vaccinietosum* Ellenberg 1963" are presented as constancy table. Beside *Mylio taylorii-Pinetum cembrae*, part of the relevés might be classified as either *Homogyno alpinae-Pinetum cembrae* or *Cembro-Piceetum*.

The reclassification of the relevés of ZIĘBA et al. (2018) is detailed in Table 1; major points are given in the following text:

The newly published association *Swertio perennis-Pinetum cembrae* Zięba et al. 2018 (ZIĘBA et al. 2018, relevé table Suppl. 3) is notable for a characteristic mixture of calciphytes and acidophilous species, thus belonging to the alliance *Calamagrostio variae-Pinion cembrae*. The association is a syntaxonomical synonym to *Cystopterido montanae-Pinetum cembrae*; however, slight floristical differences from the original relevés of the association (cf. KANKA 2008, KUČERA 2012, p. 237) justify the establishment of a new subassociation:

***Cystopterido montanae-Pinetum cembrae calamagrostietosum arundinaceae* (Zięba et al. 2018) P. Kučera stat. nov. hoc loco**

Basionym: *Swertio perennis-Pinetum cembrae* Zięba et al. 2018; ZIĘBA et al. (2018), p. 162.

The second phytosociological table of ZIĘBA et al. (2018, suppl. S2) presents phytocoenoses of the alliance *Homogyno alpinae-Pinion cembrae*, which according to the authors belong to the association *Larici-Pinetum cembrae* Ellenberg et Klötzli 1974, nom. cons. propos. (ut "*Vaccinio-Pinetum cembrae* (Pallmann et Hafter 1933) Oberdorfer 1962", nom. inval.; cf. KUČERA 2017).

Table 1. Classification of the relevés of ZIĘBA et al. (2018) within the syntaxonomical scheme of KUČERA (2017).

Tabelle 1. Klassifikation der Vegetationsaufnahmen von ZIĘBA et al. (2018) innerhalb des syntaxonomischen Schemas von KUČERA (2017).

ZIĘBA et al. (2018)	Relevé Nr.	KUČERA (2017)	Comments to classification
Swertio perennis-Pinetum cembrae	–	*Cystopterido montanae-Pinetum cembrae*	Total absence of *Calamagrostis varia,* low presence of *Sesleria tatrae*, absence of *Bartsia alpina*, *Hedysarum hedysaroides*, *Androsace chamaejasme*
Swertio perennis-Pinetum cembrae var. *Valeriana tripteris*	all relevés	*Cystopterido montanae-Pinetum cembrae calamagrostietosum arundinaceae* (ZIĘBA et al. 2018) P. Kučera stat. nov.	Dominance of *Calamagrostis arundinacea*; high frequency of *Swertia perennis*, *Adenostyles alliariae*, *Veratrum album* ssp. *lobelianum* etc.; sporadical occurrence of *Cystopteris montana* (only 1 relevé)
Swertio perennis-Pinetum cembrae var. *Carex sempervirens*	32	*Seslerio tatrae-Pinetum cembrae*	–
Swertio perennis-Pinetum cembrae var. *Carex sempervirens*	50, 7, 4	non applicable	More or less non-forest vegetation with woody species: with canopy cover 30%, 10% and 30% respectively, with *Picea abies* and *Pinus mugo* (dominating) in the shrub layer
Vaccinio-Pinetum cembrae typicum var. *Larix decidua*	52	?	Transitional between the alliances *Calamagrostio-Pinion cembrae* (occurrence of *Sesleria varia*) and *Homogyno-Pinion cembrae* (*Cembro-Piceetum*: conjoint occurrence of *Empetrum hermaphroditum* and *Vaccinium gaultherioides*)
Vaccinio-Pinetum cembrae typicum var. *Larix decidua*	27	[cf. *Homogyno alpinae-Pinetum cembrae*]	Resembles *Prenantho-Pinetum cembrae*; however, characteristic species as *Cicerbita alpina*, *Ranunculus platanifolius* and *Doronicum austriacum* are missing.
Vaccinio-Pinetum cembrae typicum var. *Larix decidua*	remaining relevés of the unit	*Homogyno alpinae-Pinetum cembrae*	–
Vaccinio-Pinetum cembrae typicum var. *Cladonia* spp.	–	–	Differences in frequency of lichens, especially *Cetraria islandica* and *Cladonia macroceras* (cf. ZIĘBA et al. 2018, p. 161–162) in comparison to "var. *Larix decidua*" are considered insignificant.
Vaccinio-Pinetum cembrae typicum var. *Cladonia* spp.: A) with conjoint occurrence of *Lophozia ventricosa* and *Mylia taylori* B) *M. taylori* and *Cladonia coccifera* C) with *M. taylori*, *Cladonia rangiferia* and/or *Calypogeia azurea*	A: 92, 21; B: 77, 47; C: 94, 40, 25	[cf. *Homogyno alpinae-Pinetum cembrae*]	Relevés lack most of the characteristic ground layer species of *Mylio-Pinetum cembrae*, therefore such classification is disputable.

ZIĘBA et al. (2018)	Relevé Nr.	KUČERA (2017)	Comments to classification
Vaccinio-Pinetum cembrae typicum var. *Cladonia* spp., remaining relevés with *Mylia taylori*	41, 106, 45, 29, 38, 37	*Homogyno alpinae-Pinetum cembrae*	*C. pleurota*, *C. squamosa* and *C. sulphurina* occur also in *Homogyno-Pinetum cembrae* and *Cladonia digitata* is not exclusive for a specific association (KUČERA 2017). The other *Cladonia* species occur similarly in both variants (*Larix* and *Cladonia* spp.) of ZIĘBA et al. (2018, suppl. S2) without a clear preference.
Vaccinio-Pinetum cembrae typicum var. *Cladonia* spp.	remaining relevés of the unit	*Homogyno alpinae-Pinetum cembrae*	–
Vaccinio-Pinetum cembrae typicum var. *Gymnocarpium dryopteris*	96	[cf. *Homogyno alpinae-Pinetum cembrae*]	Similar to *Prenantho purpureae-Pinetum cembrae*.
Vaccinio-Pinetum cembrae typicum var. *Gymnocarpium dryopteris*	remaining relevés of the unit	*Homogyno alpinae-Pinetum cembrae*	Without floristical difference from *Homogyno alpinae-Pinetum cembrae*.
Vaccinio-Pinetum cembrae juncetosum trifidi	83	*Prenantho purpureae-Pinetum cembrae*	–
Vaccinio-Pinetum cembrae juncetosum trifidi	remaining relevés of the unit	*Homogyno alpinae-Pinetum cembrae juncetosum trifidi*	–

The most disputable unit is the newly described subassociation "*Vaccinio-Pinetum cembrae juncetosum trifidi*". Most of the relevés (cf. Table 1) with the occurrence of *Juncus trifidus*, *Calluna vulgaris* and *Festuca supina* are records of sites influenced to a lesser or greater extent by historical deforestation; relevé 100 is a record of a plot with an advanced stage of secondary succession of *Pinus mugo*. The relevés do not represent natural, non-anthropogenic vegetation. A supposed co-occurrence of "alpine, subalpine and tundra species" in this subassociation was explained as a result of a high altitude causing the formation of open stands and the retreat of *Picea* forest related species (ZIĘBA et al. 2018, p. 162, 165). This is, in the recorded plots, a characteristic attribute of the vegetation succession developing on the territory of the formerly (mostly) deforested areas (pastures) in variable stages of secondary succession, currently with remnants of their former species composition. This is true also for relevés 82 and 86 with considerably high altitudes (1,650 and 1690 m a.s.l., respectively).

Degraded communities with *Pinus cembra* (secondary forest succession) in the Tatras have been recorded already by KRAJINA (1933a) and HORÁK (1971) and more recently by ŠOLTÉS et al. (2006). The apophytic occurrence of the species *Nardus stricta*, *Potentilla aurea*, *Calluna vulgaris* (wider elevation range), *Juncus trifidus*, *Pulsatilla scherfelii*, etc. (mostly alpine zone) as well as *Pinus mugo* and *Juniperus sibirica* (commonly subalpine zone; the last-mentioned species is on former pastures of lower altitudes, i.e. below the subalpine zone, very often completely replaced by *Juniperus* ×*intermedia* Schur) usually indicate such degraded habitats, which were also documented by ZIĘBA et al. (2018). The last residua of their populations (cf. Table 2) could survive several decades on sites of former pastures and pastural open forests (Fig. 1–3, see comparison of recent and historical

Fig. 1. Withering *Pinus mugo* in secondary *Larix-Picea* forest, formerly the upper limit of pastural open forest with scattered krummholz, with mountain pastures above (Photo: P. Kučera, 21.07.2018).

Abb. 1. Absterbende *Pinus mugo* in sekundärem *Larix-Picea*-Wald, ehemals die obere Grenze von offenem Weidewald mit verstreutem Krummholz, mit darüber liegenden Bergweiden (Foto: P. Kučera, 21.07.2018).

Fig. 2. Secondary succession of forest on formerly completely deforested pastures, now with the last remnants of *Juncus trifidus*, *Pulsatilla scherfelii*, etc. preserved only along the hiking trail (Photo: P. Kučera, 21.07.2018).

Abb. 2. Sekundäre Waldsukzession auf zuvor komplett entwaldeten Weiden, nun mit letzten Überresten von *Juncus trifidus*, *Pulsatilla scherfelii* etc. entlang des Wanderweges (Foto: P. Kučera, 21.07.2018).

Fig. 3. Former pastures, afforested with *Pinus mugo* after 1950, now with fast-growing young trees. Originally high-altitude mixed *Picea abies* forest (Photo: P. Kučera, 21.07.2018).

Abb. 3. Ehemalige Weiden, nach 1950 mit *Pinus mugo* aufgeforstet, nun mit schnell wachsenden Jungbäumen. Ursprünglich gemischter *Picea abies*-Wald der Hochlagen (Foto: P. Kučera, 21.07.2018).

orthophoto maps at *Historická ortofotomapa Slovenska* (http://mapy.tuzvo.sk/HOFM/; accessed 2018-12-07) which extended to elevations far below the natural upper vertical line of the former climax closed forest (mixed forest dominated by *Picea abies* expected for the period 1950–1980 (cf. PLESNÍK 1956, 1971, JAMNICKÝ 1981a) above 1,650 m a.s.l.; original mixed woodlands of *Pinus cembra* vertically above this line) or closed subalpine *P. mugo* krummholz (likewise expected above 1,960 m a.s.l.). Establishment of a mature forest (or, in higher elevations, *Pinus mugo* krummholz) is characterised by the vanishing of such apophytic occurrences of the species mentioned.

Despite the questionable geobotanical evaluation of the subassociation *juncetosum trifidi*, the syntaxonomical position of this unit should be corrected in respect to phytogeographical differences between Arolla pine syntaxa of the Alps and the Tatras:

***Homogyno alpinae-Pinetum cembrae juncetosum trifidi* (Zięba et al. 2018) P. Kučera, comb. nov. hoc loco**

Basionym: *Vaccinio-Pinetum cembrae juncetosum trifidi* Zięba et al. 2018; ZIĘBA et al. (2018), p. 162.

Table 2. Lowest anthropogenic occurrences (coordinate accuracy ± 3–10 m) of species typical for alpine communities on the SW ridge of Baranec Mt. (2,184 m a.s.l., Západné Tatry Mts), which was extensively deforested before 1950.

Tabelle 2. Niedrigste anthropogene Vorkommen (Koordinatengenauigkeit ± 3–10 m) von typischen Arten alpiner Gesellschaften auf dem SW-Kamm des Baranec (2.184 m a.s.l., Westliche Tatra), der vor 1950 weithin entwaldet war.

	Surroundings	Latitude (N)	Longitude (E)	Elevation (m a.s.l.)	Year of observation
Nardus stricta, *Poa chaixii*[*1]	secondary *Picea abies*–*Larix decidua* forest	49°8,996'	19°43,379'	1,463	2018
withering *Pinus mugo* groups[*2] (cf. PLESNÍK 1956, Fig. 4)	secondary *Picea abies*–*Larix decidua* forest (Fig. 1), with the last remnants of former pastures (*Hypericum maculatum*, *Crocus discolor*)	49°9,007' – 49°8,980'	19°43,390' – 19°43,414'	c. 1,470	2004, 2018, 2019
Juniperus ×intermedia	secondary *Larix decidua*–*Picea abies* forest, with the pastures' remants (*Potentilla aurea*, *Hypericum maculatum*)	49°9,014'	19°43,429'	1,490	2004, 2018
Pulsatilla scherfelii	open postpastural *Larix decidua*–*Picea abies* forest (*Trommsdorffia uniflora*, *Achillea millefolium*), with scattered shrubs of *Pinus mugo* and *Juniperus ×intermedia*	49°9,025'	19°43,495'	1,517	2018, 2019
larger remnant of high-mountain pastures (completely deforested before 1950)	secondary *Larix decidua*–*Picea abies* forest, afforestation	49°9,022'	19°43,545'	1,535	2018
Gentiana punctata, *Pulsatilla scherfelii*, *Vaccinium gaultherioides*, *Juncus trifidus*, *Campanula tatrae*	remnants of the former pastures, afforested by *P. mugo*, progressively overshadowed by *L. decidua*, *P. abies*, trees here and there already dominate (Fig. 2)	49°9,044'	19°43,615'	1,564	2007, 2013 2018
dominating *P. mugo* stands on former pastures, trees only scattered	afforestations, here and there remnants of pastures (Fig. 3), trees young and fast growing	49°9,049'	19°43,649'	1,574	2018

[*1] *Poa chaixii* already lower at 1,447 m a.s.l. (N 49°9,000', E 19°43,343'; 2019).

[*2] The lowest growing living *Pinus mugo* shrub at 1,405 m a.s.l. (N 49°8,982', E 19°43,231'; 2019).

3.3 The upper forest line in the Tatras

ZIĘBA et al. (2018, p. 165) stated that the (theoretical) timberline in the Tatras reached 1,550 m a.s.l. This conventional altitudinal value (FUTÁK 1956, PAWŁOWSKI 1956, FABIJANOWSKI 1962, MEDWECKA-KORNAŚ 1972, ŠOLTÉSOVÁ 1994, VOLOŠČUK et al. 2008, FLEISCHER & CHMIEL 2010, ŠOLTÉSOVÁ et al. 2010, ŠVAJDA et al. 2011; cf. KOTULA 1890, FEKETE & BLATTNY 1913–1914, PAWŁOWSKI 1928, SOKOŁOWSKI 1928, DOMIN 1931), in fact related to an upper forest line, is outdated (PLESNÍK 1956, 1959; cf. CZAJKA et al. 2015, KACZKA et al. 2015, KAŠPAR & TREML 2016). It is based on data of mostly anthropogenic upper forest lines where the original mixed *Pinus cembra* woodlands and also *P. mugo* stands were largely destroyed to obtain high mountain pastures ("hole" in Slovak, "Almen" in German) and to harvest timber (cf. HOŁUB-PACEWICZOWA 1931, DOSTÁL 1932, SVOBODA 1936, 1939, 1940, HÄUFLER 1955, FABIJANOWSKI 1962, JAMNICKÝ 1964, 1981a, CHOLVADT 1965, HARVAN 1965, PLESNÍK 1956, 1971, 1978a, PODOLÁK 1967, HORÁK 1971, BOHUŠ 1994, MIDRIAK 1994, KUČERA 2012).

However, there are several documented relevés of *Picea abies* stands (without *Pinus cembra*) in the Tatras between altitudes 1,550–1,600 m a.s.l. (cf. KUČERA 2012). PLESNÍK (1956) recorded 17–18 metres high Norway spruce trees within a forest at 1,590 m a.s.l. Interesting results about the patterns of the upper forest line were also presented by SOMORA (1969). Moreover, PLESNÍK (1971) had already identified the uppermost section of the forest line (Arolla Pine and Norway spruce) at an altitude of 1,715 m a.s.l., and an exclave of *P. cembra* stand (with admixed *Picea abies*) at 1,732 m a.s.l. The author also referred to a closed *P. abies* forest above 1,600 m a.s.l., with the uppermost part at 1,670 m a.s.l. It should be noted that the last-mentioned locality is on the slope where the original Arolla pine stands were completely destroyed; therefore, the original upper forest line was evidently higher. MIDRIAK (1994) summarizes the results of previous studies in the following manner [translation from Slovak by P. Kučera]:

"The natural upper forest line formed by Norway spruce (where this woody species composes 90–95%) should be put within the High Tatras with regard to the individual differently exposed parts of the mountain range at approximately 1,550–1,700 (mostly 1,625–1,685) m a.s.l., within the Belianske Tatry as high as 1,600–1,740 m a.s.l. (on average approximately 1,625 m a.s.l.). In the Západné Tatry is the average elevation of the thermic upper forest line approximately 1,640 m a.s.l."

Furthermore, *P. abies* trees could grow to the same height as *Pinus cembra* in the Tatras even at the altitude 1,721 m a.s.l. Secondary succession of Arolla pine woodlands occurs on formerly deforested areas even above 1,750 m a.s.l. (KUČERA 2012, cf. also *Historická ortofotomapa Slovenska*). It seems that the upper forest line of the Arolla pine woodlands constructed for the period 1900–1980 would extend above 1,800 m a.s.l. on slopes with favourable habitat conditions, i.e. higher than expected by PLESNÍK (1971), who supposed Norway spruce-Arolla pine forests to extend vertically only 30–40 m higher than the thermic upper forest line for the closed Norway spruce forests (on favourable habitats) lying at ± 1,700 m a.s.l.

In these relations, the words of BRAUN-BLANQUET (1930, p. 122) who generalized the patterns of the upper forest line are noticeable: "Der Arven-Lärchenhorizont am oberen Rande des Fichtenwaldes verläuft auf der Südseite der Hohen Tatra bei (1,600) 1,650–1,800 m…". It should be stressed that this farsighted evaluation was presented in the time when only remnants of the original mixed Arolla pine forests existed, before the cessation of high mountain grazing and the prohibition of timber harvesting. Therefore, the above-mentioned conventional value of 1,550 m a.s.l for the theoretical upper forest line of the Tatras should be carefully reconsidered.

The same value for the average upper forest line (with maxima up to 1,570 and 1,600 m a.s.l) has been reported in the past for a considerably lower separate mountain range of the Low Tatras (in Slovak "Nízke Tatry", the highest summit 2,042 m a.s.l.; SILLINGER 1933), with a landscape likewise strongly affected by historical deforestation. In the Veľká Fatra Mts, with the highest summit reaching only 1,596 m, there are Norway spruce forests covering Smrekovica Mt. (1,530 m a.s.l.) (PLESNÍK 1978b, KUČERA 2012), and they were growing there, albeit affected by grazing and partial deforestation, before the year 1950 (*Historická ortofotomapa Slovenska*). Recovery of Norway spruce stands could be observed on formerly deforested areas even above 1,550 m a.s.l. (KUČERA 2012). These data do not support the traditionally cited value of 1,550 m a.s.l. for the "theoretical upper forest line" in the Tatras as the highest mountain range of the whole Carpathians.

3.4 The relict character of Arolla pine stands in the Tatras

In the view of a serious devastation of the uppermost forest zone in the Tatras (HOŁUB-PACEWICZOWA 1931, DOSTÁL 1932, SVOBODA 1936, 1939, 1940, PLESNÍK 1956, 1971, 1978a, FABIJANOWSKI 1962, HARVAN 1965, HORÁK 1971, KRAJČOVIČ 1975, JURČO 2019) the designation of many *Pinus cembra* phytocoenoses as "relict" by ZIĘBA et al. (2018) is disputable. In the past, Arolla pine trees were cut even on hardly accessible localities using a special harvesting technique (JAMNICKÝ 1964); therefore, woodlands of these sites were disturbed as well, at least in Slovakia.

It is obvious that the Arolla pine distribution at the beginning of the 20th century mostly represented remnants of the species' original distribution area in the Tatras. However, a substantial part of the current Arolla pine stands are not old-growth forests but rather the result of secondary succession of (usually) *P. mugo*, followed by *P. cembra* and finally *Picea abies*, growing on the anthropogenically disturbed plots where scattered old *Pinus cembra* trees already grew. This development could be determined by comparison of the current orthophoto maps with the historical ones from 1949 (*Historická ortofotomapa Slovenska*, cf. ŠVAJDA et al. 2011, KACZKA et al. 2015). They show a transformation of the previously more open communities (with isolated/scattered Arolla pine trees and with or without dwarf mountain pine) to either closed woodlands or temporary krummholz-forest succession stages; their current state differs considerably from the past. Therefore even if some of the Arolla pine trees at a particular site were of an old age, they might not indicate an old-growth/virgin forest.

In the Slovakian part of the Tatras, the gradual spontaneous recovery of forests and krummholz was supported by the prohibition (in the former territory of the Slovakian Tatra National Park, after 1950) as well as the spontaneous cessation of grazing (KRAJINA 1933b, SVOBODA 1940, PLESNÍK 1959, HARVAN 1965, BOHUŠ 1994), followed by undisturbed secondary succession (cf. JAMNICKÝ 1981a, VOLOŠČUK 1996, ŠVAJDA et al. 2011). Moreover, extensive programs of afforestation and artificial reconstruction of the upper forest line and krummholz as well as of the lower lying forests were initiated (KUBASÁK 1954, CHOLVADT 1965, KRAJČOVIČ 1969, 1996, SOMORA & HUMLOVÁ 1971, SOMORA 1976, 1977, STRNKA & MATUSKÝ 1979, JAMNICKÝ 1981a, BARANČOK & VARŠAVOVÁ 1998, JURČO 2019).

Arolla pine (both autochthonous stock and originating from the Alps) as well as *Pinus sibirica* Du Tour (!) were planted in the Tatras already during the second half of the 19th century and also in the first half of the 20th century (SOMORA 1954, SOMORA & HUMLOVÁ 1971, JAMNICKÝ 1981b). The above-mentioned historical orthophoto map therefore records such planted specimens as already-grown trees.

The observed vegetation changes mean that the old Arolla pine trees recorded in the *Historická ortofotomapa Slovenska* were mostly either the actual *remnants* of the original woodlands or were the results of an old spontaneous secondary succession, in both cases on sites with anthropogenic disturbances (cf. KRAJINA 1933a, VOLOŠČUK 1996, WEISBERG et al. 2013). In this argumentation I have deliberately disregarded the effects of the climate change cited by some authors (ŠVAJDA et al. 2011, KACZKA et al. 2015), because research on the distribution of relict Arolla pine woodlands should be based on the investigation of forest stands found stable in the 1949–2010's period without anthropogenic-driven floristic and structural changes, possibly accentuated in the time span of the recent shift of the substantial vegetation-related climate variables in Slovakian mountain ranges, i.e. 1988 – present (LAPIN et al. 2005, FAŠKO et al. 2008, MELO et al. 2013).

The effects of climate change on (mixed) Arolla pine woodlands in the Tatras (as well as mixed Norway spruce woodlands and dwarf mountain pine krummholz) can be properly evaluated by specific studies on the upper forest line and the upper krummholz line constructed for the period 1950–1980 (cf. FAŠKO et al. 2008) and based on more accurate field data from the Western Carpathians (PLESNÍK 1956, 1971, JAMNICKÝ 1981a etc., see above, cf. KUČERA 2012). In my opinion, and by evidence of the documented historical anthropogenic disturbances and afforestations in the 19th and 20th century, very careful consideration should be given before an Arolla pine woodland in the Tatras would be labelled as a "relict stand".

Erweiterte deutsche Zusammenfassung

Einführung – Die Studie von ZIĘBA et al. (2018), veröffentlicht in Tuexenia 38, gehört zu den wichtigsten syntaxonomischen und chorologischen Arbeiten über Zirbenwälder in der Tatra (Westkarpaten). Die Autoren bezeichnen die studierten Waldgesellschaften als Reliktwälder und behaupten, dass Zirbenwaldgesellschaften auf Karbonatgesteinen bisher aus der Tatra nicht beschrieben worden waren.

ZIĘBA et al. (2018) haben jedoch nur polnische Studien angeführt und relevante Arbeiten aus der Slowakei bzw. ehemaligen Tschechoslowakei unberücksichtigt gelassen, beginnend mit DOSTÁL (1932) und endend mit verschiedenen nach 2010 veröffentlichten Artikeln, einschließlich der Lektotypisierung der von polnischen Autoren beschriebenen Assoziation *Cembro-Piceetum* Myczkowski & Lesiński 1974 und anderen Einheiten (KUČERA 2010). Zirbengesellschaften der Tatra auf Karbonatgestein wurden bereits von BARANČOK (2002) und KANKA (2008) dokumentiert. Fehlende Literaturquellen spiegelten sich auch in der Verwendung der inkorrekten Angabe für die „theoretische Baumgrenze" (1.550 m ü. NHN) sowie in der kontroversen Bewertung der dokumentierten Zirbenbestände als „Reliktwälder" wider.

Das Ziel dieses Artikels ist, einen Überblick der geobotanischen Studien über *Pinus cembra*-Gesellschaften der Tatra zu präsentieren, die in der Slowakei bzw. in der ehemaligen Tschechoslowakei veröffentlicht wurden und die in der Studie von ZIĘBA et al. (2018) nicht berücksichtigt wurden. Zudem werden Hinweise zur syntaxonomischen Klassifizierung, zur oberen Waldgrenze und zum Reliktcharakter der Zirbenwälder gegeben.

Ergebnisse und Diskussion – Literatur mit pflanzensoziologischen Angaben von Zirbengesellschaften aus dem slowakischen Teil der Tatra – PAWŁOWSKI et al. (1928) waren die Ersten, die eine Aufnahme eines Zirbenwaldes aus der Tatra publizierten (polnischer Teil der Hohen Tatra). Kurz darauf charakterisierte DOSTÁL (1932) die Verbreitung der Zirbe im Westtatra-Massiv (vgl. SVOBODA 1939) und lieferte die erste pflanzensoziologische Aufnahme eines Zirbenwaldes aus der Slowakei. KRAJINA (1933a, b) veröffentlichte seine berühmte geobotanische Studie über das Mlynica-Tal in der Hohen Tatra. Seine Aufnahmen mit Zirbe repräsentieren jedoch meistens Sukzessionsstadien der anthropogen gestörten Vegetation.

Die nächsten Studien mit Aufnahmen von Zirbengesellschaften aus der Slowakei folgten erst einige Jahrzehnte später: SAMEK et al. (1957), ZLATNÍK (1970), HORÁK (1971), ŠOLTÉS (1976), ŠOMŠÁK et al. (1981). Unter der Leitung von Prof. L. Šomšák und Dr. E. Majzlanová wurden später (1987) vier Diplomarbeiten aus dem Grenzgebiet der Westtatra und der Hohen Tatra (Kobzáková, Naďová, Moravčíková, Rajcová) erarbeitet. Die dokumentierten Aufnahmen der Zirbenwälder wurden mit Ausnahme einiger Phytozönosen aus dem Krížna-Tal in der Westtatra (VIDLIČKOVÁ 1989) nicht veröffentlicht. Der Rest wurde in die Vegetationstabellen von KUČERA (2012) hineingenommen.

Die nächsten Aufnahmen sammelten KUBÍČEK et al. (1992), VOLOŠČUK (1996) und KUKLA et al. (2002). BARANČOK & VARŠAVOVÁ (1995) veröffentlichten eine Studie über die Zirbenwälder im Bielovodska-Tal in der Hohen Tatra, gefolgt von einem kurzem Überblick über die untersuchten Zirbengesellschaften im östlichen Teil der Tatra (BARANČOK 2002, nur Übersichtstabellen). KANKA (2008) erarbeitete eine umfassende Studie über die Wälder der Belauer Tatra, in der er zwei Typen von Zirbenwaldgesellschaften unterschied. KUČERA (2012) veröffentlichte eine Monografie über die Waldgesellschaften der Fichtenwaldzone der Westkarpaten und deren Verbreitung, einschließlich einer syntaxonomischen Bewertung der Fichten- und Zirbengesellschaften.

Die neuesten Arbeiten mit Zirbenvegetationsaufnahmen aus der Slowakei wurden von VALACHOVIČ (2014), JASÍK et al. (2014) und JASÍK & DÍTĚ (2016) publiziert. In den zwei letzten Artikeln sind Aufnahmen mit der in der Tatra extrem seltenen Pflanzenart *Linnaea borealis* einbezogen.

In den erwähnten Arbeiten wurden insgesamt 141 Aufnahmen (gemischter) Zirbenwaldgesellschaften aus dem slowakischen Teil der Tatra veröffentlicht. Die meisten von ihnen bildeten die Basis einer Synthese der Zirbenwaldgesellschaften der Tatra (KUČERA 2017, 2018). Diese Bearbeitung führte zur Differenzierung von sechs Assoziationen, die in folgender Weise klassifiziert wurden: *Homogyno alpinae-Pinetum cembrae* P. Kučera 2017, *Prenantho purpureae-Pinetum cembrae* P. Kučera 2017, *Mylio taylorii-Pinetum cembrae* P. Kučera 2017, *Cembro-Piceetum* Myczkowski et Lesiński 1974 (*Homogyno alpinae-Pinion cembrae* P. Kučera 2017, *Piceetalia excelsae* Pawłowski ex Pawłowski et al. 1928); *Seslerio tatrae-Pinetum cembrae* P. Kučera 2017, *Cystopterido montanae-Pinetum cembrae* P. Kučera 2017 (*Calamagrostio variae-Pinion cembrae* P. Kučera 2017, *Athyrio filicis-feminae-Piceetalia* Hadač ex Hadač et al. 1969).

Syntaxonomische Anmerkungen zu den Vegetationsaufnahmen von polnischen Autoren – Gemäß der Synopsis von KUČERA (2017) sind die Aufnahmen von WOJTERSKA et al. (2004) und ZIĘBA et al. (2018) auf folgende Weise zu bewerten:

Die einzige eigenständige Aufnahme von WOJTERSKA et al. (2004) gehört zum *Mylio taylorii-Pintum cembrae*. Der Rest der Aufnahmen, die in eine synthetische Tabelle einbezogen sind, könnten entweder als *Homogyno alpinae-Pinetum cembrae* oder sogar als *Cembro-Piceetum* klassifiziert werden.

Die Assoziation *Swertio perennis-Pinetum cembrae* Zięba et al. 2018 (ZIĘBA et al. 2018, Suppl. 3) ist ein syntaxonomisches Synonym vom *Cystopterido montanae-Pinetum cembrae*. Die *Carex sempervirens*-Variante enthält drei Aufnahmen von Nichtwaldvegetation mit einzelnen Zirbenbäumen, die verbleibende Aufnahme (Nr. 32) repräsentiert die Assoziation *Seslerio tatrae-Pinetum cembrae*.

Die zweite Vegetationstabelle von ZIĘBA et al. 2018 (Suppl. 2) enthält Phytozönosen des Verbandes *Homogyo alpinae-Pinion cembrae*. Die Mehrheit der Aufnahmen von *Larix decidua*-, *Cladonia* spp.- und *Gymnocarpium dryopteris*-Varianten des „*Vaccinio-Pinetum cembrae typicum*" gehören zur Assoziation *Homogyno alpinae-Pinetum cembrae*, die der häufigste Typ von Zirben- und gemischten Zirbenwäldern der Tatra darstellt. Die restlichen Aufnahmen zeigen eine Tendenz zu anderen Assoziationen des Verbandes oder sind spezielle Grenzfälle (Nr. 52, 27, 92, 21, 77, 47, 94, 40, 25, 96).

Die diskutabelste ist die von ZIĘBA et al. (2018) neu beschriebene Subassoziation „*Vaccinio-Pinetum cembrae juncetosum trifidi*“ [= *Homogyno alpinae-Pinetum cembrae juncetosum trifidi* (Zięba et al. 2018) P. Kučera, comb. nov.]. Während die floristisch unterschiedliche Aufnahme Nr. 83 ein *Prenantho purpureae-Pinetum cembrae* darstellt, sind die übrigen – mit Vorkommen von *Juncus trifidus*, *Calluna vulgaris* und *Festuca supina* –Aufnahmen von Standorten, die mehr oder weniger von historischer Entwaldung beeinflusst sind. Mit einer durchschnittlichen Höhe von 1.564 m ü. M. repräsentieren sie nicht die ursprünglichen Pflanzengesellschaften der höchstgelegenen Wälder der Tatra, sondern sind Degradationsstadien mit langzeitiger sekundärer Sukzession auf Standorten unterhalb der ursprünglichen oberen Waldgrenze.

Die obere Waldgrenze der Tatra – Die Höhenangabe zur Waldgrenze in der Tatra von 1.550 m ü. NHN, wie bei ZIĘBA et al. (2018) als „theoretische Waldgrenze“ (oberhalb der Fichtenwaldzone) angegeben, ist ein konventioneller Wert (FUTÁK 1956, PAWŁOWSKI 1956, ŠOLTÉSOVÁ 1994, FLEISCHER & CHMIEL 2010, ŠOLTÉSOVÁ et al. 2010; cf. KOTULA 1890, FEKETE & BLATTNY 1913–1914, SOKOŁOWSKI 1928), der als überholt gelten muss (PLESNÍK 1956, 1959 u. a.). Sie basiert auf Daten einer meistens anthropogenen oberen Waldgrenze, wo die ursprünglichen gemischten *Pinus cembra*-Wälder und größtenteils auch die *P. mugo*-Bestände stark zerstört worden waren, um Holz zu ernten und Hochgebirgsweiden zu gewinnen (vgl. HOŁUB-PACEWICZOWA 1931, SVOBODA 1939, 1940, FABIJANOWSKI 1962, HARVAN 1965, PLESNÍK 1971, KUČERA 2012 u. a.).

Bereits PLESNÍK (1956) verzeichnete 17–18 m hohe Fichten in einem Wald bei 1.590 m ü. NHN PLESNÍK (1971) identifizierte den obersten Abschnitt der Waldgrenze (mit Zirben und Fichten) in einer Höhe von 1.715 m ü. NHN und eine *Pinus cembra*- Exklave (mit beigemischter *Picea abies*) bei 1.732 m ü. NHN. Der Autor wies auch auf einen geschlossenen Wald von *P. abies* über 1.600 m ü. NHN. mit dem obersten Teil bei 1.670 m ü. NHN hin. Fichten könnten in der Tatra sogar auf einer Höhe von 1.721 m ü. NHN auf gleicher Höhe wachsen wie Zirben. Orthofotokarten zeigen, dass sich Sekundärsukzession von Zirbenwäldern auf ehemals entwaldeten Standorten sogar oberhalb von 1.750 m ü. NHN findet (KUČERA 2012, vgl. auch *Historická ortofotomapa Slovenska* (http://mapy.tuzvo.sk/HOFM/; accessed 2018-12-07).

Es scheint, dass sich die obere Waldgrenze (die für den Zeitraum von 1900–1980 konstruiert wurde) an Hängen mit günstigen Lebensraumbedingungen über 1.800 m ü. NHN erstrecken würde, das heißt höher als von PLESNÍK (1971) erwartet, der vermutete, dass sich die Fichten-Zirbenwälder vertikal nur 30–40 m oberhalb der thermischen oberen Grenze (± 1.700 m ü. NHN) der geschlossenen Fichtenwälder erstrecken würden. In diesen Zusammenhängen sind die Worte von BRAUN-BLANQUET (1930) beachtenswert, der den potenziellen (!) Verlauf der oberen Waldgrenze folgendermaßen verallgemeinerte: „Der Arven-Lärchenhorizont am oberen Rande des Fichtenwaldes verläuft auf der Südseite der Hohen Tatra bei (1.600) 1.650–1.800 m…“.

Der Reliktcharakter der Zirbenwaldbeständen in der Tatra – Im Hinblick auf eine beträchtliche Waldverwüstung der obersten Waldzone in der Tatra (HOŁUB-PACEWICZOWA 1931, DOSTÁL 1932, SVOBODA 1939, 1940, PLESNÍK 1978a, FABIJANOWSKI 1962, HARVAN 1965, HORÁK 1971) ist die von ZIĘBA et al. (2018) angegebene Kennzeichnung der meisten Zirbenphytozönosen als „Reliktwälder“ umstritten.

Die meisten heutigen Bestände mit Zirben sind keine Primärwälder, sondern das Ergebnis einer langzeitigen Sekundärsukzession auf anthropogen gestörten Standorten. Diese Entwicklung lässt sich aus dem Vergleich der aktuellen mit historischen Orthofotokarten ablesen (*Historická ortofotomapa Slovenska*). Zirbenbäume wurden mit einer speziellen Erntetechnik auch an schwer zugänglichen Stellen geschlagen (JAMNICKÝ 1964).

Die Zirbe (autochthone und aus den Alpen stammende) sowie *Pinus sibirica* wurden in der Tatra bereits in der zweiten Hälfte des 19. und in der ersten Hälfte des 20. Jhd. gepflanzt (SOMORA 1954, SOMORA & HUMLOVÁ 1971, JAMNICKÝ 1981b). Umfangreiche Aufforstungsprogramme und künstliche Rekonstruktionen der oberen Waldgrenze und des Krummholzes sowie der tiefer liegenden Wälder wurden initiiert (KRAJČOVIČ 1969, SOMORA & HUMLOVÁ 1971, SOMORA 1976, 1977). Unter Berücksichtigung dokumentierter anthropogener Störungen und Aufforstungen im 19. und 20. Jhd. sollte sorgfältig geprüft werden, ob ein Zirbenbestand in der Tatra als „Reliktbestand“ bezeichnet werden kann.

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