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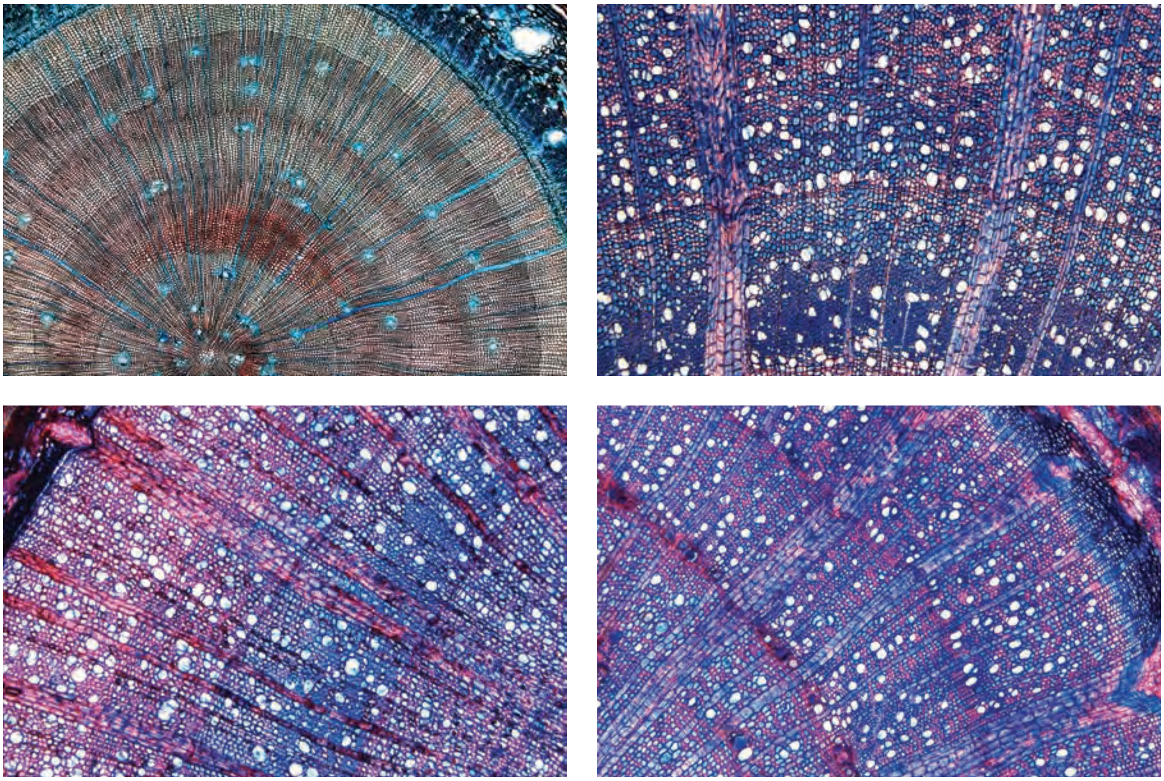

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TWO NEW SCREE PLANT COMMUNITIES IN THE TRIGLAV MOUNTAINS (JULIAN ALPS, SLOVENIA)

DVE NOVI RASTLINSKI ZDRUŽBI MELIŠČ V TRIGLAVSKEM POGORJU (JULIJSKE ALPE, SLOVENIJA)

Igor DAKSKOBLER* & Branko ZUPAN**

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ABSTRACT

Two new scree plant communities in the Triglav Mountains (Julian Alps, Slovenia)

In the Triglav Mountains, mainly on the slopes and plateaus to the west of Mt. Triglav (Glava v Zaplanji, Vrh Zelenic) we found new localities of three rare species of Slovenian flora, *Crepis terglouensis*, *Cerastium uniflorum* and *Geum reptans*, and made a phytosociological inventory of their sites. Based on comparisons with similar communities within which they occur elsewhere in the Eastern and Southeastern Alps we described two new associations, *Crepido terglouensis-Potentilletum nitidae* (alliance *Thlaspion rotundifolii*) and *Saxifrago carniolicae-Cerastietum uniflorae* (alliance *Arabidion caeruleae*).

Key words: Alpine flora, phytosociology, synsystematics, *Crepis terglouensis*, *Cerastium uniflorum*, *Geum reptans*, Triglav National Park, Slovenia

IZVLEČEK

Dve novi rastlinski združbi melišč v Triglavskem pogorju (Julijske Alpe, Slovenija)

V Triglavskem pogorju, predvsem na pobočjih in planotah zahodno od Triglava (Glava v Zaplanji, Vrh Zelenic) smo našli nova nahajališča treh redkih vrst v flori Sloveniji, *Crepis terglouensis, Cerastium uniflorum* in *Geum reptans* in fitocenološko popisali njihova rastišča. Na podlagi primerjav s podobnimi združbami, v katerih uspevajo omenjene vrste drugod v Vzhodnih in Jugovzhodnih Alpah, smo opisali dve novi asociaciji *Crepido terglouensis-Potentilletum nitidae* (zveza *Thlaspion rotundifolii*) in *Saxifrago carniolicae-Cerastietum uniflorae* (zveza *Arabidion caeruleae*).

Ključne besede: alpska flora, fitocenologija, sinsistematika, *Crepis terglouensis*, *Cerastium uniflorum, Geum reptans*, Triglavski narodni park, Slovenija

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1 INTRODUCTION

When mapping the flora on the slopes and plateaus west of Mt. Triglav in 2015 and 2016 we found and recorded fascinating scree communities with three rare species of Slovenian flora – *Crepis terglouensis*, *Cerastium uniflorum* and *Geum reptans*. We compared them to similar communities that had been studied in the Triglav Mountains and in the Julian Alps by T. Wraber (1972) and with similar communities elsewhere in the Eastern Alps, and classified them into a syntaxonomic system.

2 METHODS

Alpine communities under Mt. Triglav were studied applying the Braun-Blanquet method (Braun-Blanquet 1964). A total of 29 relevés (of which five had already been published by T. Wraber, 1972 and one by the authors of this paper – Dakskobler & Surina, 2017) were entered into the FloVegSi database (Fauna, Flora, Vegetation and Paleovegetation of Slovenia) of the Jovan Hadži Institute of Biology at SRC SASA (T. Seliškar, Vreš et A. Seliškar 2003). They were arranged into a working table based on hierarchical classification. We transformed the combined cover-abundance values with numerical values (1–9) according to van der Maarel (1979). Numerical comparisons were performed with the SYN-TAX 2000 program package (Podani 2001). The relevés were compared by means of (unweighted) average linkage method – UPGMA, using Wishart's similarity ratio.

In the first step we used numerical analyses as the basis on which we formed floristically homogeneous groups of relevés that were subsequently compared, using the same methodology, with similar communities in the Eastern Alps, also using hierarchical classification and the same method as when we compared individual relevés.

The nomenclature sources for the names of vascular plants are the Mala flora Slovenije (Martinčič et al. 2007) and Flora alpina (Aeschimann et al. 2004a,b). Prof. Andrej Martinčič determined the collected mosses. For the names of syntaxa we follow Englisch et al. (1993), Theurillat (2004), Šilc & Čarni (2012), E. Pignatti & S. Pignatti (2014) and Mucina et al. (2016). In the classification of species into phytosociological groups (groups of diagnostic species) we mainly refer to the Flora alpina (Aeschimann et al. 2004a,b). The geographic coordinates of relevés are determined according to the Slovenian geographic coordinate system D 48 (5th zone) on the Bessel ellipsoid and with Gauss-Krüger projection.

The relevés discussed in this article were made in the Triglav range of the Julian Alps, mostly on the plateuas west and southwest of Triglav. The geological bedrock in the study area is mainly calcareous, limestone and dolomite limestone (Buser 2009). The studied communities occur on initial soils (lithosols) – Lovrenčak (1998), Vidic et al. (2015). The climate is cold and humid, with mean annual precipitation of 2,500 to 3,000 mm (Zupančič 1998) and mean annual air temperature of -2 °C to 0 °C

3. RESULTS AND DISCUSSION

3.1 Review of the studied syntaxa, with types of newly described communities

Thlaspietea rotundifolii Br.-Bl. 1948
Thlaspietalia rotundifolii Br.-Bl. in Br.-Bl. et Jenny 1926
Thlaspion rotundifolii Jenny-Lips 1930
Papaveri julici-Thlaspietum rotundifolii T. Wraber 1970
Crepidetum terglouensis Seibert 1977
Crepido terglouensis-Potentilletum nitidae ass. nov. hoc. loco, the nomenclature type, *holotypus*, is relevé 12 in Table 1.
-*typicum*, subass. nov., the nomenclature type is the same as the nomenclature type of the association
-*caricetosum firmae*, the nomenclature type, *holotypus*, is relevé 5 in Table 1.
Saxifrago sedoidis-Geumetum reptantis nom. prov.
Arabidetalia caeruleae Rübel ex Nordhagen 1937
Arabidion caeruleae Br.-Bl. In Br.-Bl. et Jenny 1926
Saxifrago carniolicae-Cerastietum uniflorae ass. nov. hoc loco, the nomenclature type, *holotypus*, is relevé 18 in Table 1.
Asplenietea trichomanis (Br.-Bl. in Meier et Br.-Bl. 1934) Oberd. 1977

Potentilletalia caulescentis Br.-Bl. in Br.-Bl. et Jenny 1926

Physoplexido comosae-Saxifragion petraeae Mucina et Theurillat 2015 (syn. *Androsaco-Drabion tomentosae* T. Wraber 1970, *Phyteumato-Saxifragion petraeae* Mucina in Šilc et Čarni 2012)

Potentilletum nitidae Wikus 1959

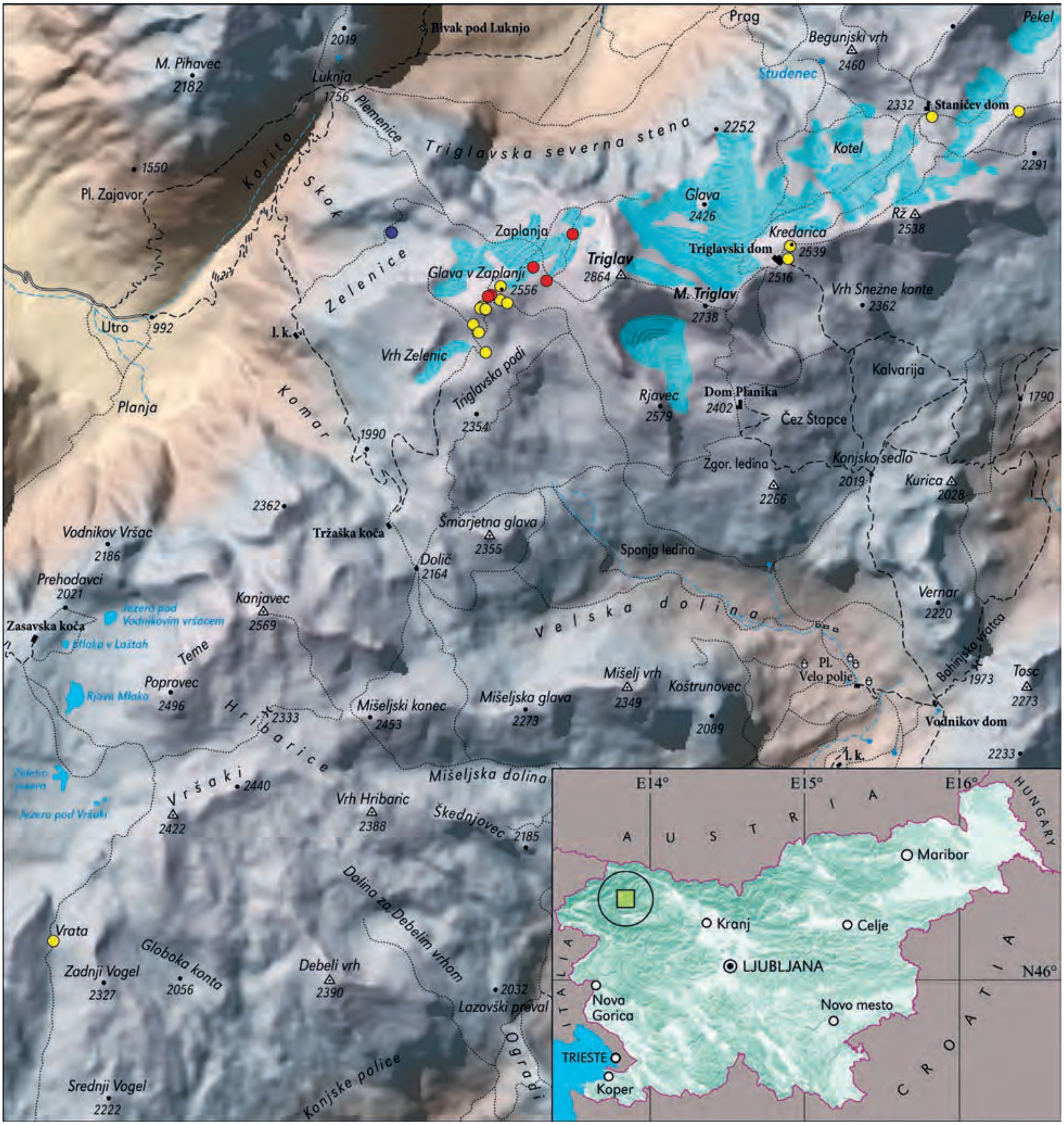

Figure 1: Localities of recorded stands in the Triglav mountains; yellow circle – stands of the association Crepido terglouensis-Potentilletum nitidae, red circle – stands of the association Saxifrago-Cerastietum uniflorae, blue circle – stand of the association Saxifrago-Geumetum reptantis
Slika 1: Nahajališča preučenih sestojev v Triglavskem pogorju: rumen krog – sestoji asociacije Crepido terglouensis-Potentilletum nitidae, rdeč krog – sestoji asociacije Saxifrago-Cerastietum uniflorae, moder krog – sestoj asociacije Saxifrago-Geumetum reptantis

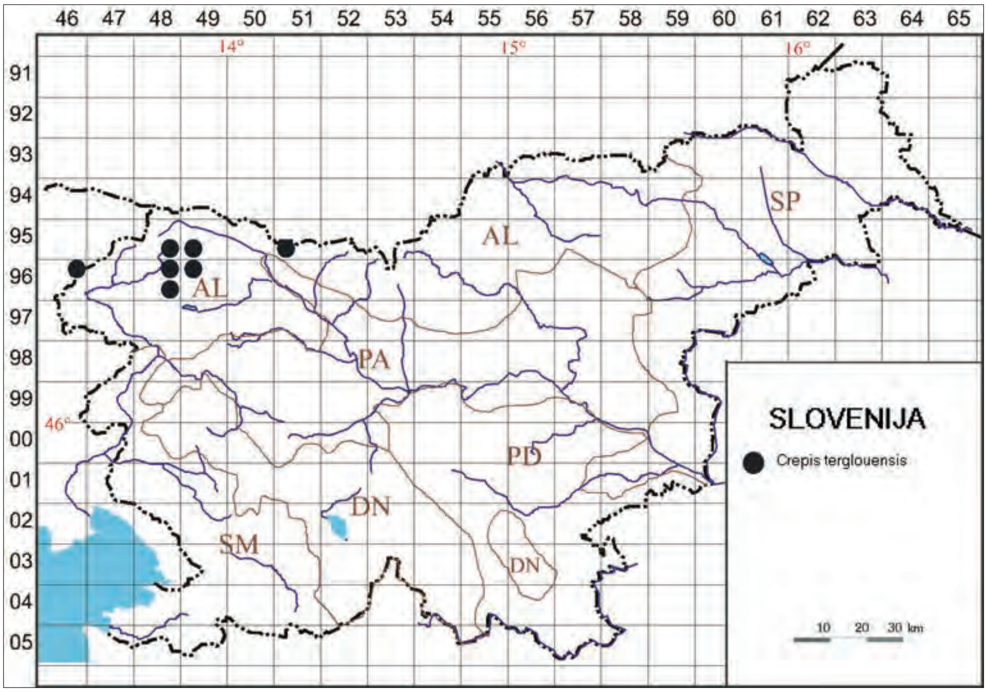

Figure 2: Distribution of Crepis terglouensis in Slovenia
Slika 2: Razširjenost vrste Crepis terglouensis v Sloveniji

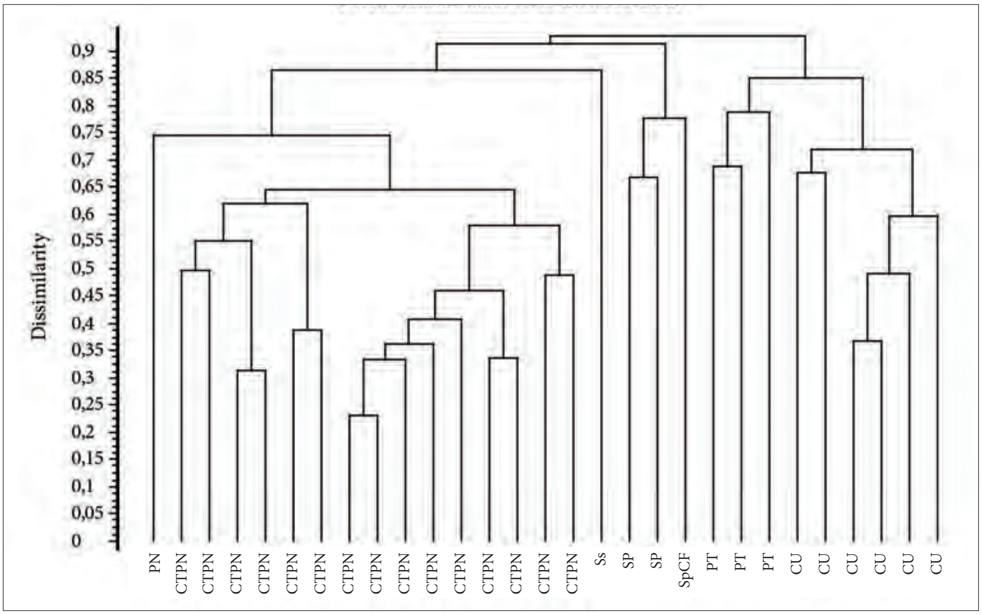

Figure 3: Dendrogram of recorded stands in the Triglav Mountains, UPGMA, 1– similarity ratio
PN Potentilletum nitidae; CTPN Crepido terglouensis-Potentilletum nitidae,Ss Salicetum serpyllifoliae nom. prov., SP Saxifragetum paniculatae nom. prov., SpCF Saxifrago paniculatae-Caricetum fuliginosae, PT Papaveri julici-Thlaspietum rotundifolii, CU Saxifrago-Cerastietum uniflorae
Slika 3: Dendrogram popisov preučenih sestojev v Triglavskem pogorju, UPGMA, komplement Wishartovega koeficienta podobnosti

3.2 *Crepis terglouensis* and its communities in Slovenia

According to Flora alpina (Aeschimann et al. 2004b: 668) *Crepis terglouensis* is an eastern-Alpine species, a character species of the alliance *Thlaspion rotundifolii* that comprises vegetation of subalpine-alpine calcareous screes. The species also gave its name to the alpine community *Crepidetum terglouensis* Seibert 1977 from the Eastern Alps, which was presented with a phytosociological table by Eggensberger (1994: 64–66, 76–77). Certain similarities with this community can be observed also in the relevé published by Sutter (1969: 353) that he had made together with T. Wraber under the Planika Lodge at Mt. Triglav. T. Wraber (1972, 1990) recorded *Crepis terglouensis* mainly in the stands of a special form of the association *Papaveri julici-Thlaspietum rotundifolii*. He found it on two screes at Kredarica and on Grlo pass between Oltar and Dovški Križ. E. & S. Pignatti (2014, 2016) mention it as a rare species in the stands of two other alpine scree communities, *Leontodontetum montani* and *Papaveretum rhaetici*, and in the special form (*Seleginella-Homogyne*) of the association *Seslerio-Caricetum sempervirentis*. A phytosociological inventory of its two new localities in the Slovenian Alps (on talus under Prestreljenik in the Kanin Mountains – Praprotnik, 1997, 2002, and on the scree under Mt. Stol in the Karavanke Mts. – Novak 2015) has not been made until now. Novak (ibid.) mentions companion species *Sesleria caerulea* and *Campanula cochleariifolia* for the locality under Mt. Stol. In our research we made most of the relevés with *Crepis terglouensis* on fine talus on Glava nad Zaplanjo under Mt. Triglav and on the neighbouring slopes towards Dolič (9648/2), but we also found a new locality on a similar site on Vrata pass between Zelnarica and Zadnji Vogel (9648/4) at the elevation of 2,192 m (leg. & det. I. Dakskobler, B. Anderle and B. Zupan, 23. 8. 2016, herbarium LJS), which is a new locality of this species in the new quadrant (Figures 1, 2). In the comparison of our relevés with *Crepis terglouensis* and (or) *Cerastium uniflorum* with similar relevés made by T. Wraber (1972), the relevés with co-dominating *Potentilla nitida* and *Crepis terglouensis* grouped

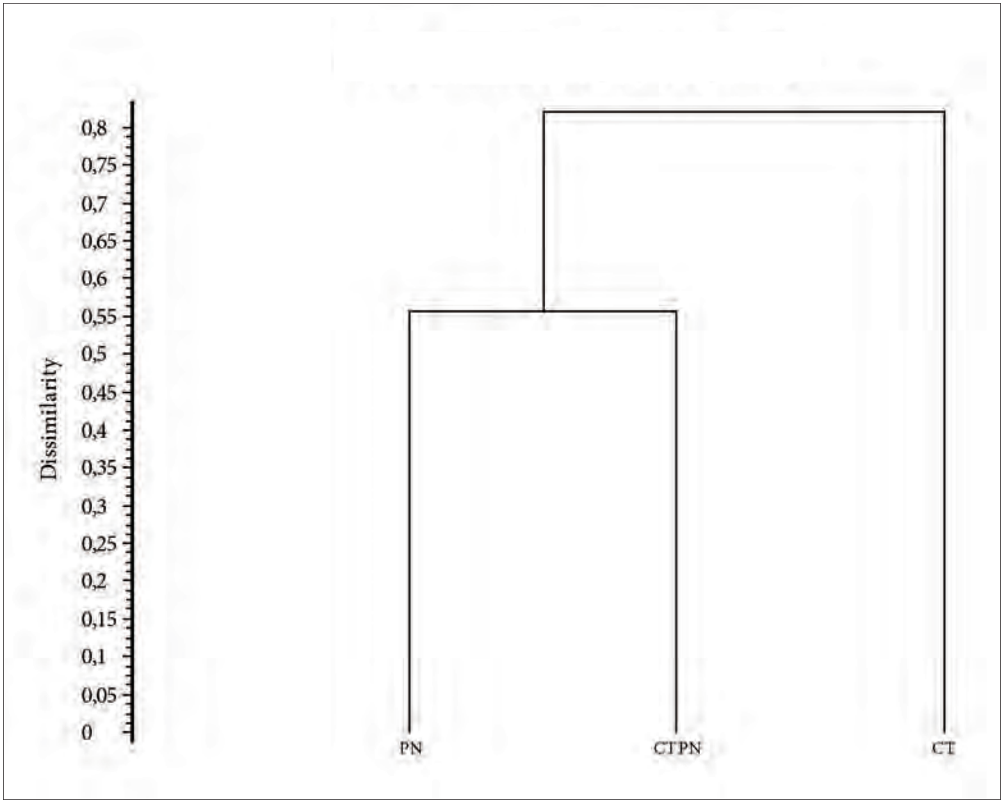

Figure 4: Dendrogram of syntaxa Potentilletum nitidae (PN), Crepidetum terglouensis (CT) and Crepido terglouensis-Potentilletum nitidae (CTPN), UPGMA, 1– similarity ratio
Slika 4: Dendrogram sintaksonov Potentilletum nitidae (PN), Crepidetum terglouensis (CT) and Crepido terglouensis-Potentilletum nitidae (CTPN), UPGMA, komplement Wishartovega koeficienta podobnosti

separately (Figure 3). We obviously inventoried a form of alpine vegetation that is transitional between scree communities, chasmophytic communities and stony grasslands, which had already been demonstrated by Sutter's relevé (ibid.) and mentioned also by Eggensberger (ibid.). We therefore made a synthetic table (Appendix 1) in which we compared 15 relevés of the studied stands with 33 relevés of the association *Potentilletum nitidae* (T. Wraber 1972, Table 3) and with 25 relevés of the association *Crepidetum terglouensis* (Eggensberger 1994, Table 6, columns 85–111). The results (Figure 4) indicate that our relevés are more similar to the stands of the association *Potentilletum nitidae*. They could therefore be classified into the new subassociation *Potentilletum nitidae crepidetosum terglouensis*, but the analysis of diagnostic species (Table 2, column 1) indicates the predominance of scree species from the order *Thlaspietelia rotundifolii* (37.43%) over the diagnostic chasmophytic species from the order *Potentilletalia caulescentis* (23.8%). Most of the relevés were made on fine talus that is almost consistently mixed with well-decomposed humus (mull), on levelled terrain with a relatively persistent snow cover. As a rule, *Potentilla nitida* is the dominant species in inventoried stands and its joint occurrence with the characteristic scree species *Crepis terglouensis* on relatively small but ecologically unique areas between rocks (fine talus) can indicate a stage in development (succession) that could be partly associated with the ongoing climate change, reduced precipitation volumes and shorter periods of snow cover on the plateaus to the west of Mt. Triglav, as demonstrated by the measurements of the Triglav Glacier at a similar elevation (Gabrovec et al. 2014). This stage in succession can be treated also at the rank of the new association *Crepido terglouensis-Potentilletum nitidae*, which is classified into the alliance *Thlaspion rotundifolii*. Diagnostic species of the new association are *Potentilla nitida*, *Crepis terglouensis*, *Alyssum ovirense*, *Eritrichium nanum* and *Minuartia cherlerioides*. We distinguish between two subassociations, typical (*-typicum*) and *-caricetosum firmae*. The differential species of the latter are *Carex firma*, *Silene acaulis* and *Salix retusa*, which might indicate a transition towards stony alpine grasslands from the association *Gentiano terglouensis-Caricetum firmae*.

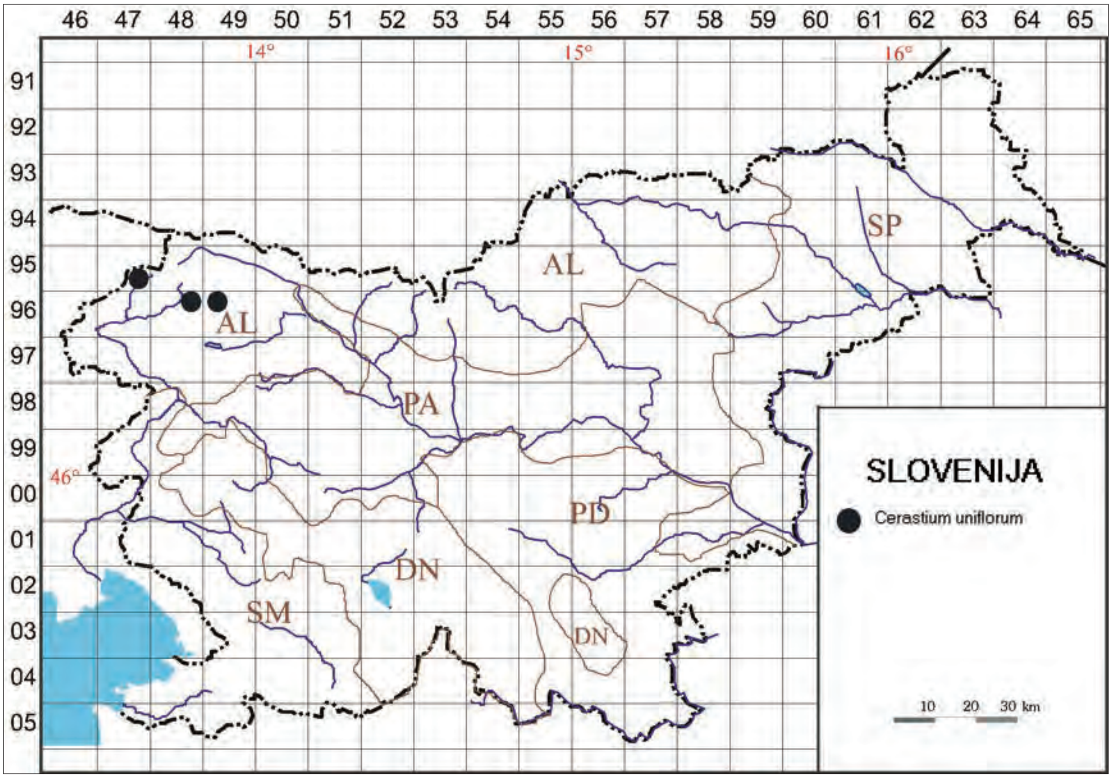

Figure 5: Distribution of Cerastium uniflorum in Slovenia
Slika 5: Razširjenost vrste Cerastium uniflorum v Sloveniji

3.3 *Cerastium uniflorum* and its communities in Slovenia

Cerastium uniflorum is an Alpine-Carpathian species, a character species of silicate subalpine and alpine screes (alliance *Androsacion alpinae*) – Aeschimann et al. (2004a: 298). Its distribution in Slovenia is shown in Figure 5. Its reported localities are only on Mt. Triglav and its vicinity, on Mt. Rjavina and on Mt. Mangart. T. Wraber (1990: 130, 1972) reported its occurrence in the stands of associations *Potentilletum nitidae* and *Papaveri julici-Thlaspietum rotundifolii*. E. & S. Pignatti (2014, 2016) recorded this species in the stands of associations *Drabetum hoppeanae*, *Saxifragetum sedoidis*, *Leontodontetum montani*, *Papaveretum rhaetici*, *Festucetum pulchellae*, *Vitaliano-Eritrichetum nani*, *Arabidetum caeruleae*, *Saxifragetum bryoidis* and several others. In our relevés it occurs with individual specimens within associations *Saxifrago paniculatae-Caricetum fuliginosae* (Dakskobler & Surina 2017) and *Crepido-Potentilletum nitidae* (this article), but it is also one of the dominating species in six relevés on mainly fine talus and on sites with a persistent snow cover (Figure 1, relevés 17–21 in Table 1). These relevés grouped separately from other relevés of alpine screes and alpine swards on rock ledges (Figure 3). The most frequent species in addition to *Cerastium uniflorum* is *Saxifrage sedoides*, so we compared them with the association *Saxifragetum sedoidis* from the Dolomites (E. & S. Pignatti 2016: 204: Association table 9.2, 406–407) – Appendix 2. Surina (2005) prepared a phytosociological table for the Krn Mts. in which he presented a similar syntaxon *Saxifragetum stellaro-sedoidis* var. geogr. *Ranunculus traunfellneri*, but in his stands he did not record *Cerastium uniflorum*, which is absent also from the original description of this association (Englisch 1999). Floristic similarity of our relevés with the relevés of the stands of the association *Saxifragetum sedoidis* is only 41% (Sørensen 1948), which does not allow for its classification into this association. These stands can also be explained as a successional stage, because in the extreme conditions of the alpine belt *Cerastium uniflorum* can grow on various sites and overgrows even areas where it may not have occurred 50 or 100 years ago. For this reason and based on the composition of diagnostic species (Table 2, column 2) we classify them into the new association *Saxifrago carniolicae-Cericetum uniflorae* and into the alliance *Arabidion caeruleae*. Its diagnostic species are *Cerastium uniflorum*, *Saxifraga sedoides* and *Saxifraga exarata* subsp. *carniolica*. The latter is endemic to the Southeastern Alps and a character species of alpine chasmophytic communities (*Potentilletum nitidae*, *Potentillo clusianae-Campanuletum zoysii*) – T. Wraber (2006: 70) and of stony grasslands from alliances *Caricion firmae* and *Seslerion variae* (Aeschimann et al. 2004: 2010). The first two listed species characterise an alpine community on fine talus in areas with long-lasting snow cover and the third characterises the new association mainly in terms of phytogeography and partly indicates similar development of communities on fine gravel with communities on stony alpine swards and rock crevices. Abundant *Sagina saginoides* in one of the stands indicates locally improved soil conditions with an abundance of fine weathered material (mull).

3.4 *Geum reptans* in the Triglav Mountains

Aeschimann et al. (2004a: 758) classify the South-European montane species *Geum reptans* as a character species of the alliance *Androsacion alpinae*. The only reported localities in the Julian Alps so far have been those on Mts. Mangart and Kanjavec (T. Wraber 2006, Zupan & Dakskobler 2007, Figure 6). On 8 August 2016 we found a new locality of this scree species on the western slopes of Triglav, in the cirque under Vrh Zelenic, on the elevation of 2,060 m (Dakskobler 2017, Figure 1). The site is a well-overgrown, consolidated scree with rocks of various sizes. Its species composition is shown in Column 2 of Table 3. Column 1 in the same table presents the relevé of the community on the locality at Teme between Kanjavec and Poprovec (Zupan & Dakskobler 2007), which was identified as a transition between the community of *Potentilletum nitidae* and the stand of the association *Papaveri julici-Thlaspietum rotundifolii*. The stand under Vrh Zelenic cannot be classified into either of the mentioned associations. It characterises a scree community with many species of stony Alpine swards (from the association *Gentiano terglouensis-Caricetum firmae*). It is provisionally classified into the association *Saxifrago sedoidis-Geumetum reptantis* nom. prov. and into the alliance *Thlaspion rotundifolii*. In addition to *Geum reptans* the species that characterise this community are mainly those from the genus *Saxifraga* (*S. sedoides*, *S. paniculata*, *S. aizoides*, *S. crustata*, *S. squarrosa*) and two typical scree species, *Festuca nitida* and *Poa minor*.

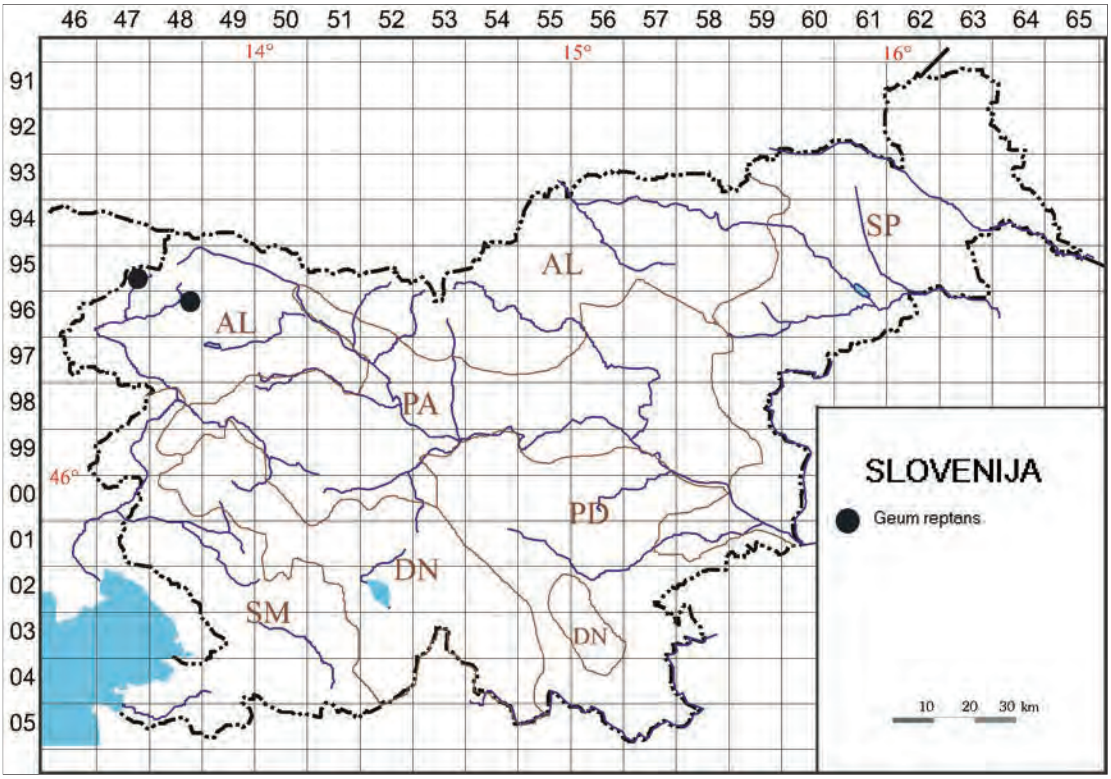

Figure 6: Distribution of Geum reptans in Slovenia
Slika 6: Razširjenost vrste Geum reptans v Sloveniji

4 CONCLUSIONS

The result of floristic mapping in the western part of Mt. Triglav (Glava v Zaplanji, Vrh Zelenic) and on Vrata pass between Velika Zelnarica and Zadnji Vogal are new localities of three alpine scree and (or) chasmophytic species that are rare in Slovenia and listed on the Red List (Anon. 2002): *Cerastium uniflorum* (new localities in quadrant 9648/2), *Crepis terglouensis* (new localities in quadrants 9648/2 and 9648/4) and *Geum reptans* (new locality in the existing quadrant, 9648/2, new to the flora of Triglav). We made a phytosociological inventory of the communities in which they grow and determined untypical stands on fine talus with fine weathered material (mull) that are transitional between alpine chasmophytic, scree and snow bed communities and could be a successional stage in areas that decades ago were covered by snow for much longer periods than they are today. Based on their comparison with similar communities from the Eastern and Southeastern Alps we described two new associations, *Crepido terglouensis-Potentilletum nitidae* and *Saxifrago carniolicae-Cerastietum uniflorae*. Even though their stands are located in the vicinity of quite popular mountain trails to Triglav they are not yet endangered by increasing numbers of tourists in the summer as there are no other interventions into this area. In addition, neither *Cerastium uniflorum* nor *Crepis terglouensis* are prominent species and are quite inconspicuous outside their flowering season. The new locality of *Geum reptans*, which occurs also in the non-typical scree community (*Saxifrago sedoidis-Geumetum reptantis* nom. prov.), is in a remote pathless area in the cirque under Vrh Zelenic and therefore still outside any direct influence of man.

5 POVZETEK

5.1 Uvod

Pri kartiranju flore na pobočjih in planotah zahodno od Triglava smo v letih 2015 in 2016 našli in popisali zanimive meliščne združbe, v katerih uspevajo tri redke vrste slovenske flore: *Crepis terglouensis*, *Cerastium uniflorum* in *Geum reptans*. Primerjali smo jih s podobnimi združbami, ki jih je v Triglavskem pogorju in v Julijskih Alpah raziskal T. Wraber (1972), in s podobnimi združbami drugod v Vzhodnih Alpah in jih uvrstili v sintaksonomski sistem.

5.2 Metode

Alpinske združbe pod Triglavom smo preučevali po ustaljeni srednjeevropski metodi (Braun-Blanquet 1964). Skupno 29 popisov (od tega jih je pet predhodno objavil že T. Wraber, 1972, enega pa mi – Dakskobler & Surina, 2017) smo vnesli v podatkovno bazo FloVegSi (T. Seliškar, Vreš & A. Seliškar 2003). Fitocenološke popise smo v delovno tabelo uredili na podlagi hierarhične klasifikacije. Kombinirane ocene zastiranja in pogostnosti smo pretvorili v številčne vrednosti (1–9) – van der Maarel 1979). Popise smo primerjali z metodo kopičenja na podlagi povezovanja (netehtanih) srednjih razdalj – (Unweighted) average linkage method – UPGMA. Uporabljali smo programski paket SYN-TAX 2000 (Podani 2001) in kot mero različnosti komplement koeficienta »similarity ratio«. V prvem koraku smo na podlagi numeričnih analiz oblikovali floristično homogene skupine popisov, ki smo jih nato z enakim metodološkim pristopom primerjali s podobnimi združbami v Vzhodnih Alpah, pri tem pa prav tako uporabili hierarhično klasifikacijo in isto metodo kot pri primerjavi posamičnih popisov.

Nomenkalturna vira za imena praprotnic in semenk sta Mala flora Slovenije (Martinčič et al. 2007) in Flora alpina (Aeschimann et al. 2004a,b). Mahove, ki v preučenih združbah nimajo večjega zastiranja, je določil prof. Andrej Martinčič. Nomenklaturni viri za imena sintaksonov so Englisch et al. (1993), Theurillat (2004), Šilc & Čarni (2012), E. Pignatti & S. Pignatti (2014) in Mucina et al. (2016). Pri uvrščanju vrst v fitocenološke skupine smo v glavnem upoštevali delo Flora alpina (Aeschimann et al., ibid.). Geografske koordinate popisov smo določili po slovenskem geografskem koordinatnem sistemu D 48 (cona 5) na Besselovem elipsoidu in z Gauss-Krügerjevo projekcijo.

Popise smo naredili v Triglavskem pogorju v Julijskih Alpah, večino na planotah zahodno in jugozahodno od vrha Triglava. Kot geološka podlaga se pojavljata na raziskovanem območju apnenec in dolomit (Buser 2009). Preučene združbe uspevajo na kamniščih (Lovrenčak 1998, Vidic et al. 2015). Podnebje je hladno in vlažno, s povprečno letno višino padavin med 2500 mm in 3000 mm (Zupančič 1998) in srednjo letno temperature zraka med -2 °C in 0 °C (Cegnar 1998).

5.3. Rezultati in razprava

5.3.1 Pregled preučenih sintaksonov s tipi na novo opisanih združb

Thlaspietea rotundifolii Br.-Bl. 1948
- *Thlaspietalia rotundifolii* Br.-Bl. in Br.-Bl. et Jenny 1926
  - *Thlaspion rotundifolii* Jenny-Lips 1930
    - *Papaveri julici-Thlaspietum rotundifolii* T. Wraber 1970
    - *Crepidetum terglouensis* Seibert 1977
  - *Crepido terglouensis-Potentilletum nitidae* ass. nov. hoc. loco, nomenklaturni tip, *holotypus*, je popis 12 v preglednici 1.
    - -*typicum*, subass. nov., nomenklaturni tip je isti kot nomenklaturni tip asociacije
    - -*caricetosum firmae*, nomenklaturni tip, *holotypus*, je popis 5 v preglednici 1.
  - *Saxifrago sedoidis-Geumetum reptantis* nom. prov.
- *Arabidetalia caeruleae* Rübel ex Nordhagen 1937
  - *Arabidion caeruleae* Br.-Bl. In Br.-Bl. et Jenny 1926
    - *Saxifrago carniolicae-Cerastietum uniflorae* ass. nov. hoc loco, nomenklaturni tip, *holotypus*, je popis 18 v preglednici 1.

Asplenietea trichomanis (Br.-Bl. in Meier et Br.-Bl. 1934) Oberd. 1977
- *Potentilletalia caulescentis* Br.-Bl. in Br.-Bl. et Jenny 1926
  - *Physoplexido comosae-Saxifragion petraeae* Mucina et Theurillat 2015 (sin. *Androsaco-Drabion tomentosae* T. Wraber 1970, *Phyteumato-Saxifragion petraeae* Mucina in Šilc et Čarni 2012)
  - *Potentilletum nitidae* Wikus 1959

5.3.2 Vrsta *Crepis terglouensis* in združbe, v katerih uspeva v Sloveniji

Po delu Flora alpina (Aeschimann et al. 2004b: 668) je *Crepis terglouensis* vzhodnoalpska vrsta, značilnica zveze *Thlaspion rotundifoliae*, ki združuje rastje subalpinsko-alpinskih melišč na karbonatni podlagi. Po njej se imenuje vzhodnoalpska alpinska združba *Crepidetum terglouensis* Seibert 1977, ki jo je s fitocenološko tabelo podrobno predstavil Eggensberger (1994: 64–66, 76–77). Nekaj podobnosti s to združbo naj bi imel tudi popis, ki ga je objavil Sutter (1969: 353) in sta ga naredila skupaj s T. Wraberjem pod planinskim domom Planika pod Triglavom. T. Wraber (1972, 1990) triglavski dimek omenja predvsem v posebni obliki asociacije *Papaveri julici-Thlaspietum rotundifolii*. Našel ga je na dveh meliščih na Kredarici in na prelazu Grlo med Oltarjem in Dovškim križem. E. & S. Pignatti (2014, 2016) to vrsto kot redko navajata v sestojih dveh drugih alpinskih meliščnih združb *Leontodontetum montani* in *Papaveretum rhaetici* in v posebni obliki (*Seleginella-Homogyne*) asociacije *Seslerio-Caricetum sempervirentis*. Dve novi nahajališči te vrste v slovenskih Alpah (na grušču pod Prestreljenikom v Kaninskem pogorju – Praprotnik, 1997, 2002 in na melišču pod Stolom v Karavnkah – Novak 2015) fitocenološko do zdaj nista popisani. Na nahajališču pod Stolom, Novak (ibid.) omenja spremljevalni vrsti *Sesleria caerulea* in *Campanula cochleariifolia*. Pri naših raziskavah smo večino popisov triglavskega dimka naredili na drobnem grušču na Glavi nad Zaplanjo pod Triglavom in na sosednjih vzpetinah v smeri proti Doliču (9648/2) – slika 1, novo nahajališče pa smo našli tudi na enakem rastišču na prelazu Vrata med Zelnarico in Zadnjim Voglom (9648/4), na nadmorski višini 2192 m (leg. & det. I. Dakskobler, B. Anderle in B. Zupan, 23. 8. 2016, herbarij LJS), kar je novo nahajališče te vrste v novem kvadrantu (slika 2). Po primerjavi naših popisov z vrstama *Crepis terglouensis* in/ali *Cerastium uniflorum* s podobnimi popisi T. Wraberja (1972), so se posebej združevali popisi, v katerih skupaj prevladujeta vrsti *Potentilla nitida* in *Crepis terglouensis* (slika 3). Očitno smo popisali prehodno obliko alpinskega rastja med meliščnimi združbami, združbami skalnih razpok in kamnitih travišč, ki jo je z enim popisom ponazoril že Sutter (ibid.) in jo omenja tudi Eggensberger (ibid.). Zato smo izdelali sintezno tabelo (Dodatek 1), v kateri smo 15 popisov preučenih sestojev primerjali s 33 popisi asociacije *Potentilletum nitidae* (T. Wraber 1972, preglednica 3) in s 25 popisi asociacije *Crepidetum terglouensis* (Eggensberger 1994, preglednica 6, stolpci 85–111). Rezultati (slika 4) kažejo na večjo podobnost naših popisov s sestoji asociacije *Potentilletum nitidae*. Mogoče bi jih bilo torej uvrstiti v novo subasociacijo, *Potentilletum nitidae crepidetosum terglouensis*, toda analiza diagnostičnih vrst (preglednica 2, stolpec 1) kaže na prevlado meliščnih vrst iz reda *Thlaspietelia rotundifolii* (37,43 %) nad diagnostičnimi vrstami skalnih razpok iz reda *Potentilletalia caulescentis* (23,8 %). Večino popisov smo naredili na drobnem grušču, med katerim je skoraj vedno nekaj dobro razkrojenega humusa (sprstenine), na uravnavah, kjer se razmeroma dolgo zadržuje sneg. Dominantna vrsta popisanih sestojev je navadno *Potentilla nitida*, njeno družno uspevanje s tipično meliščno vrsto *Crepis terglouensis* na razmeroma majhnih, a ekološko svojskih površinah med skalovjem (droben grušč) lahko označuje določeno razvojno (sukcesijsko) stopnjo, ki je morda deloma povezana tudi z zdajšnjimi podnebnimi spremembami, očitno manjšo količino snežnih padavin in krajšimi obdobji s snežno odejo na planotah zahodno od Triglava, kar dokazujejo meritve bližnjega Triglavskega ledenika na podobni nadmorski višini (Gabrovec et al. 2014). To sukcesijsko stopnjo lahko obravnavamo tudi v rangu nove asociacije *Crepido terglouensis-Potentilletum nitidae*, ki jo uvrščamo v zvezo *Thlaspion rotundifolii*. Diagnostične vrste nove asociacije so *Potentilla nitida*, *Crepis terglouensis*, *Eritrichium nanum* in *Minuartia cherlerioides*. Razlikujemo dve subasociaciji, tipično (*-typicum*) in *-caricetosum firmae*. Razlikovalnice slednje so vrste *Carex firma*, *Silene acaulis* in *Salix retusa*, ki morda nakazujejo prehod proti kamnitim alpinskim traviščem iz asociacije *Gentiano terglouensis-Caricetum firmae*.

5.3.3 Vrsta *Cerastium uniflorum* in združbe, v katerih uspeva v Sloveniji

Cerastium uniflorum je alpsko-karpatska vrsta, značilnica zveze silikatnih melišč subalpinskega in alpinskega pasu *Androsacion alpinae* (Aeschimann et al. 2004a: 298). Njeno razširjenost v Sloveniji prikazuje slika 5. Znana nahajališča so le na Triglavu in v njegova soseščini, na Rjavini in Mangartu. T. Wraber (1990: 130, 1972) navaja njeno pojavljanje v sestojih asociacij *Potentilletum nitidae* in *Papaveri julici-Thlaspietum rotundifolii*. E. & S. Pignatti (2014, 2016) sta to vrsto popisala v sestojih asociacij *Drabetum hoppeanae, Saxifragetum sedoidis, Leontodontetum montani, Papaveretum rhaetici, Festucetum pulchellae, Vitaliano-Eritrichetum nani, Arabidetum caeruleae, Saxifragetum bryoidis* in v še nekaterih drugih. V naših popisih jo imamo kot posamično primes v sestojih asociacij *Saxifrago paniculatae-Caricetum fuliginosae* (Dakskobler & Surina 2017) in *Crepido-Potentilletum nitidae* (ta članek), je pa ena od prevladujočih vrst v šestih popisih na večinoma drobnem grušču in na krajih, kjer se dolgo zadržuje sneg (slika 6, popisi 17–21 v preglednici 1). Ti popisi so se združevali ločeno od drugih popisov alpinskih melišč in alpskih trat na skalnatih policah (slika 2). Poleg vrste *Cerastium uniflorum* je na njih najbolj pogosta vrsta *Saxifrage sedoides*, zato smo jih primerjali s popisi asociacije *Saxifragetum sedoidis* iz Dolomitov (E. & S. Pignatti 2016: 204: asociacijska preglednica 9.2, 406–407) – Dodatek 2. V Krnskem pogorju je Surina (2005) s fitocenološko tabelo predstavil nekoliko podoben sintakson *Saxifragetum stellaro-sedoidis* var. geogr. *Ranunculus traunfellneri*, vendar v njegovih sestojih ni popisal enocvetne smiljke in tudi v izvornem opisu te asociacije (Englisch 1999) je ni. Floristična podobnost naših popisov s popisi sestojev asociacije *Saxifragetum sedoidis* je precej manj kot polovična, le 41-odstotna (Sørensen 1948), kar ne dopušča uvrstitve v to asociacijo. Tudi te sestoje lahko razložimo kot razvojno (sukcesijsko) stopnjo, saj vrsta *Cerastium uniflorum* v skrajnih razmerah alpinskega pasu lahko uspeva na različnih rastiščih in porašča tudi površine, ki jih morda pred 50 ali 100 leti še ni poraščala. Zato in na podlagi sestave diagnostičnih vrst (tabela 2, stolpec 2) jih uvrščamo v novo asociacijo *Saxifrago carniolicae-Cericetum uniflorae* in v zvezo *Arabidion caeruleae*. Njene diagnostične vrste so *Cerastium uniflorum*, *Saxifraga sedoides* in *Saxifraga exarata* subsp. *carniolica*. Slednja je endemit Jugovzhodnih Alp in značilnica alpinskih združb skalnih razpok (*Potentilletum nitidae*, *Potentillo clusianae-Campanuletum zoysii*) – T. Wraber (2006: 70) in kamnitih travišč iz zvez *Caricion firmae* in *Seslerion variae* (Aeschimann et al. 2004: 2010). Prvi dve našteti vrsti označujeta alpinsko združbo drobnega grušča v območjih z dolgotrajno snežno odejo, tretja pa novo asociacijo označuje predvsem fitogeografsko in deloma kaže na razvojno povezanost združb drobnega grušča z združbami kamnitih alpskih trat in skalnih razpok. V enem sestoju je v veliki količini prisotna vrsta *Sagina saginoides*, ki kaže na krajevno boljše talne razmere, z obilico drobne preperine (sprstenine).

5.3.4 Vrsta *Geum reptans* v Triglavskem pogorju

Tudi južnoevropsko montansko vrsto *Geum reptans* Aeschimann et al. (2004a: 758) uvrščajo med značilnice zveze *Androsacion alpinae*. V Julijskih Alpah so bila do zdaj znana le nahajališča na Mangartu in Kanjavcu (T. Wraber 2006, Zupan & Dakskobler 2007, slika 7). 8. 8. 2016 smo našli novo nahajališče te meliščne vrste na zahodnih pobočjih Triglava, v krnici pod Vrhom Zelenic, na nadmorski višini 2060 m (Dakskobler 2017). Rastišče je ustaljeno melišče z različno velikimi kosi kamenja in precej poraslo. Njegova vrstna sestava je v stolpcu 2, v preglednici 3. V stolpcu 1 te tabele je popis združbe na nahajališču na Temenu med Kanjavcem in Poprovcem (Zupan & Dakskobler 2007), ki smo ga označili kot prehod med združbo triglavske rože (*Potentilletum nitidae*) in sestojem asociacije *Papaveri julici-Thlaspietum rotundifolii*. Sestoja pod Vrhom Zelenic ne moremo uvrstiti v nobeno od obeh navedenih asociacij. Označuje združbo melišč s precej vrstami kamnitih alpskih trat (iz asociacije *Gentiano terglouensis-Caricetum firmae*). Začasno jo uvrščamo v provizorno asociacijo *Saxifrago sedoidis-Geumetum reptantis* in v zvezo *Thlaspion rotundifolii*. Združbo poleg prevladujoče vrste *Geum reptans* označujejo predvsem vrste iz rodu *Saxifraga* (*S. sedoides*, *S. paniculata, S. aizoides, S. crustata, S. squarrosa*) ter dve tipični meliščni vrsti: *Festuca nitida* in *Poa minor*.

5.4 Sklepne misli

Razultat florističnega kartiranja v zahodnem delu Triglava (Glava v Zaplanji, Vrh Zelenic) in na prevalu Vrata med Veliko Zelnarico in Zadnjim Voglom so nova nahajališča treh v Sloveniji redkih vrst alpinskih melišč in/ali skalnih razpok, ki so uvrščene na rdeči seznam (Anon. 2002): *Cerastium uniflorum* (nova nahajališča v kvadrantu 9648/2), *Crepis terglouensis* (nova nahajališča v kvadrantih 9648/2 in 9648/4) ter *Geum reptans* (novo nahajališče v že znanem kvadrantu, 9648/2, novost v flori Triglava). Fitocenološko smo popisali združbe, v katerih uspevajo navedene vrste in ugotovili njihove netipične sestoje na drobnem grušču z drobno preperino (sprstenino), ki so prehodni med alpinskimi združbami skalnih razpok, melišč in snežnih dolinic ter so lahko sukcesijska stopnja na površinah, ki so bile pred desetletji precej dlje pokrita s snegom. Na podlagi primerjave s podobnimi združbami iz Vzhodnih in Jugovzhodnih Alp smo opisali dve novi asociaciji *Crepido terglouensis-Potentilletum nitidae* in *Saxifrago carniolicae-Cerastietum uniflorae.* Čeprav so njuni sestoji v bližini precej obiskanih planinskih poti, ki vodijo proti Triglavu, jih vsako leto večji poletni turistični obisk za zdaj ne ogroža, saj drugih posegov v ta prostor tu ni in sta vrsti *Cerastium uniflorum* in *Crepis terglouensis* precej neopazni, še posebej v času, ko ne cvetita. Novo nahajališče vrste *Geum reptans*, ki tudi raste v netipični meliščni združbi (*Saxifrago sedoidis-Geumetum reptantis* nom. prov.), je v odmaknjenem brezpotju v krnici pod Vrhom Zelenic in nanj za zdaj človek nima nobenega neposrednega vpliva.

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REFERENCES – LITERATURA

Aeschimann, D., K. Lauber, D. M. Moser & J.-P. Theurillat, 2004a: *Flora alpina*. Bd. 1: *Lycopodiaceae-Apiaceae*. Haupt Verlag, Bern, Stuttgart, Wien.

Aeschimann, D., K. Lauber, D. M. Moser & J.-P.Theurillat, 2004b: *Flora alpina*. Bd. 2: *Gentianaceae–Orchidaceae*. Haupt Verlag, Bern, Stuttgart, Wien.

Aeschimann, D., K. Lauber, D. M. Moser & J.-P.Theurillat, 2004c: *Flora alpina*. Bd. 3: *Register*. Haupt Verlag, Bern, Stuttgart, Wien.

Anonymous, 2002: *Pravilnik o uvrstitvi ogroženih rastlinskih in živalskih vrst v rdeči seznam*. Uradni list RS 82/2002.

Braun-Blanquet, J., 1964: *Pflanzensoziologie. Grundzüge der Vegetationskunde*. 3. Auflage. Springer, Wien – New York.

Buser, S., 2009: *Geološka karta Slovenije 1: 250.000. Geological map of Slovenia 1: 250,000*. Geološki zavod Slovenije, Ljubljana.

Cegnar, T., 1998: *Temperatura zraka*. In: J. Fridl, D. Kladnik, M. Orožen Adamič & D. Perko (eds.): *Geografski atlas Slovenije. Država v prostoru in času*. Državna založba Slovenije, Ljubljana, pp. 100–101.

Dakskobler, I., 2017: *Dve botanični opombi pod črto: plazeča sretena (Geum reptans) pod Triglavom in venerini laski (Adiantum capillus-veneris) v grapi Volarje pri Seliščih*. Proteus (Ljubljana) 79 (5): 216–223.

Dakskobler, I. & B. Surina, 2017: *Phytosociological analysis of alpine swards and heathlands (pioneer patches) on ridges and peaks in the Julian Alps (NW Slovenia).* Hacquetia (Ljubljana) 16 (1): 49–171. https://doi.org/10.1515/hacq-2016-0022

Eggensberger, P., 1994: *Die Pflanzengesellschaften der subalpinen umd alpinen Stufe der Ammergauer Alpen und ihre Stellung in den Ostalpen*. Ber. Bayer. Bot. Ges., Beihefte 8: 3–239.

Englisch, T., 1999: *Multivariate Analysen zur Synsystematik und Standortsökologie der Schneebodenvegetation (Arabidetalia caerulae) in den Nördlichen Kalkalpen*. Stapfia (Linz) 59: 1– 211 + Tables.

Englisch, T., M. Valachovič, L. Mucina, G. Grabherr, G.& T. Ellamuer, 1993: *Thlaspietea rotundifolii*. In: G. Grabherr & L. Mucina (eds.): *Die Pflanzengesellschaften Österreichs. Teil II: Natürliche waldfreie Vegetation*, Gustav Fischer Verlag, Jena - Stuttgart - New York, pp. 276–342.

Gabrovec, M., M. Hrvatin, B. Komac, J. Ortar, M. Pavšek, M. Topole, M. Triglav Čekada & M. Zorn, 2014: *Triglavski ledenik*. Založba ZRC, Ljubljana.

Lovrenčak, F., 1998: *Prsti*. In: J. Fridl, D. Kladnik, M. Orožen Adamič & D. Perko (eds.): *Geografski atlas Slovenije. Država v prostoru in času*. Državna založba Slovenije, Ljubljana, pp. 114–115.

Maarel van der, E., 1979: *Transformation of cover-abundance values in phytosociology and its effects on community similarity.* Vegetatio 39 (2): 97–114. https://doi.org/10.1007/BF00052021

Martinčič, A., T. Wraber, N. Jogan, A. Podobnik, B. Turk, B. Vreš, V. Ravnik, B. Frajman, S. Strgulc Krajšek, B. Trčak, T. Bačič, M. A. Fischer, K. Eler & B. Surina, 2007: *Mala flora Slovenije. Ključ za določanje praprotnic in semenk*. Četrta, dopolnjena in spremenjena izdaja. Tehniška založba Slovenije, Ljubljana.

Mucina, L., H. Bültmann, K. Dierssen, J-P. Theurillat, T. Raus, A. Čarni, K. Šumberová, W. Willner, J. Dengler, R. Gavilán García, M. Chytrý, M. Hájek, R. Di Pietro, D. Iakushenko, J. Pallas, F. J. A. Daniëls, E., Bergmeier, A. Santos Guerra, N. Ermakov, M. Valachovič, J. H. J. Schaminée, T. Lysenko, Y. P. Didukh, S. Pignatti, J. S. Rodwell, J. Capelo, H. E. Weber, A. Solomeshch, P. Dimopoulos, C. Aguiar, S. M. Hennekens & L. Tichý, 2016: *Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities.* Applied Vegetation Science 19, Suplement 1: 3–264. http://dx.doi.org/10.1111/avsc.12257

Novak, Š., 2015: *Crepis terglouensis (Hacquet) Kerner.* Notulae ad floram Sloveniae. Hladnikia (Ljubljana) 36: 47–50.

Pignatti, E. & S. Pignatti, 2014: *Plant Life of the Dolomites. Vegetation Structure and Ecology.* Publication of the Museum of Nature South Tyrol Nr. 8, Naturmuseum Südtirol, Bozen, Springer Verlag, Heidelberg. https://doi.org/10.1007/978-3-642-31043-0

Pignatti, E. & S. Pignatti, 2016: *Plant Life of the Dolomites.Vegetation Tables.* Publication of the Museum of Nature South Tyrol Nr. 11, Bozen, Springer Verlag, Heidelberg. https://doi.org/10.1007/978-3-662-48032-8

Podani, J., 2001: SYN-TAX 2000. *Computer Programs for Data Analysis in Ecology and Systematics.* User's Manual, Budapest.

Praprotnik, N., 1997: *Crepis terglouensis (Hacq.) A. Kerner.* In: Jogan N.: *Nova nahajališča.* Hladnikia (Ljubljana) 8/9: 59.

Praprotnik, N., 2002: *Triglavski dimek.* Gea (Ljubljana) 12 (5): 65–66.

Seliškar, T., B. Vreš & A. Seliškar, 2003: *FloVegSi 2.0. Fauna, Flora, Vegetation and Paleovegetation of Slovenia. Computer programme for arranging and analysis of biological data.* Biološki inštitut ZRC SAZU, Ljubljana.

Sørensen, Th., 1948: *A method of establishing groups of equal amplitude in plant sociology based on similarity of species content.* Det Kongelige Danske Videnskaberns Selskab, Biologiske Skrifter (København) 5 (4): 1–34.

Surina, B., 2005: *Subalpinska in alpinska vegetacija Krnskega pogorja v Julijskih Alpah.* Scopolia (Ljubljana) 57: 1–122.

Sutter, R., 1969: *Ein Beitrag zur Kenntnis der soziologischen Bindung süd-südostalpiner Reliktendemismen.* Acta Bot. Croatica (Zagreb) 28: 349–365.

Šilc, U. & A. Čarni, 2012: *Conspectus of vegetation syntaxa in Slovenia.* Hacquetia (Ljubljana) 11 (1): 113–164. https://doi.org/10.2478/v10028-012-0006-1

Theurillat, J.-P., 2004: *Pflanzensoziologisches System.* In: Aeschimann, D., K. Lauber, D. M. Moser & J.-P. Theurillat: *Flora alpina 3: Register.* Haupt Verlag, Bern, Stuttgart, Wien, pp. 301–313.

Vidic, N. J., T. Prus, H. Grčman, M. Zupan, A. Lisec, T. Kralj, B, Vrščaj, J. Rupreht, M. Šporar, M. Suhadolc, R. Mihelič, R. & F. Lobnik, 2015: *Tla Slovenije s pedološko karto v merilu 1: 250 000. Soils of Slovenia with soil map 1: 250 000.* European Union & University of Ljubljana, Luxemburg, Ljubljana.

Wraber, T., 1972: *Contributo alla conoscenza della vegetazione pioniere (Asplenietea rupestria e Thlaspeetea rotundifolii) delle Alpi Giulie.* Tesi di laurea. Università degli Studi di Trieste, Facoltà di Scienze, Trieste (Doktorska naloga, 81 pp.)

Wraber, T., 1990: *Sto znamenitih rastlin na Slovenskem.* Prešernova družba, Ljubljana.

Wraber, T., 2006: *2 x Sto alpskih rastlin na Slovenskem.* Prešernova družba, Ljubljana.

Zupan, B. & I. Dakskobler, 2007: *Geum reptans* L. Notulae ad floram Sloveniae 83. Hladnikia (Ljubljana) 20: 36–38.

Zupančič, B., 1998: *Padavine.* In: J. Fridl, D., Kladnik, M. Orožen Adamič & D. Perko (eds.): *Geografski atlas Slovenije. Država v prostoru in času.* Državna založba Slovenije, Ljubljana, pp. 98–99.

Figures 7–14: Photo/Foto: I. Dakskobler

Figure 7: Crepis terglouensis
Slika 7: Triglavski dimek (Crepis terglouensis)

Figure 8: Stand of the association Crepido terglouensis-Potentilletum nitidae
Slika 8: Sestoj asociacije Crepido terglouensis-Potentilletum nitidae

Figure 9: Glava nad Zaplanjo under Mt. Triglav, the area where we have recorded stands of the association Crepido terglouensis-Potentilletum nitidae
Figure 9: Glava nad Zaplanjo, območje, kjer smo popisovali sestoje asociacije Crepido terglouensis-Potentilletum nitidae

Figure 10: Cerastium uniflorum
Slika 10: Enocvetna smiljka (Cerastium uniflorum)

Figure 11: Stand of the association Saxifrago carniolicae-Cerastietum uniflorae
Slika 11: Sestoj asociacije Saxifrago carniolicae-Cerastietum uniflorae

Figure 12: Plateau west from Mt. Triglav, area, where we have recorded stands of the association Saxifrago carniolicae-Cerastietum uniflorae
Slika 12: Planota zahodno od Triglava, kjer smo popisovali sestoje asociacije Saxifrago carniolicae-Cerastietum uniflorae

Figure 13: Geum reptans under Mt. Triglav
Slika 13: Plazeča sretena (Geum reptans) pod Triglavom

Figure 14: Stand of the association Saxifrago sedoidis-Geumetum raptantis
Slika 14: Sestoj asociacije Saxifrago sedoidis-Geumetum raptantis

Table 1 : *Crepido terglouensis-Potentilletum nitidae* and *Saxifrago carniolicae-Cerastietum uniflorae*
Preglednica 1: *Crepido terglouensis-Potentilletum nitidae* in *Saxifrago carniolicae-Cerastietum uniflorae*

	Number of relevé (Zaporedna številka popisa)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21				
	Database number of relevé (Delovna številka popisa)		200147	258065	257626	263298	263403	263404	257613	257623	262576	263406	257664	263408	263409	257614	257617	258067	262577	258068	258073	258071	262578				
	Author of the relevé (Avtor popisa)		TW	ID	IDBZ	ID	ID	ID	IDBZ	IDBZ	ID	ID	IDBZ	ID	ID	IDBZ	IDBZ	ID	ID	ID	ID	ID	ID				
	Elevation in m (Nadmorska višina v m)		2520	2535	2320	2192	2540	2541	2424	2509	2460	2540	2320	2540	2545	2450	2530	2510	2520	2500	2515	2505	2520				
	Aspect (Lega)		SE	NW	NE	SW	NW	SW	SW	SE	W	SSW	NE	SE	SE	S	SSE	SE	NW	N	NWW	SE	NW				
	Slope in degree (Nagib v stopinjah)		10	3	5	0-3	10	5	5	2	30	5	3	10	5	15	15	1	20	25	35	5	20				
	Parent material (Matična podlaga)		Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr				
	Soil (Tla)		Li	Li	Li	Li	Li	Li	Li	Li	Li	Li	Li	Li	Li	Li	Li	Re	Li	Li	Li	Li	Li				
	Stoniness in % (Kamnitost v %)		70	80	70	90	100	100	100	60	20	100	70	100	100	70	70	5	20	70	70	20	90				
	Cover of herb layer in % (Zastiranje zeliščne plasti v %)	E1	30	30	30	30	40	40	30	40	80	30	30	30	40	30	30	90	90	30	30	80	30				
	Cover of moss layer in % (Zastiranje mahovne plasti v %)	E0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	60	.	.	.	.				
	Number of species (Število vrst)		18	14	10	12	19	15	7	3	5	6	3	12	18	15	11	13	6	7	7	12	6				
	Relevé area (Velikost popisne ploskve)	m^2	10	10	4	5	10	10	3	4	2	10	3	10	10	10	5	2	10	2	2	10	10				
	Date of taking relevé (Datum popisa)		7/23/1963	9/1/2015	7/31/2015	8/23/2016	8/24/2016	8/24/2016	8/1/2015	8/1/2015	8/24/2016	8/24/2016	7/31/2015	8/24/2016	8/24/2016	8/1/2015	8/1/2015	9/1/2015	8/24/2016	9/1/2015	9/1/2015	9/1/2015	8/24/2016				
	Locality (Nahajališče)		Kredarica	Glava v Zaplanji	Staničev dom	Vrata-Zelnarica	Glava v Zaplanji	Glava v Zaplanji	Glava v Zaplanji	Kredarica	Glava v Zaplanji	Glava v Zaplanji	Dovška vratca	Glava v Zaplanji	Glava v Zaplanji	Glava v Zaplanji	Glava v Zaplanji	Zaplanja-Morbegna	Glava v Zaplanji	Zaplanja-Morbegna	Zaplanja-Plemenice	Zaplanja-Plamenice	Glava v Zaplanji				
	Quadrant (Kvadrant)		9649/1	9648/2	9649/1	9648/4	9648/2	9648/2	9648/2	9649/1	9648/2	9648/2	9649/1	9648/2	9648/2	9648/2	9648/2	9649/1	9648/2	9649/1	9649/1	9649/1	9648/2				
	Coordinate GK Y (D-48)	m	411886	410068	412723	407539	410065	410057	410088	411865	410015	410082	413236	410173	410178	410048	410213	410448	410103	410369	410602	410448	410119				
	Coordinate GK X (D-48)	m	5137964	5137604	5138748	5133849	5137604	5137597	5137334	5137887	5137499	5137597	5138757	5137644	5137726	5137454	5137628	5137755	5137667	5137842	5138033	5137754	5137676				
	Diagnostic species of the syntaxa (Diagnostične vrste sintaksonov)																							Pr. 1-15	Fr- 1-15	Pr. 16-21	Fr. 16-21
PS	*Potentilla nitida*	E1	2	2	1	1	1	2	3	3	4	3	2	3	3	2	2	.	.	.	.	.	.	15	100	0	0
TR1	*Crepis terglouensis*	E1	1	1	2	3	1	+	2	1	1	+	1	2	1	1	1	.	.	.	.	.	.	15	100	0	0
PC	*Eritrichium nanum*	E1	1	+	.	.	+	+	+	.	.	+	.	+	1	.	.	.	.	.	.	.	.	8	53	0	0
TR1	*Alyssum ovirense*	E1	1	+	.	.	+	+	.	.	.	1	.	+	+	.	.	.	.	.	.	.	.	7	47	0	0
PC	*Minuartia cherlerioides*	E1	.	1	.	.	1	1	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.	6	40	0	0
AA	*Cerastium uniflorum*	E1	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1	2	3	2	4	1	2	13	6	100
TR1	*Saxifraga sedoides*	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	+	2	0	0	6	100
Cfir	*Saxifraga exarata subsp. carniolica*	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	1	.	0	0	4	67
TR1	***Thlaspion rotundifolii***																										
	Papaver julicum	E1	+	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	1	+	.	1	3	20	3	50
	Thlaspi cepeaefolium (T. rotundifolium, Noccaea rotundifolia)	E1	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	2	13	0	0
TR2	***Thlaspieetalia rotundifolii***																										
	Poa minor	E1	.	.	.	.	.	.	.	.	+	.	.	+	+	1	+	.	.	.	.	.	.	5	33	0	0

	Number of relevé (Zaporedna številka popisa)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Pr. 1-15	Fr- 1-15	Pr. 16-21	Fr. 16-21
	Achillea atrata	E1	+	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	.	.	.	.	.	3	20	1	17
	Cerastium carinthiacum subsp. carinthiacum	E1	.	.	+	1	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	4	27	0	0
	Moehringia ciliata	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	1	7	1	17
	Armeria alpina	E1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	7	0	0
AC	***Arabidetalia caeruleae***																										
	Salix retusa	E1	+	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	27	0	0
	Salix serpyllifolia	E1	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	2	13	2	33
CD	*Carex capillaris*	E1	.	.	.	.	+	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	3	20	0	0
	Carex ornithopodoides	E1	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	13	0	0
	Carex parviflora	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	0	0	1	17
SH	*Sagina saginoides*	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	1	.	0	0	2	33
	Saxifraga androsacea	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	+	.	0	0	2	33
DH	*Sesleria ovata*	E1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	7	0	0
TR3	***Thlaspietea rotundifolii***																										
	Taraxacum alpinum	E1	.	r	.	.	+	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	4	27	0	0
	Saxifraga oppositifolia s.str.	E1	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2	13	1	17
	Linaria alpina	E1	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	1	7	0	0
	Festuca nitida	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	1	7	0	0
	Arabis alpina	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	0	0	1	17
PC	***Potentilletalia caulescentis***																										
	Valeriana elongata	E1	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	20	0	0
	Festuca alpina	E1	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	1	.	2	13	1	17
	Campanula cochleariifolia	E1	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	2	13	0	0
	Saxifraga paniculata	E1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+	.	.	.	.	.	.	2	13	0	0
	Petrocallis pyrenaica	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	+	.	2	13	1	17
Cfir	***Caricion firmae***																										
	Minuartia verna	E1	1	.	+	+	.	.	+	1	.	.	.	+	+	.	.	.	+	.	.	+	.	7	47	2	33
	Silene acaulis	E1	+	2	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	5	33	2	33
	Carex firma	E1	1	+	1	1	1	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	7	47	0	0
	Minuartia sedoides	E1	1	2	+	1	.	.	+	.	.	.	.	.	+	.	.	.	.	1	.	.	.	6	40	1	17
	Phyteuma sieberi	E1	.	+	.	+	+	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	7	47	0	0
	Sesleria sphaerocephala	E1	.	.	.	.	+	+	+	.	.	+	.	.	+	.	.	.	.	.	.	.	.	5	33	0	0
	Gentiana terglouensis	E1	.	1	.	.	+	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	4	27	0	0
	Festuca quadriflora	E1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	1	7	2	33
	Saussurea pygmaea	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1	7	0	0
	Veronica aphylla	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	0	0	1	17
OE	***Oxytropido-Elynion***																										
	Arenaria ciliata	E1	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	13	0	0
	Erigeron uniflorus	E1	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	1	7	1	17
	Lloydia serotina	E1	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1	7	0	0
ES	***Elyno-Seslerietea***																										
PAT	*Poa alpina*	E1	+	+	+	+	.	+	.	.	.	.	.	+	.	+	.	1	4	1	+	1	1	7	47	6	100
	Myosotis alpestris	E1	+	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	1	5	33	1	17
	Polygonum viviparum	E1	+	.	.	1	+	+	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	6	40	0	0
ML	**Mosses (Mahovi)**																										
	Syntrichia norvegica	E0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4	.	.	.	.	0	0	2	33
	Bryum sp.	E0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	0	0	1	17

Legend - Legenda
ID Igor Dakskobler
BZ Branko Zupan
TW Tone Wraber
Gr Gravel - grušč
Li Lithosol - kamnišče
Pr. Presence (number of relevés in which the species is presented) - število popisov, v katerih se pojavlja vrsta
Fr. Frequency in % - frekvenca v %
Re Rendzina - rendzina
PS Physoplexido-Saxifragion petraeae
AA *Androsacion alpinae*
CD *Caricetalia davallianae*
SH *Salicetea herbaceae*
DH *Drabion hoppeanae*
PAT *Poo alpinae-Trisetetalia*

Table 2: Groups of diagnostic species in the stands of syntaxa *Crepido terglouensis-Potentilletum nitidae* (CtPn) and *Saxifrago carniolicae-Cerastietum uniflorae* (ScCu), relative frequencies

Preglednica 2: Skupine diagnostičnih vrst v sestojih sintaksonov *Crepido terglouensis-Potentilletum nitidae* (CtPn) and *Saxifrago carniolicae-Cerastietum uniflorae* (ScCu), relativne frekvence

Successive number (Zaporedna številka)	1	2
Sign for syntaxa (Oznaka sintaksona)	CtPn	ScCu
Number of relevés (Število popisov)	15	6
Arabidetalia caeruleae	**8,304**	**26,01**
Thlaspion rotundifolii	**16,07**	**18,01**
Thlaspieetalia rotundifolii	**8,333**	4,002
Thlaspietea rotundifolii	4,762	4,002
Potentilletalia caulescentis	**23,81**	4,002
Caricion firmae	25,6	**24,01**
Oxytropido-Elynion	2,381	2,001
Elyno-Seslerietea	10,71	**14,01**
Moses (Mahovi)	0	4,002
Total (Skupaj)	100	100

Table 3: Communities with *Geum reptans* in the Triglav Mts.
Preglednica 3: Združbi z vrsto *Geum reptans* v Triglavskem pogorju

	Number of relevé (Zaporedna številka popisa)		1	2	
	Database number of relevé (Delovna številka popisa)		217413	262400	
	Author of the relevé (Avtor popisa)		IDBZ	ID	
	Elevation in m (Nadmorska višina v m)		2470	2060	
	Aspect (Lega)		SSE	SW	
	Slope in degrees (Nagib v stopinjah)		5	25	
	Parent material (Matična podlaga)		Gr	Gr	
	Soil (Tla)		Li	Li	
	Stoniness in % (Kamnitost v %)		20	80	
	Cover of herb layer in % (Zastiranje zeliščne plasti v %):	E1	80	35	
	Number of species (Število vrst)		13	31	
	Relevé area (Velikost popisne ploskve)	m^2	5	100	
	Date of taking relevé (Datum popisa)		7/26/2007	8/8/2016	
	Locality (Nahajališče)		Poprovec-Teme	Vrh Zelenic-Skok	
	Quadrant (Kvadrant)		9648/2	9648/2	
	Coordinate GK Y (D-48)	m	408402	409533	
	Coordinate GK X (D-48)	m	5135506	5138047	
AA	***Androsacion alpinae***				Pr.
	Geum reptans	E1	4	3	2
AC	***Arabidetalia caeruleae***				
	Doronicum glaciale	E1	.	+	1
	Galium noricum	E1	.	+	1
	Salix retusa	E1	.	+	1
TR1	***Thlaspion rotundifolii***				
	Thlaspi cepeaefolium (T. rotundifolium, Noccaea rotundifolia)	E1	+	+	2
	Alyssum ovirense	E1	+	.	1
	Papaver julicum	E1	+	.	1
	Saxifraga sedoides	E1	.	1	1
TR2	***Thlaspieetalia rotundifolii***				
	Achillea atrata	E1	+	+	2
	Moehringia ciliata	E1	+	+	2
	Festuca nitida	E1	.	1	1
	Poa minor	E1	.	1	1
TR3	***Thlaspietea rotundifolii***				
	Saxifraga oppositifolia s.str.	E1	+	.	1
	Taraxacum alpinum agg.	E1	+	.	1
	Arabis alpina	E1	.	+	1
PS	***Physoplexido-Saxifragion petraeae***				
	Potentilla nitida	E1	1	.	1
	Paederota lutea	E1	.	+	1
	Saxifraga crustata	E1	.	+	1
	Saxifraga squarrosa	E1	.	+	1
PC	***Potentilletalia caulescentis***				
	Saxifraga paniculata	E1	+	1	2
	Festuca alpina	E1	+	.	1
	Campanula cochleariifolia	E1	.	+	1
CA	***Caricion austroalpinae***				
	Arabis vochinensis	E1	.	+	1
Cfir	***Caricion ferrugineae***				
	Gentiana pumila	E1	.	+	1
OE	***Oxytropido-Elynion***				
	Arenaria ciliata	E1	.	+	1
Cfir	***Caricion firmae***				
	Minuartia verna	E1	+	+	2
	Carex firma	E1	.	+	1
	Dryas octopetala	E1	.	+	1
	Pedicularis rostratocapitata	E1	.	+	1
	Phyteuma sieberi	E1	.	+	1
	Silene acaulis	E1	.	+	1

	Number of relevé (Zaporedna številka popisa)		1	2	Pr.
ES	***Elyno-Seslerietea***				
	Polygonum viviparum	E1	.	1	1
	Aster bellidiastrum	E1	.	+	1
	Pedicularis verticillata	E1	.	+	1
	Achillea clavenae	E1	.	+	1
MC	***Montio-Cardaminetea***				
	Saxifraga aizoides	E1	.	1	1
PAT	***Poo alpinae-Trisetetalia***				
	Poa alpina	E1	+	1	2

Legend - Legenda
ID Igor Dakskobler
BZ Branko Zupan
Gr Gravel - grušč
Li Lithosol - kamnišče

Appendix 1: Synthetic table of communities with *Potentilla nitida* and/or *Crepis terglouensis* in Eastern and Southeastern Alps
Dodatek 1: Sintezna tabela združb z vrstama *Potentilla nitida* in/ali *Crepis terglouensis* v Vzhodnih in Jugovzhodnih Alpah

	Successive number (Zaporedna številka)		1	2	3	4
	Number of relevés (Število popisov)		25	15	33	1
	Sign for syntaxa (Oznaka sintaksonov)		CT	CTPN	PN	CTPN
TR1	***Thlaspion rotundifolii***					
	Crepis terglouensis	E1	100	100	.	1
	Galium megalospermum	E1	76	.	.	.
	Arabis bellidifolia subsp. bellidifolia	E1	52	.	.	.
	Pritzelago alpina subsp. alpina (Hutchinsia alpina)	E1	44	.	3	.
	Saxifraga aphyla	E1	12	.	.	.
	Thlaspi cepeaefolium (T. rotundifolium, Noccaea rotundifolia)	E1	8	13	.	.
	Alyssum ovirense	E1	.	47	15	1
	Papaver julicum	E1	.	20	12	.
	Saxifraga sedoides	E1	.	.	15	.
	Festuca rupicaprina	E1	.	.	8	.
TR2	***Thlaspietalia rotundifolii***					
	Poa cenisia	E1	24	.	.	.
	Poa minor	E1	16	33	.	.
	Linaria alpina	E1	8	7	6	+
	Doronicum grandiflorum	E1	4	.	.	.
	Cerastium carinthiacum	E1	.	27	3	+
	Achillea atrata	E1	.	20	3	.
	Armeria alpina	E1	.	7	.	+
	Moehringia ciliata	E1	.	7	.	.
	Sedum atratum	E1	.	.	3	.
AC	***Arabidetalia caeruleae***					
	Salix serpyllifolia	E1	16	13	15	1
MC	*Saxifraga aizoides*	E1	12	.	3	.
	Ranunculus alpestris	E1	4	.	.	.
	Salix retusa	E1	.	27	24	.
CD	*Carex capillaris*	E1	.	20	9	.
AA	*Cerastium uniflorum*	E1	.	13	3	.
	Carex ornithopodoides	E1	.	13	3	.
DH	*Sesleria ovata*	E1	.	7	.	.
JT	*Carex fuliginosa*	E1	.	.	30	.
	Ranunculus traunfellneri	E1	.	.	12	.
	Doronicum glaciale	E1	.	.	6	.
	Salix reticulata	E1	.	.	3	.
	Trifolium pallescens	E1	.	.	3	.
TR3	***Thlaspietea rotundifolii***					
	Athamantha cretensis	E1	36	.	.	.
	Trisetum distichophyllum	E1	12	.	.	.
	Gypsophila repens	E1	8	.	.	.
	Silene vulgaris subsp. glareosa	E1	8	.	.	.
	Taraxacum alpinum	E1	.	27	.	.
	Saxifraga oppositifolia s.str.	E1	.	13	70	.
	Festuca nitida	E1	.	7	.	.
	Pritzelago alpina subsp. brevicaulis	E1	.	.	3	.
PS	***Physoplexido-Saxifragion petraeae***					
	Potentilla nitida	E1	.	100	97	2
	Saxifraga squarrosa	E1	.	.	73	.
	Saxifraga crustata	E1	.	.	27	.
	Campanula zoysii	E1	.	.	24	.
	Paederota lutea	E1	.	.	3	.
PC	***Potentilletalia caulescentis***					
	Campanula cochleariifolia	E1	56	13	42	+
	Eritrichium nanum	E1	.	53	52	+
	Minuartia cherlerioides	E1	.	40	55	.
	Valeriana elongata	E1	.	20	3	.
	Festuca alpina	E1	.	13	79	.
	Petrocallis pyrenaica	E1	.	13	42	+

	Successive number (Zaporedna številka)		1	2	3	4
	Saxifraga paniculata	E1	.	13	61	.
	Draba tomentosa	E1	.	.	45	.
	Saxifraga exarata subsp. carniolica	E1	.	.	24	.
	Potentilla clusiana	E1	.	.	21	1
	Arabis bellidifolia subsp. stellulata	E1		.	18	.
	Saxifraga burseriana	E1	.	.	12	.
	Androsace helvetica	E1	.	.	6	.
	Primula auricula	E1	.	.	3	.
	Dianthus sylvestris	E1	.	.	3	.
CF	***Caricion ferrugineae***					
	Viola biflora	E1	40	.	3	.
	Heliosperma pusillum	E1	12	.	.	.
	Carex ferruginea	E1	4	.	.	.
Cfir	***Caricion firmae***					
	Festuca quadriflora	E1	76	7	6	.
	Carex firma	E1	56	47	45	+
	Dryas octopetala	E1	32	.	3	.
	Minuartia verna	E1	24	47	61	+
	Silene acaulis	E1	24	33	30	+
	Minuartia sedoides	E1	12	40	82	+
	Crepis kerneri	E1	8	.	.	.
	Saxifraga caesia	E1	8	.	3	.
	Phyteuma sieberi	E1	.	47	.	.
	Sesleria sphaerocephala	E1	.	33	70	.
	Gentiana terglouensis	E1	.	27	52	+
	Saussurea pygmaea	E1	.	7	6	.
	Helianthemum alpestre	E1	.	.	18	.
	Gentiana orbicularis	E1	.	.	12	.
	Salix alpina	E1	.	.	9	+
	Oxytropis neglecta	E1	.	.	6	.
	Pedicularis rostratocapitata	E1	.	.	6	.
	Carex rupestris	E1	.	.	3	.
	Pedicularis rosea	E1	.	.	3	.
	Veronica aphylla	E1	.	.	3	.
OE	***Oxytropido-Elynion***					
	Arenaria ciliata	E1		13	33	.
	Lloydia serotina	E1	.	7	15	.
	Erigeron uniflorus	E1	.	7	3	.
ES	***Elyno-Seslerietea***					
	Polygonum viviparum	E1	40	40	39	.
	Sesleria caerulea	E1	28	.	9	.
	Euphrasia salisburgensis	E1	12	.	3	.
	Carex sempervirens	E1	4	.	3	.
	Pedicularis oederi	E1	4	.	.	.
	Galium anisophyllon	E1	4	.	.	.
PaT	*Poa alpina*	E1	.	47	55	.
	Myosotis alpestris	E1	.	33	3	.
	Draba aizoides	E1	.	.	33	.
	Erigeron glabratus	E1	.	.	18	.
	Achillea clavenae	E1	.	.	15	.
	Leontopodium alpinum	E1	.	.	6	.
	Agrostis alpina	E1	.	.	3	.
	Aster bellidiastrum	E1	.	.	3	.
EP	***Erico-Pinetea***					
	Asperula aristata	E1	8	.	.	.
	Rhodothamnus chamaecistus	E1	.	.	3	.
O	**Other species (Druge vrste)**					
	Saxifraga sp.	E1	.	.	3	.
	Thymus sp.	E1	.	.	3	.
ML	**Mosses and lichens (Mahovi in lišaji)**					
	Tortella tortuosa	E0	8	.	.	.
	Distichum capillaceum	E0	8	.	.	.

Successive number (Zaporedna številka)		1	2	3	4
Ctenidium molluscum	E0	4	.	.	.
Orthotecium rufescens	E0	4	.	.	.
Cladonia sp.	E0	4	.	.	.
Pohlia cruda	E0	4	.	.	.
Encalypta streptocarpa	E0	4	.	.	.
Hypnum bambergeri	E0	4	.	.	.
Ctenidium procerrimum	E0	4	.	.	.

Legend - Legenda
CT *Crepidetum terglouensis* (Eggensbeger 1994, Table 6, Columns 85–111)
CTPN *Crepido-Potentilletum nitidae,* this article, Table 1, Coliumns 1-15
PN *Potentilletum nitidae,* T. Wraber 1972, Table 3
CTPN *Crepido-Potentilletum nitidae,* Sutter (1969: 353)
MC *Montio-Cradaminetea*
CD *Caricetalia davallianae*
AA *Androsacion alpinae*
DH *Drabion hoppeanae*
PAT *Poo alpinae-Trisetetalia*
JT *Juncetea trifidi*

Appendix 2: Communities with *Cerastium uniflorum* and *Saxifraga sedoides* in SE Alps
Preglednica 2: Združbi z vrstama *Cerastium uniflorum* in *Saxifraga sedoides* v JV Alpah

	Successive number (Zaporedna številka)		1	2
	Number of relevés (Število popisov)		15	6
	Sign for syntaxa (Oznaka sintaksonov)		Ss	ScSu
AC	***Arabidetalia caeruleae***			
AA	*Cerastium uniflorum*	E1	47	100
MC	*Saxifraga stellaris subsp. alpigena*	E1	13	
	Soldanella minima	E1	13	.
AA	*Doronicum clusii*	E1	7	.
	Ranunculus alpestris	E1	7	.
DH	*Draba hoppeana*	E1	7	.
	Salix serpyllifolia	E1	.	33
	Saxifraga androsacea	E1	.	33
SH	*Sagina saginoides*	E1	.	33
	Carex parviflora	E1	.	17
TR1	***Thlaspion rotundifolii***			
	Saxifraga sedoides	E1	100	100
	Pritzelago alpina subsp. alpina	E1	60	.
	Thlaspi cepeaefolium (T. rotundifolium, Noccaea rotundifolia)	E1	53	.
	Papaver rhaeticum	E1	27	.
	Arabis bellidifolia subsp. bellidifolia	E1	20	.
	Papaver julicum	E1	.	50
TR2	***Thlaspietalia rotundifolii***			
	Poa minor	E1	67	.
	Arabis alpina	E1	60	17
	Moehringia ciliata	E1	47	17
	Cerastium carinthiacum	E1	20	.
	Achillea oxyloba	E1	13	.
	Achillea atrata	E1	.	17

	Successive number (Zaporedna številka)		1	2
TR3	***Thlaspietea rotundifolii***			
	Saxifraga oppositifolia s.str.	E1	13	17
	Pritzelago alpina subsp. brevicaulis	E1	7	.
	Taraxacum alpinum	E1	7	.
PC	***Potentilletalia caulescentis***			
	Festuca alpina	E1	20	17
	Campanula cochleariifolia	E1	13	.
	Androsace hausmanii	E1	7	.
	Phyteuma sieberi	E1	7	.
	Valeriana elongata	E1	7	.
	Cystopteris regia	E1	7	.
	Petrocallis pyrenaica	E1	.	17
	Saxifraga exarata subsp. carniolica	E1	.	67
Cfir	***Caricion firmae***			
	Minuartia sedoides	E1	20	17
	Sesleria sphaerocephala	E1	13	.
	Minuartia verna	E1	7	33
	Silene acaulis	E1	7	33
OE	*Erigeron uniflorus*	E1	7	17
	Festuca quadriflora	E1	.	33
	Veronica aphylla	E1	.	17
ES	***Elyno-Seslerietea***			
PAT	*Poa alpina*	E1	27	100
	Polygonum viviparum	E1	13	.
CF	*Heliosperma pusillum*	E1	7	.
	Myosotis alpestris	E1	.	17
M	**Mosses and lichens (Mahovi in lišaji)**			
	Musci spp.	E0	13	.
	Grimmia sp.	E0	7	.
	Marchantia sp.	E0	7	.
	Syntrichia norvegica	E0	.	33
	Bryum sp.	E0	.	17

Legend - Legenda

Ss *Saxifragetum sedoidis*, E. & S. Pignatti, 2016, Association Table 9.2
ScCu *Saxifrago carniolicae-Cerastietum uniflorae*, this article
MC *Montio-Cradaminetea*
CD *Caricetalia davallianae*
AA *Androsacion alpinae*
DH *Drabion hoppeanae*
PAT *Poo alpinae-Trisetetalia*
SH *Salicetea herbaceae*
CF *Caricion ferrugineae*

NEW LOCALITIES OF *ADIANTUM CAPILLUS-VENERIS* IN THE RIVER-BASIN OF VOLARJA/VOLARNIK (THE JULIAN ALPS) AND PHYTOSOCIOLOGICAL ANALYSIS OF ITS SITES

NOVA NAHAJALIŠČA VRSTE *ADIANTUM CAPILLUS-VENERIS* V POREČJU VOLARJE/VOLARNIKA (JULIJSKE ALPE) IN FITOCENOLOŠKA ANALIZA NJENIH RASTIŠČ

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ABSTRACT

New localities of *Adiantum capillus-veneris* in the river basin of the Volarja/Volarnik (the Julian Alps) and a phytosociological analysis of its sites

The article describes the localities, sites and communities of *Adiantum capillus-veneris* along the Volarja/Volarnik, the right tributary of the Soča River between Tolmin and Kobarid (9747/4). We classified its communities from three locations at elevations between 210 and 250 m into the subassociation *Eucladio-Adiantetum cratoneuretosum commutati*, a new variant *Eucladio-Adiantetum hymenostylietosum recurvirostri* var. *Pinguicula alpina* and into the new association *Adianto-Molinietum arundinaceae.*

Key words: phytosociology, synsystematics, *Eucladio--Adiantetum, Adianto-Molinietum arundinaceae*, Natura 2000, Upper Soča Valley, Julian Alps, Slovenia

IZVLEČEK

Nova nahajališča vrste *Adiantum capillus-veneris* v porečju Volarje/Volarnika (Julijske Alpe) in fitocenološka analiza njenih rastišč

V članku opisujemo nahajališča, rastišča in združbe vrste *Adiantum capillus-veneris* ob Volarji/Volarniku, desnem pritoku Soče med Tolminom in Kobaridom (9747/4). Njene združbe na treh krajih, na nadmorski višini od 210 m do 250 m, uvrščamo v subasociacijo *Eucladio-Adiantetum cratoneuretosum commutati*, v novo varianto *Eucladio--Adiantetum hymenostylietosum recurvirostri* var. *Pinguicula alpina* in v novo asociacijo *Adianto-Molinietum arundinaceae.*

Ključne besede: fitocenologija, sinsistematika, *Eucladio-Adiantetum, Adianto-Molinietum arundinaceae*, Natura 2000, Zgornje Posočje, Julijske Alpe, Slovenija

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1 INTRODUCTION

The Mediterranean (subtropical, paleotemperate) fern *Adiantum capillus-veneris*, a character species of communities growing on permanently moist to wet rocks, is distributed in the hill belt across the entire southern stretch of the Alps (Aeschimann et al. 2004: 66). Two localities have been reported so far for the Alpine part of Slovenia, in the Brezna/Brizna Grapa gorge at the foothills of Mali Vrh above Grahovo ob Bači and in the river beds of the Mrzlica/Mrzli Potok brook under the village of Krn (at the elevation of 510 m, which makes it its highest locality in Slovenia). Both localities have recently been described by Rojšek (2015a). We examined them in terms of phytosociology as well and looked also into the localities of this fern in the Soča Valley between Ročinj and Solkan, in the Idrija Valley, in the Karst region (Škocjan Caves) and on several other localities in Istria (Dakskobler, Martinčič & Rojšek 2014). On 24 July 2016 we discovered new localities of this fern on three spots on the right bank of the Volarja/Volarnik at the village of Selišče (Dakskobler 2017 and Figures 1 and 2). They are situated in the basin of the same river (the Volarja) as the locality in the Mrzlica gorge, but are much more extensive and occupy a different quadrant of Central-European flora mapping (9747/4). In this article we provide a detailed description of these localities and present the species composition of the studied communities with a phytosociological table. Based on our comparison with relevés from other regions of Slovenia we will classify these communities into the syntaxonomic system.

2 METHODS

Vegetation on the localities of *Adiantum capillus-veneris* was researched applying the standard Central-European method (Braun-Blanquet 1964). On 12 recorded plots we collected mosses and liverworts which one of the authors, Andrej Martinčič, determined in the laboratory. All relevés were entered into the

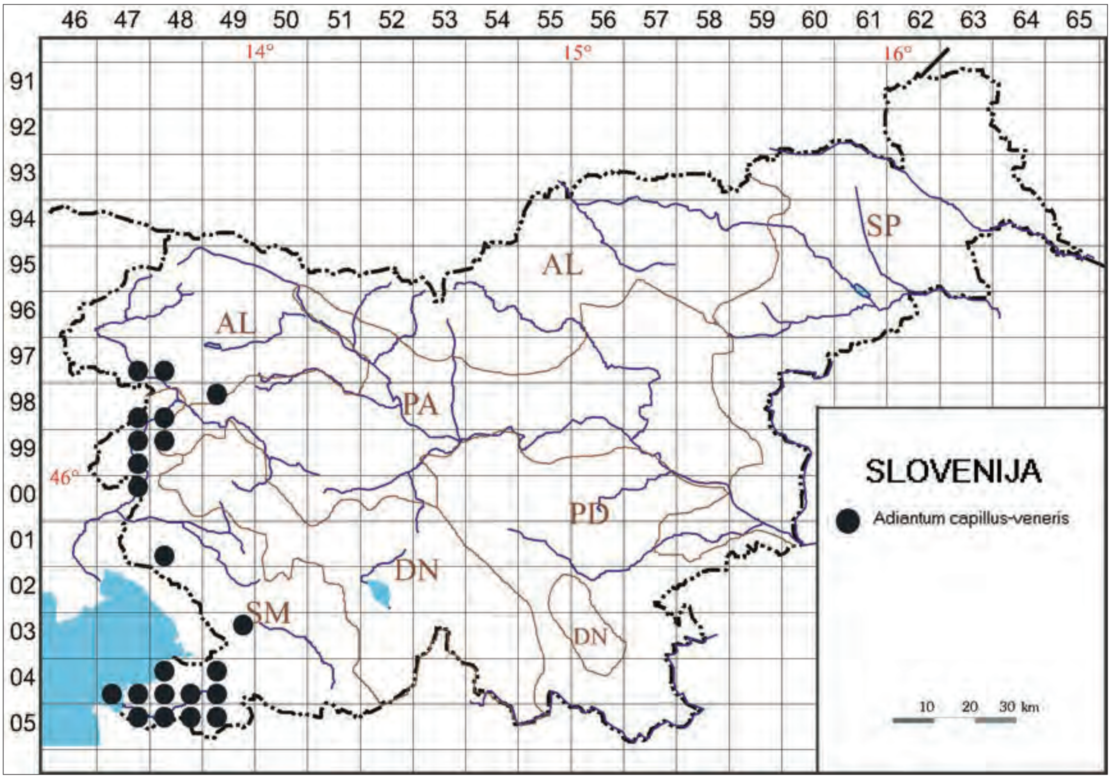

Figure 1: Distribution of Adiantum capillus-veneris in Slovenia
Slika 1: Razširjenost vrste Adiantum capillus-veneris v Sloveniji

FloVegSi database (T. Seliškar, Vreš & A. Seliškar 2003). Combined cover-abundance values were transformed into numerical values 1–9 (van der Maarel 1979). Programme package SYN-TAX (Podani 2001) was used in numerical comparisons. The relevés were mutually compared by means of hierarchical classification. We applied the (unweighted) pair group method with arithmetic mean (UPGMA) and Wishart's similarity ratio as a measure of dissimilarity. The nomenclature source for the names of vascular plants is the Mala flora Slovenije (Martinčič et al. 2007). Ros et al. (2007) is the nomenclature source for the names of liverworts (*Marcanthiophyta*) and Ros et al. (2013) for the names of mosses. The nomenclature sources for the names of syntaxa are Theurillat (2004), Šilc & Čarni (2012) and Dakskobler, Martinčič & Rojšek (2014). The source for geological bedrock data was Buser (1986, 1987, 2009), and Zupančič (1995, 1998), Mekinda-Majaron (1995) and Cegnar (1998) for climatic data.

3 RESULTS AND DISCUSSION

3.1 Description of new localities of *Adiantum capillus-veneris* in the gorge of the Volarja

The Volarja/Volarnik is the right tributary of the Soča River that originates from several distributaries on the southern slopes of the Krn Mountains and runs into the Soča at Selišče. In the lower course, for about 1.6 km between the confluence with the Soča and the confluence with the left tributary Mrzlica/Mrzli Potok/Mrzuc/Zalazčenca, it has a relatively wide bed, whereas the beds above this section are narrow as they had been cut into troughs and ravines. The right (western)

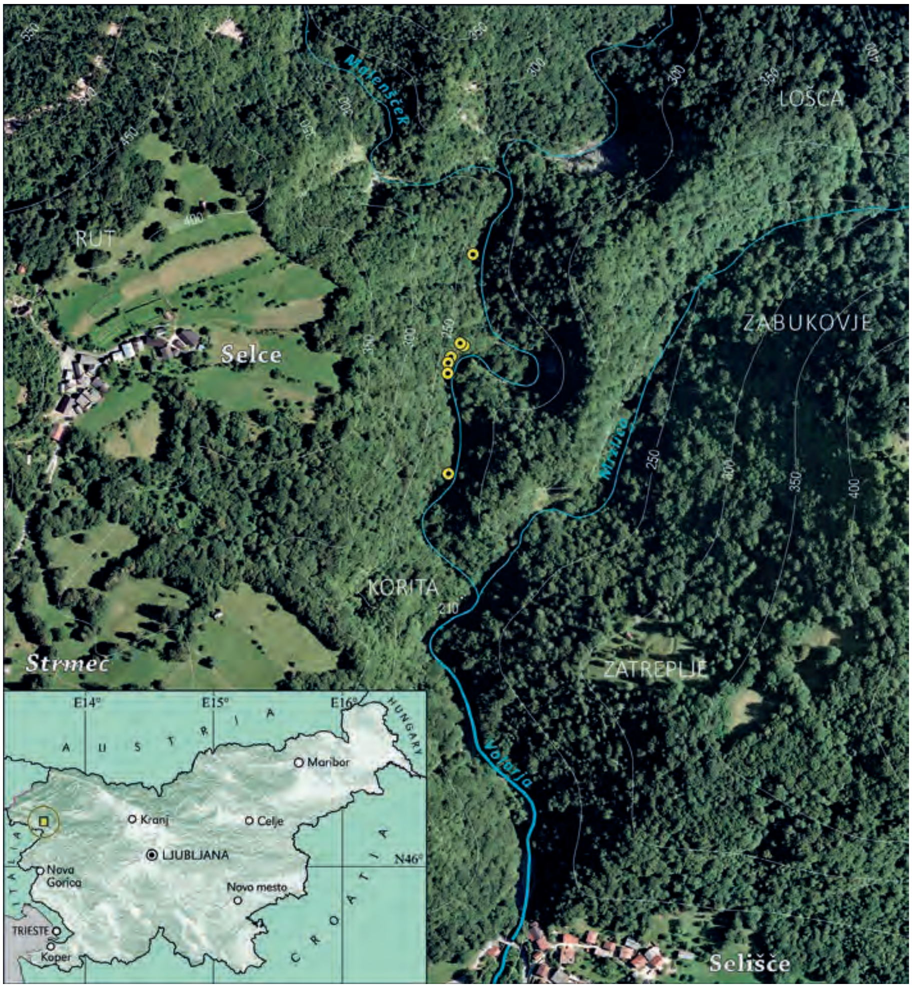

Figure 2: New localities of Adiantum capillus-veneris in the gorge of the Volarja near the village of Selišče
Slika 2: Nova nahajališča vrste Adiantum capillus-veneris v grapi Volarje pri vasi Selišče

branch of the Volarja, in the terms used by Podobnik (1983), has the same name, Volarja, even though it is marked as Malenšček on some of the older maps. This is also the name of the next right (western) tributary that joins the Volarja about 500 m upstream from the confluence with the Mrzlica. Its lower course as well as the section of the Volarja up until the confluence with the Mrzlica is known also as Brinta (Medvešček & Skrt 2016: 34). The Volarja/Volarnik has a distinctly torrential outflow and in autumn and spring, when the river bed is full of water, it looks like a small river in its lower course, but turns into a brook with little water in summer and spring. All of the new maidenhair fern localities are on the right bank along the sources in the relatively short section of the Volarja/Volarnik river bed (spanning about 500 m) above the confluence with the Mrzlica, at elevations between 210 and 250 m (Figure 2). Heavily fractured and folded rock is formed by reddish platy limestone and marlstone interlayered with chert sheets and nodules (K21+2, Cenomanian and Turonian, between 90 and 105 million years old). The climate in this part of the Soča Valley is relatively warm and humid, with mean annual temperature between 8 and 10 °C and mean annual precipitation volume exceeding 2000 mm.

The first maidenhair fern locality (relevé 14 in Table 1) is situated about 100 m above the confluence with the Mrzlica at the elevation of about 210 m. More than one hundred maidenhair ferns grow here (a little more than 2 m high and 1.5 m wide) in tufa deposited by the seeping water in the lower part of a perpendicular and rather heavily overgrown, more than 10 m high rock level with distinct, heavily folded and fractured layers of limestone with intercalated marlstone (Figures 2 and 3).

The next locality is situated about 150 m upstream from the first, in a pronounced bend (Figures 2 and 4). The almost perpendicular right bank (slope break) is almost 80 metres high there and overgrown with open scrub communities. It is dominated by *Salix appendiculata*, *Ostrya carpinifolia*, *Ulmus glabra* and *Fraxinus ornus*, and by *Molinia caerulea* subsp. *arundinacea*, *Calamagrostis varia* and *Erica carnea* in the herb layer. Tufa is deposited from the seeping water. It is overgrown with maidenhair ferns that occur also on the moist parts of the parent material. The total surface

Figure 3: The first locality of Adiantum capillus-veneris in the gorge of the Volarja. Photo: I. Dakskobler
Slika 3: Prvo nahajališče vrste Adiantum capillus-veneris v grapi Volarje. Foto: I. Dakskobler

Figure 4: The second locality of Adiantum capillus-veneris in the gorge of the Volarja. Photo: I. Dakskobler
Slika 4: Drugo nahajališče vrste Adiantum capillus-veneris v grapi Volarje. Foto: I. Dakskobler

area extends over several ares at between 220 a d 250 m a.s.l. It is estimated to comprise several thousand specimens of *Adiantum capillus-veneris* and is therefore its most prolific locality both in the Soča Valley and Slovenia. It is divided into two parts, the south and the north, by a 15-m-high and up to 7-m-wide, dry pillar of bare rock. The pillar is composed of striking limestone folds with marlstone intercalations. Five of our relevés (relevés 10, 11, 12, 13 and 20 in Table 1) were made on this locality.

The third locality is about 200 m above the second, at the elevation of ca. 235 m. While the bank here is also perpendicular it is not as high as on the previous localities as it ascends only about four metres above the stream. Water seeping through the bedrock forms tufa deposits. These and marlstone layers are overgrown with maidenhair fern, a total of 20 plants. This is a modest yet striking locality, with vertical limestone and marlstone layers that are overgrown with mosses and maidenhair ferns (relevé 15 in Table 1).

3.2 Phytosociological analysis of relevés with *Adiantum capillus-veneris* in the gorge of the Volarja

Our comparison was based on 39 previously published relevés (Dakskobler, Martinčič & Rojšek 2014) to which we added seven relevés from the gorge of the Volarja and three relevés from the Sopet gorge at Plave (Rojšek, 2015b). The new table comprises also the relevé from the small brecciated spring above the Brezna/Brizna gorge at Grahovo ob Bači (det. I. Dakskobler and D. Rojšek, 9. 12. 2014, relevé 19 in Table 1, mosses determined by A. Martinčič, 20. 2. 2017) and a relevé from the Piševec gorge (Šmarje pri Kopru, 0548/1, det. I. Dakskobler and Z. Sadar, 7. 5. 2014, mosses determined by A. Martinčič, 20. 2. 2017, relevé 18 in Table 1). A total of 51 relevés clustered into several groups that mainly correspond to the syntaxa we described in 2014 (Figure 6): *Eucladio-Adiantetum eucladietosum*,- *-hymenostylietosum recurvirostri*, *-cratoneuretosum commutati*, *-conocephaletosum conici* and *Phyteumato columnae-Adiantetum capilli-veneris*. New relevés

Figure 5: The third locality of Adiantum capillus-veneris in the gorge of the Volarja. Photo: I. Dakskobler
Slika 5: Tretje nahajališče vrste Adiantum capillus-veneris v grapi Volarje. Foto: I. Dakskobler

from the Volarja grouped mainly with the relevés from the Brezna Grapa gorge at Grahovo ob Bači and the nearby Mrzlica (subassociation -*hymenostylietosum recurvirostri*), while the relevés from the first and third locality grouped with the relevés of the subassociation -*cratoneuretosum commutati*.

Table 1 comprises new, previously unpublished relevés (12) as well as some already published relevés that show the greatest similarity to the new relevés. Based on the previously described comparison they are classified into the association *Eucladio-Adiantetum* Br.-Bl. 1931. Its subassociation -*hymenostylietosum recurvirostri* Dakskobler, Martinčič et Rojšek 2014 comprises the relevés from the Brezna/Brizna Grapa gorge at Grahovo ob Bači and the Mrzlica (which is the closest to the new locality in the nearby Volarja) as well as one relevé from the Sopet brook at Plave and four relevés from the Volarja gorge. The latter grouped separately and based on their species composition they can be classified into the new variant with *Pinguicula alpina*. Its differential species include *Calamagrostis varia* (mainly on account of higher coverage that it has here compared to the relevés of other syntaxa compared), *Carex brachystachys*, *Campanula cespitosa* and *Saxifraga aizoides*. The last three species have not yet been recorded on other maidenhair fern localities in Slovenia. While T. Wraber reported *Campanula cespitosa* for the maidenhair fern locality at Grahovo ob Bači (field notes from 1984, Wraber's library at the Botanical Garden of the University of Ljubljana), he gave no mention of this species for this locality in the published article (Wraber 1986). Individual occurrences of these taxa, which are mainly distributed in the Alps, characterise the stands of the new variant both in terms of phytogeography and ecology. Such occurrence can be attributed to the proximity of mountains rising to 2,000 m and higher under which these gorges with their headwaters are situated as well as with special geological and geomorphological conditions and the local climate. An even more prominent example of co-occurrence of Mediterranean fern and hygrophilous subalpine-alpine chasmophytic species, grassland and headwaters species is known from Italy, where a new association *Himenostylio recurvirostri-Pinguiculetum*

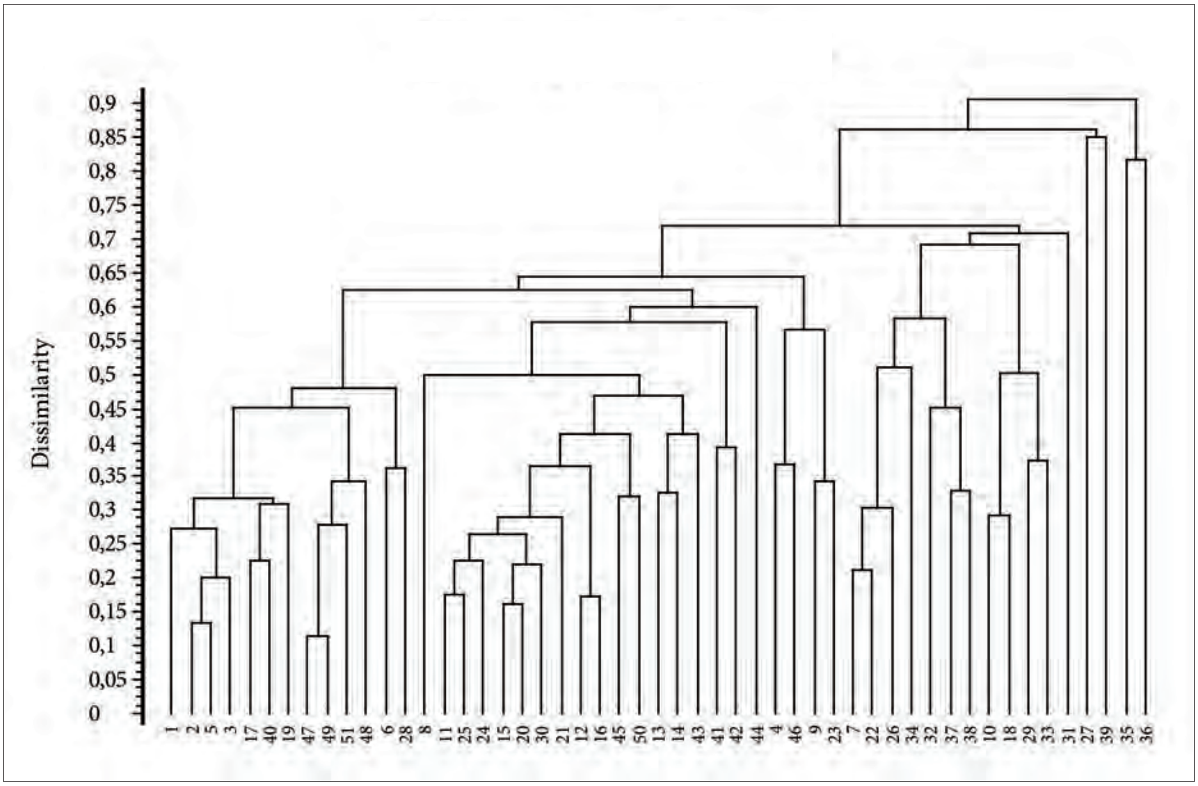

Figure 6: Dendrogram of relevés of communities with dominant Adiantum capillus-veneris in Slovenia (UPGMA, 1-similarity ratio). Stands of the subassociation Eucladio-Adiantetum hymenostylietosum recurvirostri are on the left side of the dendrogram, stands of the syntaxa Eucladio-Adiantetum cratoneuretosum commutati, -eucladietosum and Adianto-Molinietum are in the central part and stands of the syntaxa Eucladio-Adiantetum conocepahaletosum conici and Phyteumato columnae-Adiantetum on the right.
Slika 6: Dendrogram popisov združb z vrsto Adiantum capillus-veneris v Sloveniji (UPGMA, komplement Wishartovega koeficienta podobnosti). V levem delu dendrograma so sestoji subasociacije Eucladio-Adiantetum hymenostylietosum recurvirostri, v srednjem delu sestoji sintaksonov Eucladio-Adiantetum cratoneuretosum commutati, -eucladietosum in Adianto-Molinietum, v desnem delu pa sestoji sintaksonov Eucladio-Adiantetum conocepahaletosum conici in Phyteumato columnae-Adiantetum

poldinii (Giovagnoli & Tasinazzo 2012) with *Pinguicula alpina* and *Carex brachystachys* was described several years ago in the ravines of the Venetian Prealps.

Two relevés from the Volarja gorge at Selišče and the Sopet at Plave as well as the relevé from Istria (Piševec) show greater similarity with the relevés classified into the subassociation *Eucladio-Adiantetum cratoneuretosum commutati* (Pritivera & Lo Guidice) Deil 1996.

Four relevés stand out in Table 1, namely those that grouped separately also in the comparison of all relevés from Slovenia (relevés 44, 4, 46 and 9 in Figure 6 or relevés 20 to 23 in Table 1). They are classified into the new association *Adianto capilli-veneris-Molinietum arundinaceae* ass. nov. that was provisionally described already in 2014. For now it is known on four very different localities situated far apart from each other in the Alpine, pre-Alpine-sub-Mediterranean and sub-Mediterranean phytogeographical regions. The largest area that its stands occupy is in the gorge of the Volarja (Figure 7) and based also on these large surface areas it can be typified as new. Its nomenclature type, *holotypus*, is relevé 21 in Table 1. The stands of the new association are characterised by two herb layers. The upper, which is very distinct and conspicuous, is dominated by *Molinia caerulea* subsp. *arundinacea* (*M. arundinacea*), and the lower, which is less conspicuous and recognisable only close up, is dominated by *Adiantum capillus-veneris*. The Central-European nomenclature requires communities to be named after the dominating species of the highest stand layer, so the rank of the subassociation *Eucladio-Adiantetum molinietosum arundinaceae* would be less appropriate for these stands. Nevertheless, because of maidenhair

Figure 7: Stands of the syntaxa Eucladio-Adiantetum hymenostylietosum recurvirostri (the smaller area in the left part of the figure) and Adianto-Molinietum arundinaceae (the bigger area in the central part of the figure) in the gorge of the Volarja. Photo: I. Dakskobler
Slika 7: Sestoja sintaksonov Eucladio-Adiantetum hymenostylietosum recurvirostri (manjša površina bolj v levem delu slike) in Adianto-Molinietum arundinaceae (večja površina v srednjem delu slike) v grapi Volarje. Foto: I. Dakskobler

fern and diagnostic moss species (*Eucladium verticillatum, Hymenostylium recurvirostre, Palustriella commutata*) the new association is classified into the alliance *Adiantion capilli-veneris* Br.-Bl. ex Horvatić 1934, order *Adiantetalia capilli-veneris* Br.-Bl. ex Horvatić 1934 and class *Adiantetea capilli-veneris* Br.-Bl. 1948. Its stands on steep to very steep slopes with dolomite, limestone or flysch bedrock, where tufa is frequently deposited from, characterise a long-term successional stage in the gradual overgrowing of these extreme sites with shrub vegetation, in the case of the Volarja on the edges of the slope break.

4 CONCLUSIONS

On three locations in the gorge of the Volarja/Volarnik at Selišče (Krn Mountains, Julian Alps) we came across a rare and protected fern *Adiantum capillus-veneris*. Compared to the only known locality in the basin of the Volarja brook (in the Mrzlica gorge), the second new locality along the brook is very large (extending over several ares) and the richest in the number of specimens in the entire Soča Valley. In terms of the species composition the maidenhair communities there are similar to the communities on other localities known so far in the Julian Alps and in the Central Soča Valley. Two relevés are classified into the subassociation *Eucladio-Adiantetum cratoneuretosum commutati* and four into the new variant of the subassociation *Eucladio-Adiantetum hymenostylietosum recurvirostri*, var. *Pinguicula alpina*. This montane headwaters species has been reported for maidenhair fern localities in the Alpine foothills of northeastern Italy, whereas in

Slovenia the Volarja is the only place where these two species occur together. One of the differential species of the new variant is also *Saxifraga aizoides*, a montane-alpine species of moist screes and headwaters, one of whose lowest localities in Slovenia is along the Volarja, at the elevation of only 230 m.

Maidenhair ferns along the Volarja occur on a very large area also in a community with tall moor grass (*Molinia caerulea* subsp. *arundinaceae*) and such stands, known on smaller areas also elsewhere in western and southwestern Slovenia, were classified into the new association *Adianto capilli-veneris-Molinietum arundinaceae.*

The diverse basin of the Volarja/Volarnik under Mt. Krn with its numerous waterfalls and other fascinating geomorphological and geological phenomena (Podobnik 1983, Rojšek 1991) have been declared a natural monument and part of the Natura 2000 site named Soča with the Volarja. The new maidenhair fern localities are not endangered yet as they are not easily accessible, although they are in the vicinity of a popular path leading to the waterfalls. There are no other significant human interventions in these localities, but their populations nevertheless require careful monitoring in the future.

5 POVZETEK

V grapi Volarje/Volarnika pri Seliščih (Krnsko pogorje, Julijske Alpe) smo na treh krajih našli redko in zavarovano praprotnico *Adiantum capillus-veneris*. V primerjavi z do zdaj znanim edinim nahajališčem v porečju tega potoka (v soteski Mrzilce), je drugo novo nahajališče ob Volarji zelo obsežno (na površini več arov) in po številu primerkov najbogatejše v celotnem Posočju. Po vrstni sestavi so združbe venerinih laskov na njem podobne združbam na drugih do zdaj znanih nahajališčih v Julijskih Alpah in v Srednjem Posočju. Dva popisa uvrščamo v subasociacijo *Eucladio-Adiantetum cratoneuretosum commutati*, štiri pa v novo varianto *Eucladio-Adiantetum hymenostylietosum recurvirostri* var. *Pinguicula alpina.* To gorsko vrsto povirij že poznajo na nahajališčih venerinih laskov v alpskem prigorju severovzhodne Italije, v Sloveniji pa je Volarja za zdaj edini kraj, kjer rasteta skupaj. Ena izmed razlikovalnic nove variante je tudi (visoko)gorska vrsta vlažnih melišč in povirij *Saxifraga aizoides*, ki ima ob Volarji na nadmorski višini le 230 m eno izmed svojih najnižje ležečih nahajališč v Sloveniji.

Ob Volarji venerini laski na precej veliki površini rastejo tudi v združbi s trstikasto stožko (*Molinia caerulea* subsp. *arundinaceae*) in take sestoje, ki jih na manjših površinah poznamo tudi drugod v zahodni in jugozahodni Sloveniji, smo uvrstili v novo asociacijo *Adianto capilli-veneris-Molinietum arundinaceae.*

Razgibano porečje Volarje/Volarnika pod Krnom je zaradi številnih slapov in drugih zanimivih geomorfoloških in geoloških pojavov (Podobnik 1983, Rojšek 1991) razglašeno za naravni spomenik in sodi tudi v območje Natura 2000 z imenom Soča z Volarjo. Nova nahajališča venerinih laskov za zdaj še niso ogrožena, saj so razmeroma težko dostopna, vendar poteka blizu precej obiskana pot k slapovom. Drugih človekovih posegov na nahajališčih ni zaznati. Kljub vsemu bo v prihodnje potrebno pozorno spremljati njihove populacije.

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REFERENCES – LITERATURA

Aeschimann, D., K. Lauber, D. M. Moser & J.-P. Theurillat, 2004: *Flora alpina*. Bd. 1: *Lycopodiaceae-Apiaceae*. Haupt Verlag, Bern, Stuttgart, Wien.

Braun-Blanquet, J., 1964: *Pflanzensoziologie. Grundzüge der Vegetationskunde*. 3. Auflage. Springer, Wien – New York.

Buser, S., 1986: *Tolmač listov Tolmin in Videm (Udine) L 33-64 L 33-63. Osnovna geološka karta 1:100 000.* Beograd.

Buser, S., 1987: *Osnovna geološka karta SFRJ. Tolmin in Videm 1 : 100 000.* Zvezni geološki zavod, Beograd.

Buser, S., 2009: *Geološka karta Slovenije 1: 250.000. Geological map of Slovenia 1.250,000.* Geološki zavod Slovenije, Ljubljana.

Cegnar T., 1998: *Temperatura zraka*. In: J. Fridl, D. Kladnik, M., Orožen Adamič & D. Perko (eds.): *Geografski atlas Slovenije. Država v prostoru in času*. Državna založba Slovenije, Ljubljana, pp. 100–101.

Dakskobler, I., 2017: *Dve botanični opombi pod črto: plazeča sretena (Geum reptans) pod Triglavom in venerini laski (Adiantum capillus-veneris) v grapi Volarje pri Seliščih*. Proteus 79 (5): 216–223.

Dakskobler, I., A. Martinčič, D. Rojšek, 2014: *Phytosociological analysis of communities with Adiantum capillus-veneris in the foothills of the Julian Alps (Western Slovenia*). Hacquetia (Ljubljana) 13 (2): 235–258. https://doi.org/10.2478/hacq-2014-0016

Giovagnoli, L. & S. Tasinazzo, 2012: *Hymenostylio recurvirostri-Pinguiculetum poldinii* ass. *nova in the Valbrenta ravines (Venetian Prealps): a new palaeoendemic plant association belonging to the class Adiantetea Br.-Bl. 1948*. Plant Sociology 29 (2): 49–58. https://doi.org/10.7338/pls2012492/03

Maarel, van der E., 1979: *Transformation of cover-abundance values in phytosociology and its effects on community similarity.* Vegetatio 39 (2): 97–114. https://doi.org/10.1007/BF00052021

Martinčič, A., T. Wraber, N. Jogan, A. Podobnik, B. Turk, B. Vreš, V. Ravnik, B. Frajman, S. Strgulc Krajšek, B. Trčak, T. Bačič, M. A. Fischer, K. Eler & B. Surina, 2007: *Mala flora Slovenije. Ključ za določanje praprotnic in semenk*. Četrta, dopolnjena in spremenjena izdaja. Tehniška založba Slovenije, Ljubljana.

Medvešček, P. & D. Skrt, 2016: *Staroverstvo in straroverci. Katalog etnološke zbirke Pavla Medveščka* 2. Goriški muzej, Nova Gorica.

Mekinda-Majaron,T., 1995: *Klimatografija Slovenije. Temperatura zraka 1961–1990.* Hidrometeorološki zavod Republike Slovenije, Ljubljana.

Podani, J., 2001: SYN-TAX 2000. *Computer Programs for Data Analysis in Ecology and Systematics.* User's Manual, Budapest.

Podobnik, R., 1983: *Slapovi v okolici Vrsna in Krna*. In: A. Ramovš: *Slapovi v Sloveniji*. Slovenska matica, Ljubljana, pp. 110–118.

Rojšek, D., 1991: *Naravne znamenitosti Posočja*. Državna založba Slovenije, Ljubljana.

Rojšek, D., 2015a: *Venerini laski (Adiantum capillus-veneris L.) v Posočju*. Prvi del. Proteus (Ljubljana) 77 (9–10): 399–408.

Rojšek, D., 2015b: *Venerini laski (Adiantum capillus-veneris L.) v Posočju*. Drugi del. Proteus (Ljubljana) 78 (1): 24–34.

Ros, R. M., V. Mazimpaka, U. Abou-Salama, M. Aleffi, T. L. Blockeel, M. Brugués, M. J. Cano, R. M. Cros, M. G. Dia, G. M. Dirkse, W. El Saadawi, A. Erdağ, A. Ganeva, J. M. González-Mancebo, I. Hernstadt, K. Khalil, H. Kürschner, E. Lanfranco, A. Losada-Lima, M. S. Refai, S. Rodríguez-Nunez, M. Sabovljević, C, Sérgio, H. Shabbara, M. Sim-Sim & M. Söderström, 2007: *Hepatics and Anthocerotes of the Mediterranean, an annotated checklist.* Cryptogamie, Bryologie 28 (4): 351–437.

Ros, R. M., V. Mazimpaka, U. Abou-Salama, M. Aleffi, T. L. Blockeel, M. Brugués, R. M. Cros, M. G. Dia, G. M. Dirkse, I. Draper, W. El Saadawi, A. Erdağ, A. Ganeva, R. Gabriel, J. M. González-Mancebo, I. Hernstadt, V. Hugonnot, K. Khalil, H. Kürschner, A. Losada-Lima, L. Luís, S. Mifsud, M., Privitera, M. Puglisi, M. Sabovljević, C. Sérgio, H. M. Shabbara, M. Sim-Sim, A. Sotiaux, R. Tacchi, A. Vanderpoorten & O. Werner, 2013: *Mosses of the Mediterranean, an annotated checklist.* Cryptogamie, Bryologie 34 (2): 99–283.

Seliškar, T., B. Vreš & A. Seliškar, 2003: FloVegSi 2.0. *Fauna, Flora, Vegetation and Paleovegetation of Slovenia. Computer programme for arranging and analysis of biological data.* Biološki inštitut ZRC SAZU, Ljubljana.

Šilc, U. & A. Čarni, 2012: *Conspectus of vegetation syntaxa in Slovenia.* Hacquetia (Ljubljana) 11 (1): 113–164. https://doi.org/10.2478/v10028-012-0006-1

Theurillat, J.-P., 2004: *Pflanzensoziologisches System*. In: D. Aeschimann, K. Lauber, D. M. Moser & J-P. Theurillat: *Flora alpina 3*: Register. Haupt Verlag, Bern, Stuttgart, Wien, pp. 301–313.

Wraber, T., 1986: *Vsega po nekaj o venerinih laskih*. Proteus (Ljubljana) 48 (7): 259–263.

Zupančič, B., 1995: *Klimatografija Slovenije*. *Padavine 1961–1990*. Hidrometeorološki zavod Republike Slovenije, Ljubljana.

Zupančič, B., 1998: *Padavine*. In: J. Fridl, D. Kladnik, M. Orožen Adamič & D. Perko (eds.): *Geografski atlas Slovenije*. *Država v prostoru in času*. Državna založba Slovenije, Ljubljana, pp. 98–99.

Table 1: Communities with *Adiantum capillus-veneris* in westertn and southwestern Slovenia
Preglednica 1: Združbe z vrsto *Adiantum capillus-veneris* v zahodni in jugozahodni Sloveniji

	Number of relevé (Zaporedna številka popisa)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23		
	Database number of relevé (Delovna številka popisa)		245266	249922	245260	245261	245264	245262	247815	251661	247819	262257	262259	262268	262258	262255	262260	251662	251663	252436	255440	245263	262256	247658	249162		
	Elevation in m (Nadmorska višina v m)		370	500	395	360	360	360	180	97	120	230	230	230	230	210	240	107	107	110	400	365	224	150	150		
	Aspect (Lega)		SE	SE	SE	SE	S	SW	SW	S	SW	SEE	NEE	E	E	E	E	SW	SSW	NE	SE	S	SE	SW	SW		
	Slope in degrees (Nagib v stopinjah)		90	90	100	100	100	100	90	90	90	80	90	90	90	80	80	80	90	70	80	50	85-95	80	45		
	Parent material (Matična podlaga)		D	Tu	B	D	D	D	Tu	Tu	Tu	Tu	Tu	LM	LM	LM	LM	Tu	Tu	Tu	B	D	LM	Tu	Tu		
	Cover of herb layer in % (Zastiranje zeliščne plasti v %)	E1	40	20	70	70	70	80	70	70	60	80	60	70	60	70	70	20	30	60	30	80	90	70	70		
	Cover of moss layer in % (Zastiranje mahovne plasti v %)	E0	70	100	40	60	60	40	90	80	70	80	60	50	60	60	60	80	80	70	80	20	60	60	50		
	Number of species (Število vrst)		10	16	14	9	9	12	12	24	11	11	9	17	16	22	25	12	20	16	12	16	15	9	21		
	Relevé area (Velikost popisne ploskve)	m^2	6	4	6	5	4	5	2	8	2	8	6	4	4	4	4	1	1	4	1	6	10	3	2		
	Date of taking relevé (Datum popisa)		10/24/2012	9/12/2013	10/24/2012	10/24/2012	10/24/2012	10/24/2012	4/11/2013	1/29/2014	4/11/2013	7/24/2016	7/24/2016	7/25/2016	7/24/2016	7/24/2016	7/24/2016	1/29/2014	1/29/2014	5/7/2014	12/9/2014	10/24/2012	7/24/2016	3/22/2013	7/15/2013		
	Locality (Nahajališče)		Brezna grapa	Mrzlica	Brezna grapa	Brezna grapa	Brezna grapa	Brezna grapa	Avče	Plave -Sopet	Ročinj-Ajba	Volarja	Volarja	Volarja	Volarja	Volarja	Volarja	Plave -Sopet	Plave -Sopet	Istra-Piševec	Brezna grapa	Brezna grapa	Volarja	Trebež	Koštabona-Supot		
	Quadrant (Kvadrant)		9849/1	9748/3	9849/1	9849/1	9849/1	9849/1	9948/1	9947/4	9847/4	9747/4	9747/4	9747/4	9747/4	9747/4	9747/4	9947/4	9947/4	0548/1	9849/1	9849/1	9747/4	9947/2	0548/1		
	Coordinate GK Y (D-48)	m	412756	397664	412714	412764	412768	412764	398588	390772	396806	396632	396629	396643	396629	396629	396655	390729	390737	399677	412711	412770	396646	391703	402145		
	Coordinate GK X (D-48)	m	5113536	5120786	5113572	5113542	5113566	5113552	5106944	5100468	5107796	5120271	5120254	5120286	5120264	5120145	5120384	5100448	5100455	5039212	5113572	5113560	5120284	5102350	5038991		
	Diagnostic species of the association (Diagnostične vrste asociacije)																									Pr.	Fr.
AD	*Adiantum capillus-veneris*	E1	2	1	4	4	4	5	4	4	4	4	3	3	3	3	3	1	2	4	2	2	3	4	3	23	100
AD	*Eucladium verticillatum*	E0	.	+	.	.	.	+	+	+	.	+	1	+	+	r	+	4	3	3	1	.	1	4	3	17	74
EP	*Molinia caerulea subsp. arundinacea*	E1	1	.	r	1	+	+	+	.	.	1	1	1	2	.	+	.	.	+	.	5	4	3	4	16	70

	Number of relevé (Zaporedna številka popisa)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Pr.	Fr.
	Differential species of the subassotiation (Razlikovalnice subasociacij)																										
AD	*Hymenostylium recurvirostre*	E0	4	5	3	4	4	3	4	4	3	4	4	3	2	2	1	+	1	.	.	1	2	2	.	20	87
TR	*Petasites paradoxus*	E1	.	.	.	+	+	1	.	.	.	+	+	+	+	+	.	.	.	.	.	+	1	.	.	10	43
ES	*Sesleria caerulea*	E1	+	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	4	17
CD	*Tofieldia calyculata*	E1	+	.	r	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	4	17
MC	*Palustriella commutata*	E0	1	1	+	1	2	2	1	2	.	4	4	2	3	3	4	1	3	3	4	3	4	+	+	22	96
	Differential species of the variant (Razlikovalnice variante)																										
EP	*Calamagrostis varia*	E1	+	+	+	.	.	r	.	.	+	3	2	4	1	+	1	.	.	.	.	+	+	.	.	13	57
CD	*Pinguicula alpina*	E1	.	.	.	.	.	.	.	.	.	1	1	1	+	.	.	.	.	.	.	.	+	.	.	5	22
CF	*Carex brachystachys*	E1	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	4
TR	*Campanula cespitosa*	E1	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	1	4
MC	*Saxifraga aizoides*	E1	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1	4
AD	***Adiantion, Adiantetea***																										
	Pellia endiviifolia	E0	.	+	1	.	.	+	1	+	+	1	+	+	1	1	1	+	+	3	.	.	+	.	+	17	74
	Didymodon tophaceus	E0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	+	2	9
MC	***Montio-Cardaminetea***																										
	Conocephalum conicum	E0	.	+	.	.	.	.	+	2	2	.	.	.	.	+	+	.	2	.	.	.	.	.	.	7	30
	Campylium stellatum	E0	.	.	.	.	.	.	.	.	.	.	.	r	.	.	+	.	.	.	+	.	.	.	.	3	13
	Cratoneuron filicinum	E0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	4
CF	***Cystopteridion fragilis***																										
	Orthothecium rufescens	E0	.	.	+	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	4	17
	Jungermannia atrovirens	E0	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	2	9
AT	***Asplenietea trichomanis***																										
	Phyteuma scheuchzeri subsp. columnae	E1	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4
O	*Hieracium cf. pospichalii*	E1	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	r	.	.	2	9
TR	***Thlaspietea rotundifolii***																										
	Peucedanum verticillare	E1	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	1	4
	Hieracium bifidum	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	1	4
FB	***Festuco-Brometea***																										
	Blackstonia perfoliata	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1	4
	Globularia punctata	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	4
TG	***Trifolio-Geranietea***																										
	Viola hirta	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	+	.	.	.	.	2	9
	Laserpitium latifolium	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	1	4
MA	***Molinion, Molinio-Arrhenatheretea***																										
	Angelica sylvestris	E1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	r	+	.	.	4	17
	Caltha palustris	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	2	9
	Galium mollugo	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	4
	Pulicaria dysenterica	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	4
MuA	***Mulgedio-Aconitetea, Betlo-Adenostyletea***																										
	Senecio ovatus	E1	.	r	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	2	9
	Chaerophyllum hirsutum	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	2	9
	Salix appendiculata	E2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	1	4
EA	***Epilobioetea angustifolii***																										
	Eupatorium cannabinum	E1	.	.	.	.	.	.	.	r	.	.	.	r	.	.	.	.	.	.	.	1	.	.	.	3	13

	Number of relevé (Zaporedna številka popisa)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Pr.	Fr.
GU	***Galio-Urticetea***																										
	Petasites hybridus	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	2	9
	Equisetum arvense	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	2	9
RP	***Rhamno-Prunetea***																										
	Ligustrum vulgare	E2a	.	.	.	.	.	r	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	2	9
	Rubus macrophyllus	E2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	4
	Rubus sp.	E2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	1	4
EP	***Erico-Pinetea***																										
	Buphthalmum salicifolium	E1	.	.	.	.	.	.	.	.	.	r	.	r	.	.	r	.	.	.	.	.	.	+	.	4	17
VP	***Vaccinio-Piceetea***																										
	Veronica urticifolia	E1	.	r	.	.	.	.	.	+	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	4	17
	Oxalis acetosella	E1	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4
	Solidago virgaurea	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1	4
TA	***Tilio-Acerion***																										
	Aruncus dioicus	E1	.	r	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+	.	.	.	.	.	4	17
	Phyllitis scolopendrium	E1	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	2	9
	Geranium robertianum	E1	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4
AF	***Aremonio-Fagion***																										
	Cyclamen purpurascens	E1	.	.	.	.	.	.	.	+	.	.	.	.	.	r	.	r	+	.	.	.	.	.	.	4	17
	Lamium orvala	E1	.	.	.	.	.	.	.	r	.	.	.	.	.	r	.	r	.	.	.	.	.	.	.	3	13
	Anemone trifolia	E1	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4
	Cardamine trifolia	E1	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4
	Epimedium alpinum	E1	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4
EC	***Erythronio-Carpinion***																										
	Primula vulgaris	E1	.	.	.	.	.	.	+	1	.	.	.	.	.	1	+	.	r	r	+	.	.	.	.	7	30
	Galanthus nivalis	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	1	4
	Lonicera caprifolium	E2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	4
FS	***Fagetalia sylvaticae***																										
	Galeobdolon flavidum	E1	.	+	.	.	.	.	.	1	.	.	.	.	.	+	.	+	r	.	.	.	.	.	.	5	22
	Pulmonaria officinalis	E1	.	.	.	.	.	.	r	+	.	.	.	.	.	r	.	.	+	.	.	.	.	.	.	4	17
	Brachypodium sylvaticum	E1	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	4	17
	Mycelis muralis	E1	.	r	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	3	13
	Sambucus nigra	E2a	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	2	9
	Salvia glutinosa	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	+	.	.	.	.	2	9
	Allium ursinum	E1	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4
	Melica nutans	E1	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4
	Lathyrus vernus	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	1	4
	Asarum europaeum subsp. caucasicum	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	1	4
	Fraxinus excelsior	E2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	1	4
	Viola reichenbachiana	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1	4
QP	***Quercetalia pubescenti-petraeae* (inc. *Quercetea ilicis*)**																										
	Carex flacca	E1	+	.	.	r	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	3	13
	Ruscus aculeatus	E1	.	.	.	.	.	.	.	r	r	.	.	.	.	.	.	r	.	.	.	.	.	.	.	3	13
	Asparagus acutifolius	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	+	2	9

	Number of relevé (Zaporedna številka popisa)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Pr.	Fr.
	Fraxinus ornus	E2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	+	2	9
	Quercus pubescens	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	4
	Sesleria autumnalis	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	1	4
QF	***Querco-Fagetea***																										
	Hedera helix	E1	.	.	+	+	+	.	+	+	+	.	.	.	.	+	+	+	1	.	1	r	+	.	+	14	61
	Clematis vitalba	E2a	.	.	.	.	.	.	.	.	.	.	.	.	.	+	r	.	.	.	.	.	.	.	+	3	13
	Carex digitata	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	r	.	.	.	.	.	.	2	9
	Vinca minor	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	2	9
	Cephalanthera sp.	E1	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	1	4
	Viola riviniana	E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	+	1	4
M	**Mosses (Mahovi)**																										
	Oxyrrhynchium schleicheri	E0	.	.	.	.	+	.	r	+	.	.	.	.	r	.	.	+	.		.	.	.	+	.	6	26
	Oxyrrhynchium hians	E0	.	.	.	.	.	.	1	+	+	.	.	.	+	.	+	.	1		.	.	.	.	.	6	26
	Jungermannia sp.	E0	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	+	2	9
	Bryum pseudotriquetrum	E0	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	+	2	9
	Preissia quadrata	E0	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.		.	.	.	.	.	2	9
	Ctenidium molluscum	E0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.		.	+	.	.	.	2	9
	Pedinophyllum interruptum	E0	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	1	4
	Fissidens taxifolius	E0	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	1	4
	Seligeria trifaria	E0	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	1	4
	Gymnostomum aeruginosum	E0	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	1	4
	Brachythecium rutabulum	E0	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.		.	.	.	.	.	1	4
	Plagiomnium rostratum	E0	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.		.	.	.	.	.	1	4
	Aneura pinguis	E0	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.		.	.	.	.	.	1	4
	Plagiomnium undulatum	E0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.		.	.	.	.	.	1	4
	Platyhypnidium riparioides	E0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+		.	.	.	.	.	1	4
	Rhynchostegium murale	E0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+		.	.	.	.	.	1	4
	Riccardia chamaedryfolia	E0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	1	4
	Fissidens dubius	E0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	1	4
	Fissidens adianthoides	E0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	1	4

Legend - Legenda

Pr. Presence (number of relevés in which the species is presented) - število popisov, v katerih se pojavlja vrsta
Fr. Frequency in % - frekvenca v %
L Limestone - apnenec
M Marlstone - laporovec
Tu Tufa - lehnjak
D Dolomite - dolomit
B Breccia - breča

ZNAČILNOSTI ZGRADBE LESA SADIK BORA (*PINUS SYLVESTRIS*) IN BUKVE (*FAGUS SYLVATICA*) IZPOSTAVLJENIH TREM RAZLIČNIM OKOLJSKIM RAZMERAM

CHARACTERISTICS OF WOOD STRUCTURE OF PINE (*PINUS SYLVESTRIS*) AND BEECH (*FAGUS SYLVATICA*) SEEDLINGS EXPOSED TO DIFFERENT ENVIRONMENTAL REGIMES

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IZVLEČEK

Značilnosti zgradbe lesa sadik bora (*Pinus sylvestris*) in bukve (*Fagus sylvatica*) izpostavljenih trem različnim okoljskim razmeram

Poznavanje strukture in lastnosti lesa je ključno z vidika njegove smotrnejše obdelave, predelave in končne rabe. V članku opisujemo in primerjamo značilnosti zgradbe lesa triletnih sadik bora (*Pinus sylvestris*) in bukve (*Fagus sylvatica*) izpostavljene trem različnim temperaturnim režimom v rastnih sezonah 2010–2011: kontrola (K, na prostem, povprečna temperatura v času rastne sezone = 17–19°C), rastlinjak (G, povprečna temperatura v času rastne sezone = 22–24°C) in hladilna komora (C, povprečna temperatura v času rastne sezone = 15–17°C). Na preparatih prečnih prerezov lesa smo tako preverili prisotnost in delež reakcijskega lesa, prisotnost gostotnih fluktuacij, prisotnost kalusa ter za bor še gostoto in položaj aksialnih smolnih kanalov. Rezultati kažejo na vrstno specifičen odziv pionirskega rdečega bora in sencovzdržne bukve na različne okoljske razmere v smislu debelinske rasti in strukturnih posebnosti lesa. Pojavnost lesno-anatomskih značilnosti je bila v splošnem večja v letu 2010 kot v 2011. To bi lahko pojasnili s presaditvenim šokom in z večjo verjetnostjo povzročitve mehanskih poškodb ob manipulaciji sadik, ki so negativno vplivali na kakovost lesa. Razlike v strukturnih posebnosti lesnih prirastkov v obeh proučevanih letih tudi kažejo na nujnost večletnih tovrstnih poskusov v nadzorovanih razmerah, saj se nekateri odzivi lahko pokažejo šele v daljšem časovnem obdobju. Širina lesnega prirastka in lesno-anatomske značilnosti niso nujno povezane, zato na podlagi priraščanja ne moremo sklepati o kakovosti lesa.

Ključne besede: rdeči bor, navadna bukev, reakcijski les, smolni kanal, gostotne fluktuacije, juvenilni les, anatomija, kakovost lesa

ABSTRACT

Characteristics of wood structure of pine (*Pinus sylvestris*) and beech (*Fagus sylvatica*) seedlings exposed to different environmental regimes

Knowledge on structure and properties of wood is crucial for its optimal woodworking, processing and end-use. In the paper, we describe and compare characteristics of wood structure of three-year-old pine (*Pinus sylvestris*) and beech (*Fagus sylvatica*) seedlings exposed to different temperature regimes in the growing seasons of 2010-2011: control (K, outdoors, mean temperature during the growing season = 17–19°C), greenhouse (G, mean temperature during the growing season = 22–24°C) and climatized room (C, mean temperature during the growing season = 15–17°C). On transverse-sections of xylem, presence and proportion of the reaction wood, presence of the density fluctuations, presence of callus tissue, and in the case of pine also density and position of the axial resin canals were evaluated. The results show species-specific response of pioneer Scots pine and late-successional beech to different environmental conditions in terms of radial growth and structural characteristics of wood. Incidence of wood-anatomical characteristics were generally higher in 2010 than in 2011. This may be explained by the transplant shock, and higher probability of mechanical wounding of cambium, which have a negative impact on the wood quality, when setting up the experiment. The differences in the structure of xylem increments of 2010 and 2011 demonstrate that a continuation of such observations over several growing seasons is necessary to capture the short- and long-term response of tree growth under changing environmental conditions. Finally, width of the wood increment and wood-anatomical characteristics are not necessarily linked, thus increment width cannot be an indicator of wood quality.

Key words: Scots pine, common beech, reaction wood, resin canal, density fluctuations, juvenile wood, anatomy, wood quality

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1 UVOD

Les je ena pomembnejših svetovnih naravnih surovin, tudi v Sloveniji (Vlada RS 2015) in ima kot material številne dobre lastnosti: je naraven in obnovljiv, vsesplošno razširjen in nastaja ob blagodejnem učinku na okolje. Les je tudi dekorativen in ima sorazmerno dobre mehanske lastnosti glede na nizko gostoto, zato je široko uporaben material za različne namene (Čufar 2006). Pomanjkljivost lesa je strukturna nehomogenost, saj je zgrajen iz različnih tkiv in tipov celic, ki so različno usmerjene. Zaradi tega ima se lastnosti v različnih smereh razlikujejo (anizotropnost). Je tudi zelo variabilen material, kajti lastnosti lesa variirajo znotraj ene letne prirastne plasti, med različnimi deli drevesa, kakor tudi med drevesi na istem ali na različnih rastiščih (Panshin & de Zeeuw 1980). Poznavanje strukture in lastnosti lesa je zato ključno z vidika njegove smotrnejše obdelave, predelave in končne rabe.

Les uporabljamo za različne namene (npr. v gradbeništvu, pohištveni industriji, za ogrevanje) in pri tem izkoriščamo različne lastnosti. Kakovost lesa je osnovni kriterij za primernost lesa za določeno rabo in je posledica rasti drevesa, rastnih posebnosti ter poškodb zaradi delovanja različnih dejavnikov. V določenih primerih so posebnosti lesa lahko zaželene, v drugih primerih pa jih pojmujemo kot napake, ki ovirajo predelavo, obdelavo in uporabo lesa. Napake lahko ovrednotimo glede na obliko debla, strukturo lesa ter na napake, ki so nastale zaradi zunanjih vplivov. Med napake, ki se nanašajo na strukturo lesa, prištevamo: grčavost, zavitost, reakcijski les, nepravilno zgradbo, odklon vlaken od osi drevesa, razpoke, napake srca (npr. ekscentričnost srca, dvojno srce) (Gričar 2011).

Strukturne značilnosti lesa so lahko vidne na mikroskopski ali makroskopski ravni in jih lahko bodisi kvantificiramo ali binarno določimo (tj. znak prisoten/ odsoten). Slednje znake lahko nadalje razvrstimo glede na: (i) frekvenco in intenziteto pojavnosti ali (ii) mesto v lesni braniki, kot denimo pojav smolnih kanalov v ranem lesu, prehodnem lesu ali kasnem lesu. Številni znaki (gostotna nihanja, manjkajoče branike, travmatski smolni kanali itd.) se pojavijo kot odziv dreves na stresne vremenske dogodke (poplave, suša, pozeba) in jih zato s pridom izkoriščamo za datiranje tovrstnih dogodkov (dendrokronologija). Kot že omenjeno, pa lahko spremembe v zgradbi lesa v veliki meri negativno vplivajo na lastnosti lesa in s tem zmanjšujejo njegovo vrednost (Bräuning et al. 2016). A po drugi strani lahko rastne posebnosti tudi pozitivno vplivajo na vrednost lesa, kot je to v primeru lokalno zavrtega delovanja kambija pri sladkornem javorju, pri čemer nastanejo drobne ugreznine, ki dajo lesu v vzdolžnem prerezu značilno teksturo ptičjih oči, ki je izredno cenjena (Torelli 1998).

V pričujočem prispevku se bomo osredotočili na strukturne (rastne posebnosti) lesa sadik rdečega bora in navadne bukve izpostavljene trem različnim temperaturnim režimom v rastnih sezonah 2010–2011. Prisotnost strukturnih posebnosti bomo primerjali med letoma, tudi v odvisnosti od širine prirastka, ki je eden izmed kazalcev stresnih razmer za rast dreves (Bigler et al. 2004).

2 MATERIAL IN METODE

2.1 Izbor in priprava sadik

Eksperiment je potekal na enoletnih sadikah bora in bukve v rastnih sezonah 2010 in 2011. Pozimi 2009/2010 smo 120 sadikam rdečega bora (*Pinus sylvestris* L.) in 90 sadikam navadne bukve (*Fagus sylvatica* L.), ki smo jih kupili v drevesnici Omorika (Muta), s pomočjo sistema za analizo slike WinRHIZO (Regent Instruments Inc.) in 3D skenerja izmerili volumen korenin in stebla. Sadikam smo nato s kljunastim merilom izmerili še premer stebla, približno 2 cm na koreninskim vratom (bor = 0,2–0,3 cm; bukev = 0,3–0,4 cm) ter višino (bor = 15–20 cm; bukev = 30–40 cm) z merilnim trakom, jih označili in posadili v plastične lonce z volumnom 3 L. V spodnjo četrtino loncev smo nasuli pesek kot drenažni material za odtekanje odvečne vode. Ostale tri četrtine smo napolnili z mešanico avtoklavirane zemlje (distrični kambisol iz peščenjaka in skrilavca, zgornji horizont tal = 0–30 cm), iz mešanega gozda Rožnik za Gozdarskim inštitutom Slovenije (46°03'N, 14°28'E, 323 m a.s.l.), ki pripada gozdni združbi *Blechno fagetum*, ter vemikulita (1/3 mešanice) za izboljšanje zračnosti in uravnavanje vlažnosti zemlje. Zalivanje sadik je potekalo ročno glede na predhodno izmerjeno vlažnost substrata, ki smo ga merili s FD sondo Dacagon EC-5. Vlažnost substrata smo vzdrževali nad 15 %. Spremljali smo relativno zračno vlažnost v obeh prostorih in jo vzdrževali z zračnimi vlažilci (50–80 %) ter CO_2 koncentracije (v povprečju 400–700 ppm) (Popović et al. 2015).

2.2 Temperaturne razmere v različnih režimih

Eksperiment smo zastavili v treh različnih temperaturnih razmerah. V vsakem režimu je bilo tako 40 sadik bora in 30 sadik bukve, ki so bile naključno razvrščene v posamezne skupine. Ob koncu poskusa smo za podrobnejše lesno-anatomske analize naključno izbrali po 10 sadik vsake vrste iz posameznega režima (skupno torej 60 sadik). Kontrolne sadike (K) so rasle na prostem, približno 10 m od rastlinjaka, in zaščitene pred dežjem in neposrednim vetrom. Izpostavljene so bile naravnim temperaturnim razmeram v Ljubljani v letih 2010 in 2011. Vremenska postaja, ki je beležila povprečne, maksimalne in minimalne dnevne temperature zraka in količino padavin, je bila nameščena v neposredni bližini sadik. Povprečna temperatura zraka med rastnima sezonama je bila = 17–19°C. Druga skupina sadik (G) je bila podvržena višjim temperaturam (T tekom rastne sezone = 22–24°C), tretja skupina pa nižjim (T tekom rastne sezone = 15–17°C).

2.3 Histometrične analize

Ob koncu raste sezone 2011 (tj. oktober) smo sadike vzeli iz loncev in na steblu, približno 5 cm nad koreninskim vratom, odvzeli 2 cm dolge koščke stebel ter jih dali v fiksirno raztopino FAA (mešanica formalina, 50 % etanola in ocetne kisline). Po enem tednu smo vzorce dehidrirali v etanolni vrsti (30 %, 50 % in 70 %) in jih trajno shranili v 70 % etanolu. Z drsnim mikrotomom G.S.L. 1 (©Gärtner and Schweingruber; Design and production: Lucchinetti, Schenkung Dapples, Zürich, Švica) smo pripravili 20–25 µm debele prečne prereze lesa in skorje (Gričar et al. 2013), ki smo jih obarvali v vodni mešanici barvil safranin (Merck, Darmstadt, Nemčija) (0.04 %) in astra modro (Sigma-Aldrich, Steinheim, Nemčija) (0.15 %) (van der Werf et al. 2007) ter jih vklopili v vklopni medij Euparal (Waldeck, Münster, Nemčija).

Vse potrebne histometrične analize smo opravili s svetlobnim mikroskopom Olympus BX51 (Olympus, Tokio, Japonska) in programom za analizo slike Elements Basic Research v.2.3 (Nikon, Tokio, Japonska). Na prečnem prerezu vsake sadike smo izmerili širine lesnih prirastkov 2010 in 2011. Meritve smo opravili na štirih mestih in nato izračunali povprečje. V lesnih branikah bukve smo zabeležili: prisotnost in delež tenzijskega lesa, prisotnost gostotnih fluktuacij ter prisotnost kalusa. V lesnih branikah bora smo zabeležili: prisotnost in delež kompresijskega lesa, prisotnost gostotnih fluktuacij in kalusa ter gostoto (število/mm^2) in položaj (rani, prehodni oz. kasni les) aksialnih smolnih kanalov. Za statistične analize smo uporabili program Statgraphics, za izdelavo grafov pa Microsoft Excel. Za primerjavo izmerjenih lesno-anatomskih parametrov med posameznimi režimi smo uporabili test One-way ANOVA, za primerjavo med leti pa t-test. Za ugotavljanje moči povezanosti med različnimi lesno-anatomskimi spremenljivkami smo uporabili Pearsonov koeficient korelacije.

2.4 Osnovna zgradba lesa rdečega bora in bukve

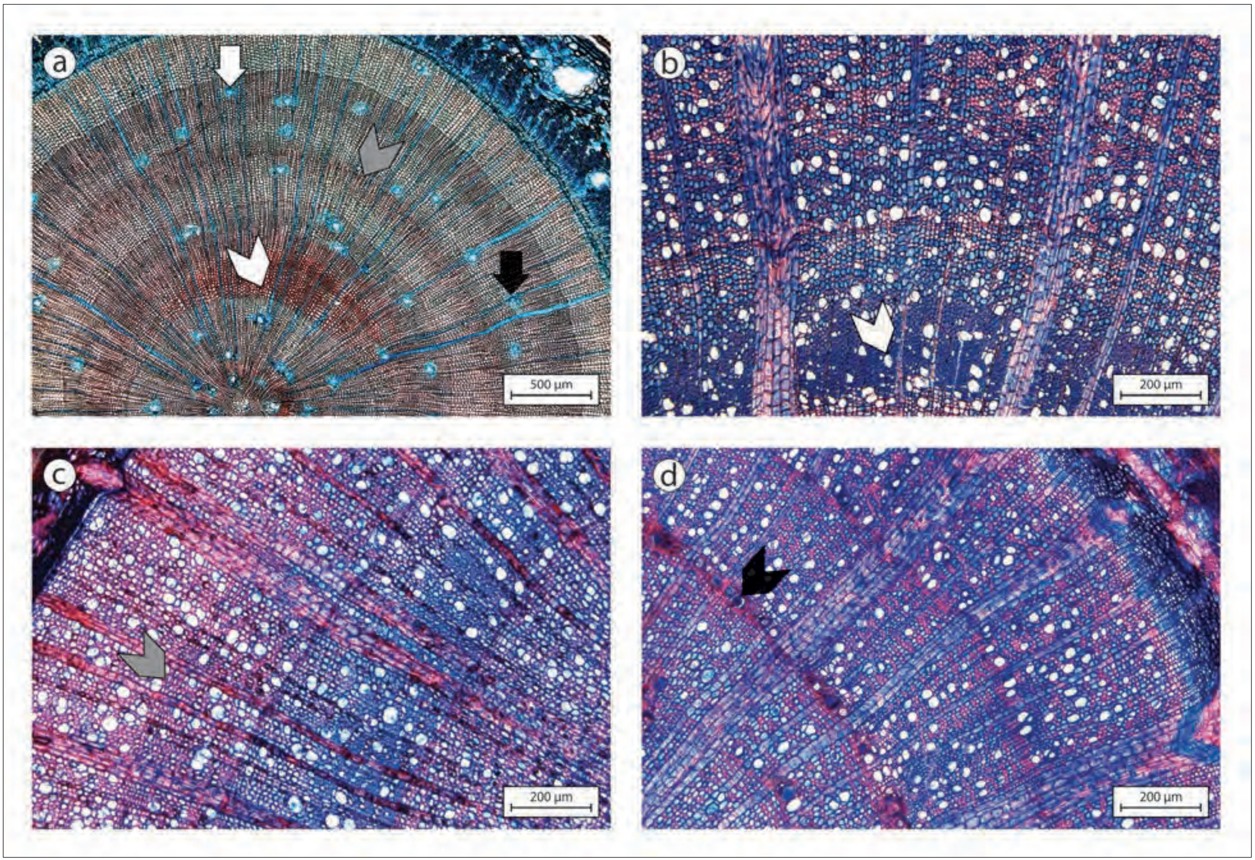
Rdeči bor je iglavec z razločnimi branikami in jasnim prehodom iz ranega v kasni les. Zanj so značilni normalni smolni kanali, ki so radialno in aksialno usmerjeni in skupaj tvorijo omrežje (Grosser 1977). Radialni smolni kanali se nahajajo v trakovih. Smolni kanal je cevast intercelularni prostor, ki je nastal z razmaknitvijo nezrelih aksialnih elementov v procesu diferenciacije. Ta prostor obdajajo epitelne celice in v beljavi vsebuje smolo (Torelli 1990). Pri rdečem boru so epitelne celice okrog smolnih kanalov tankostene in nelignificirane (slika 1a). Bukev je raztreseno porozen listavec. Majhne, enakomerno razpršene traheje so vidne le z lupo. Trakovno tkivo je na letnicah značilno kolenčasto razširjeno, široki trakovi so vidni tudi s prostim očesom. Branike v lesu so razločne, rani les se loči od nekoliko temnejšega kasnega lesa. Prehod iz ranega v kasni les je postopen (slika 1b, c, d) (Čufar 2006).

3 IZSLEDKI IN RAZPRAVA

3.1 Pojavnost gostotnih fluktuacij

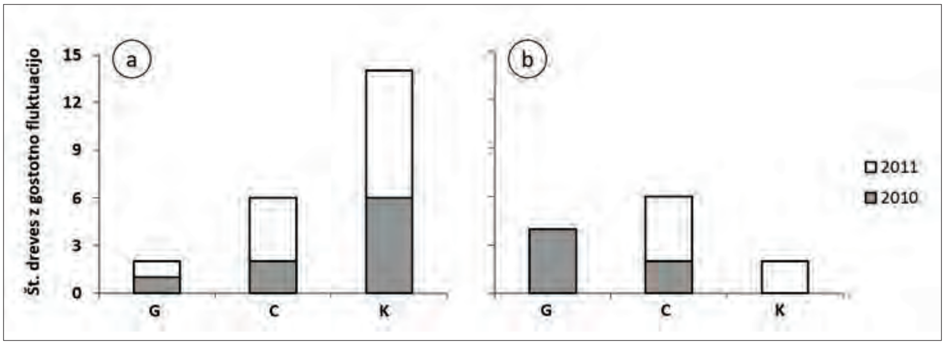
Kambijevo delovanje drevesnih vrst zmernega in hladnega pasu je periodično, s tipičnimi obdobji aktivnosti in mirovanja. Tako nastane značilna struktura letnih prirastkov lesa (t.i. branik) z redkejšim in svetlejšim ranim lesom, ki se oblikuje na začetku rastne sezone ter gostejšim in temnejšim kasnim lesom, ki nastaja v drugi polovici rastne sezone. Za rani les iglavcev so značilne velike radialne dimenzije traheid s tankimi celičnimi stenami, za kasni les pa ravno obratno: majhne radialne dimenzije celičnih lumnov in debele celične stene (Panshin & de Zeeuw 1980). Pri raztreseno poroznih listavcih, kamor spada bukev, se morfološke značilnosti lesnih celic ranega in kasnega lesa ne razlikujejo tako opazno, kot denimo pri venčasto poroznih listavcih (npr. hrast). Kljub temu pa so površine lumnov trahej oz. njihove radialne in tangencialne dimenzije v ranem lesu nekoliko večje. Poleg tega je lahko v ranem lesu večja gostota trahej (tj. število trahej na enoto površine) (Čufar 2006). Vendar pa se lahko v določenih primerih značilna lesno-anatomska zgradba branik posamezne drevesne vrste spremeni in so lahko prisotne t.i. gostotne fluktuacije, ko se v ranem lesu pojavijo celice z morfološkimi značilnostmi celic kasnega lesa in obratno, ko v kasnem lesu nastanejo ranem lesu podobne celice (slika 1a, c) (De Micco et al. 2016a, c).

Z vidika debelinskega in višinskega prirastka so boru najmanj ustrezale razmere v C in najbolj v K. Bukvi so najbolj ustrezale razmere v C in najmanj v K. Dvoletni lesni prirastek je bil v vseh primerih širši pri boru kot pri bukvi, in sicer za okoli 57 % v G, 9 % v C in 45 % v K (Gričar 2014). Gostotne fluktuacije so se pri boru v letu 2011 v splošnem pogosteje pojavljale v primerjavi s predhodnim letom (slika 2a). Najmanj gostotnih fluktuacij smo v obeh letih zasledili v G (2010: ena sadika; 2011: ena sadika), največ pa v K, kjer so bile prisotne pri več kot polovici sadik (2010: šest sadik; 2011: osem sadik). V C so bile gostotne fluktuacije v letu 2010 prisotne pri dveh sadikah, v letu 2011 pa pri štirih. Zveze med širino lesne branike in pojavnostjo gostotnih fluktuacij pri boru nismo potrdili. Pri bukvah je prisotnost fluktuacij med leti v posameznih



Slika 1: a) Prisotnost kompresijskega lesa (bela puščična ost), gostotnih fluktuacij (siva puščična ost) ter aksialnih smolnih kanalov v prehodnem lesu (črna puščica) in kasnem lesu (bela puščica) pri boru, merilce je 500 µm. b) Prisotnost tenzijskega lesa (bela puščična ost) pri bukvi, merilce 200 je µm. c) Prisotnost gostotnih fluktuacij (siva puščična ost) pri bukvi, merilce je 200 µm. d) Prisotnost anomalij (vključki v trahejah) (črna puščična ost) pri bukvi, merilce je 200 µm.
Figure 1: a) Presence of compression wood (white arrow-head), density fluctuations (grey arrow-head), and axial resin canals in transition wood (black arrow) and latewood (white arrow) in pine, bar = 500 µm. b) Presence of tension wood (white arrow-head) in beech, bar = 200 µm. c) Presence of density fluctuations (grey arrow-head) in beech, bar = 200 µm. d) Presence of anomalies (deposits in vessels) (black arrow-head) in beech, bar = 200 µm.

režimih variirala (slika 2b). V letu 2010 jih je bilo največ pri sadikah v G, kjer so se pojavile pri štirih sadikah, v C so bile prisotne pri dveh sadikah, pri sadikah K jih nismo zabeležili. V letu 2011 se je to razmerje med režimi nekoliko obrnilo, saj v G nismo zabeležili gostotnih fluktuacij pri nobeni sadiki, v C pri štirih sadikah in v K pri dveh sadikah. Zveze med širino lesne branike in prisotnostjo gostotnih fluktuacij tudi pri bukvi nismo potrdili. Pojavnost gostotnih fluktuacij se je pri vrstah razlikovala, pri boru so se fluktuacij pojavile v obeh rastnih sezonah pri posameznih sadikah v vseh treh režimih. V splošnem je bilo največ gostotnih fluktuacij pri boru v K, v C pa je bilo v obeh letih njihovo število enako pri obeh vrstah.



Slika 2: Prisotnost gostotnih fluktuacij v lesu a) bora in b) bukve v lesnih branikah 2010 in 2011, ki so bile izpostavljene različnim temperaturnim režimom.
Figure 2: Presence of density fluctuations in wood of a) pine and b) beech seedlings in annual xylem increments of 2010 in 2011, exposed to different temperature regimes.

Na nastanek gostotnih fluktuacij vplivajo vremenske spremembe, zlasti temperatura in padavine, ki neposredno vplivajo na kambijevo delovanje in celično diferenciacijo. Gostotne fluktuacije so se tako izkazale za primerne indikatorje sprememb okoljskih razmer pri različnih drevesih vrstah (Wimmer & Grabner 2000, de Luis et al. 2007). V sredozemski klimi, naprimer, se gostotne fluktuacije pojavijo v lesnih branikah jeseni, po poletni suši. Zaradi pomanjkanja vode in visokih temperatur poleti se v tem obdobju kambijeva celična produkcija upočasni ali celo ustavi, nastajati pa začnejo celice kasnega lesa (de Luis et al. 2007). Takrat se zaradi zmanjšanega vodnega potenciala zmanjša turgorski tlak v celicah, ki negativno vpliva na njihovo rast (Hölttä et al. 2010). Manjša velikost celic pa obenem zmanjšuje tveganje za kavitacijo (Steppe et al. 2015). Jesenske padavine in nižje temperature ponovno spodbudijo kambijevo celično produkcijo, ko nastanejo ranem lesu podobne celice s tankimi celičnimi stenami v kasnem lesu. A da gostotno fluktuacijo opazimo, mora nastati zadostno število celic (de Luis et al. 2011).

Gostotne fluktuacije se pojavljajo tudi pri drevesih, ki rastejo v zmerni in hladni klimi, in sicer bodisi zaradi sušnega stresa v poletnih mesecih ali pa nadpovprečno vlažnih in hladnih razmer na višku rastne sezone (De Micco et al. 2016c). Poleg tega je pogostost gostotnih fluktuacij pri mladih drevesih z mladostnim lesom večja (Wimmer 2002). Juvenilni ali mladostni les nastaja v prvih letih debelinske rasti drevesa, v t.i. juvenilnem obdobju, ki mnogokrat sovpada s časom prvega cvetenja in ploditve. Juvenilno obdobje navadno traja 10–20 let (od 5–60 let). Vlakna tedaj še ne dosežejo svoje maksimalne dimenzije, ki je značilna za zreli les. Za mladostni les so značilne manj izrazite letnice, pravi kasni les pa manjka, zato je tudi gostota manjša od gostote zrelega lesa. Za mladostni les je še značilno, da pogosto vsebuje večji delež reakcijskega lesa. Lastnosti mladostnega lesa so v splošnem slabše od zrelega lesa. Kljub temu je ta les je gospodarsko zelo pomemben, saj so drevesa dostikrat posekana še pred koncem juvenilnega obdobja (Torelli et al. 1998), zato so raziskave njegovih lastnosti nujne. Nenazadnje gostotne fluktuacije lahko nastanejo tudi zaradi zmanjšanja fotosintetske aktivnosti v primeru poškodbe krošnje zaradi abiotskih dejavnikov (npr. požar, zmrzal) ali/in patogenov (Panshin & de Zeeuw 1980, De Luis et al. 2011), zato je razlog za njihov nastanek navadno težko določiti brez dodatnih kemijskih, morfoloških, ekoloških, geografskih ali zgodovinskih informacij (De Micco et al. 2016c). So pa gostotne fluktuacije zelo koristne za ugotavljanje (nenadnih) sprememb rastnih razmer pri posamezni drevesni vrsti v nekem okolju.

3.2 Pojavnost reakcijskega lesa

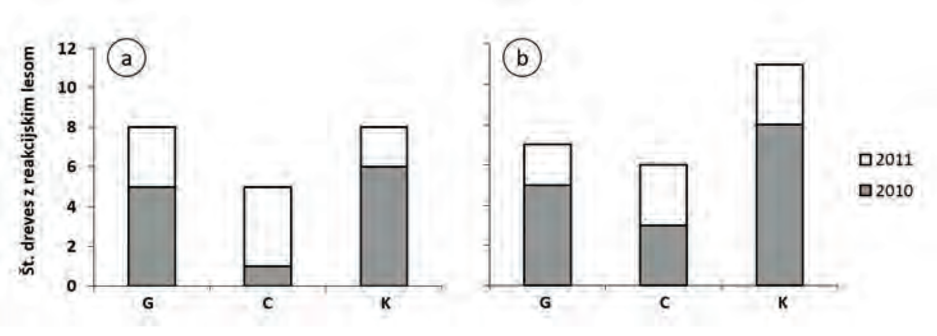
Reakcijski les imenujemo aktivno usmerjevalno tkivo anomalne anatomske zgradbe, ki nastaja pri ekscentričnih deblih ali vejah na strani z večjim polmerom. Pri iglavcih se imenuje kompresijski les in se nahaja na spodnji, tlačni strani nagnjenih debel ali vej (slika 1a). Pri listavcih se imenuje tenzijski les in se v večini primerov nahaja na zgornji natezni strani ukrivljenih debel ali vej (slika 1b). Za poravnavanje debla kompresijski les razvije tlačne sile, ki potisnejo deblo v vertikalno lego, medtem ko v tenzijskem lesu nastanejo natezne sile, ki povlečejo deblo v negativno geotropsko lego. V kompresijskem lesu je zvišana vsebnost lignina in zmanjšana vsebnost celuloze. Tenzijski les vsebuje več celuloze, vsebnost lignina in hemiceluloz je znižana (Torelli 2002).

Kompresijski les je bil pri sadikah bora izpostavljenih trem različnim režimom v veliki meri prisoten (slika 3a). V letu 2010 G in K režimih je bil kompresijski les tako prisoten kar pri polovici sadik, a le pri eni sadiki v C. V G in K je prisotnost kompresijskega lesa v letu 2011 upadla, in sicer za 40 % v G in 67 % v K. Nasprotno se je njegova prisotnost za 30 % povečala v C. Ocenili smo tudi njegov delež v posamezni lesni braniki, kadar se je pojavil. Tako je v letu 2010 znašal 10–20 % v G, 10 % v C in med 5–23 % v K, v leti 2011 pa 5–15 % v G, 3–50% v C in 3–7 % v K. Pri bukvah je bila prisotnost tenzijskega lesa v letu 2010 znatno večja kot v naslednjem letu (slika 3b). V 2010 se je pojavil pri polovici sadik v G, pri treh v C in kar pri osmih sadikah v K. Pri sadikah, kjer smo ga zabeležili, smo ocenili, da je bil njegov delež med 15–25 % v G, med 10–40 % v C in med 12–40 % v K. V letu 2011 se je v G pojavil le še v dveh primerih, v C je število ostalo nespremenjeno, v K pa se je pojavil le še pri treh sadikah. Njegov delež smo ocenili na 18–25 % v G, 15–50% v C in 18–20 % v K. Zvez med širino lesne branike in prisotnostjo oz. deležem reakcijskega lesa pri boru in bukvi nismo zasledili (podatki niso prikazani).

Reakcijski les se pogosto pojavi pri drevesih, ki rastejo na pobočju ali na območjih, kjer pihajo stalni in močni vetrovi ali pri drevesih, ki imajo asimetrično obliko krošnje (npr. robovi jas), saj morajo drevesa navpično lego debla nenehno vzdrževati. Na njegovo pojavnost lahko vplivajo tudi svetlobne razmere. Ker prisotnost reakcijskega lesa, četudi v majhnih količinah, bistveno vpliva na kakovost lesa (Torelli 2002), so raziskave povezane z njegovim nastankom gleda na okoljske razmere zelo zanimive, a redke. Pojavnost reakcijskega lesa je zelo primerna za rekonstrukcije geomorfoloških procesov (npr. plazovi) (Bräuning et al. 2016).

3.3 Gostota in položaj aksialnih smolnih kanalov pri boru

Gostota aksialnih smolnih kanalov se je pri borih izpostavljenih različnim rastnim razmeram le nekoliko razlikovala (slika 4a). V letu 2010 je bila gostota aksialnih smolnih kanalov najmanjša pri borih v G (4,13±1,85 mm-2), največja pa v K (6,63±2,29 mm-2), razlike pa niso bile statistično značilne (F = 3,09, p = 0,0617). V letu 2011 je v splošnem gostota smolnih kanalov upadla, vendar nismo zabeležili značilnih razlik med režimi (F = 1,35, p = 0,2787) (slika 4b). Gostota smolnih kanalov je bilo tokrat najmanjša pri borih v K (3,31±0,97 mm-2) in največja pri borih v C (5,51±2,56 mm-2). Med letom 2010 in 2011 smo zabeležili značilne razlike v gostoti aksialnih smolnih kanalov le v K (t = 4,806, p=0,0001). Gostota aksialnih smolnih kanalov je bila v

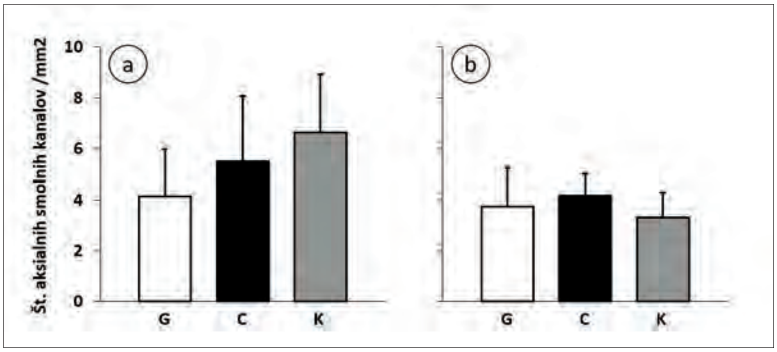


Slika 3: Prisotnost a) kompresijskega lesa pri sadikah bora in b) tenzijskega lesa pri sadikah bukve v lesnih branikah 2010 in 2011, ki so bile izpostavljene različnim temperaturnim režimom.
Figure 3: Presence of a) compression wood in pine and b) tension wood in beech seedlings in annual xylem increments of 2010 in 2011, exposed to different temperature regimes.

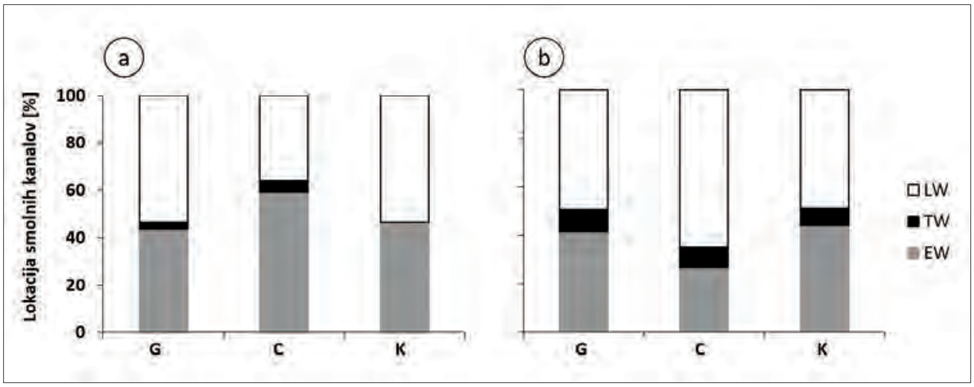
splošnem v negativni zvezi s širino branike (r = −0,275), razen v C (r = 0,242) in K (r = 0,321) v 2010.

Z izjemo travmatskih smolnih kanalov, ki smo jih zasledili v par primerih ob kalusu kot odziv na poškodbo kambija in so bili tangencialno razporejeni, so bili normalni aksialni smolni kanali posamično razpršeni po lesni braniki (slika 1a). Preverili smo njihovo lokacijo v braniki, ki smo jo razdelili na tri dele: rani les, prehodni les in kasni les. To razdelitev smo naredili vizualno pod 10x povečavo svetlobnega mikroskopa na osnovi obarvanosti tkiva ter radialnih dimenzij in debeline celičnih sten traheid. V splošnem se je najmanj aksialnih smolnih kanalov nahajalo v prehodnem lesu (2010 = pod 5 %). V letu 2011 se je njihov delež nekoliko povečal v vseh treh režimih, a še vedno ni presegel 10 % (slika 5). Pri K borih aksialnih smolnih kanalov v tem delu branike sploh nismo zabeležili. Pri G in C borih je bil delež aksialnih smolnih kanalov v ranem in kasnem lesu primerljiv v obeh letih in je v kasnem lesu znašal nekoliko več kot 50 % v letu 2010 (G = 53,58 %; C = 53,48 %) ter v letu 2011 upadel za okoli 4 % (G = 49,34 %; C = 48,98 %). Porast deleža aksialnih smolnih kanalov v prehodnem lesu je sorazmerno zmanjšala njihove delež v ranem in kasnem lesu (slika 5). Pri C borih je delež aksialnih smolnih kanalov v ranem lesu predstavljal 59,09 %, v letu 2011 pa se je razmerje obrnilo in se je njihov delež v ranem lesu zmanjšal na 26,49 %.

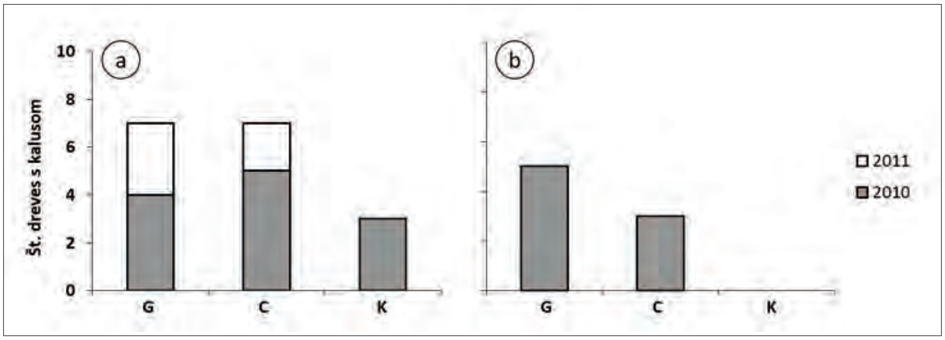
Prisotnost normalnih smolnih kanalov je zelo pomembna karakteristika lesa pri določanju vrste. Za les borov so značilni (Grosser 1977). Smolni kanali so pomembna pasivna zaščita iglavcev v primeru napada patogenov. Ob stresnem dogodku (npr. ranitev drevesa) se lahko tvorijo tudi poškodbeni ali travmatski smolni kanali, ki so urejeni v tangencialnih nizih in predstavljajo aktivni obrambni sistem (Bräuning et al. 2016).



Slika 4: Gostota aksialnih smolnih kanalov v lesu sadik bora v letu a) 2010 in b) 2011, ki so bile izpostavljene različnim temperaturnim režimom.
Figure 4: Density of axial resin canals in wood of pine seedlings in a) 2010 and b) 2011, exposed to different temperature regimes.



Slika 5: Položaj aksialnih smolnih kanalov v lesu sadik bora v letu a) 2010 in b) 2011, ki so bile izpostavljene različnim temperaturnim režimom. EW – rani les, TW – prehodni les, LW – kasni les
Figure 5: Position of axial resin canals in wood of pine seedlings in a) 2010 and b) 2011, exposed to different temperature regimes. EW – earlywood, TW – transition wood, LW – latewood



Slika 6: Prisotnost kalusa v lesu a) bora in b) bukve v lesnih branikah 2010 in 2011, ki so bile izpostavljene različnim temperaturnim režimom.
Figure 6: Presence of callus tissue in wood of a) pine and b) beech in annual xylem increments of 2010 in 2011, exposed to different temperature regimes.

Normalni smolni kanali so pri rdečem boru večinoma prisotni v kasnem lesu, njihova pojavnost pa naj bi bila povezana s spremenjenimi okoljskimi razmerami (Rigling et al. 2003). Sicer je položaj normalnih smolnih kanalov v lesni braniki in natančen čas stresnega dogodka težko povezati, saj navadno nastanejo nekoliko z zamikom v procesu celične diferenciacije. Nekateri avtorji navajajo, da je neodvisno od rastiščnih pogojev, njihov nastanek v pozitivni zvezi s poletnimi temperaturami in vodnim stresom (Wimmer & Grabner 1997, Rigling et al. 2003, de Luis et al. 2007). V našem primeru bi lahko njihovo večjo gostoto v leto 2010 povezali s presaditvenimi šokom, ki je potem vplival tudi na njihovo debelinsko rast. Rigling in sodelavci (2003) za rdeči bor navajajo, da je v širokih branikah delež smolnih kanalov višji v ranem lesu, pri ožjih pa višji v kasnem lesu. V našem primeru teh zvez ni bilo mogoče potrditi, kar bi lahko pojasnili s tem, da so omenjeni avtorji raziskovali lesno-anatomske značilnosti odraslih borov, mi pa triletnih sadik (mladostni les).

3.4 Pojavnost kalusa

Prisotnost poškodb kambija smo določili na podlagi prisotnosti kalusa in anomalij v strukturi lesa, kot naprimer netipična obarvanja celičnih sten ali vključki v lumnih aksialnih lesnih celic in trakovnih celic (De Micco et al. 2016b). Pri borih so se anomalije oz. poškodbe v večji meri pojavljale v letu 2010, in sicer pri štirih sadikah v G, pri polovici sadik v C in pri treh sadikah v K (slika 6a). V letu 2010 se je prisotnost poškodb v vseh treh režimih zmanjšala, pri čemer smo jih zabeležili pri treh sadikah v G, pri dveh v C, medtem ko jih pri sadikah v K nismo opazili. Pri bukvah smo opazili le anomalije, in sicer v obliki netipičnih obarvanj celičnih sten ali lumnov aksialnih lesnih celic in trakovnih celic. V letu 2010 smo ta pojav zabeležili pri polovici sadik v G in pri treh sadikah v C (slika 6b). Pri K sadikah anomalij v obeh letih nismo zasledili. V letu 2011 nasploh nismo zasledili anomalij v strukturi lesnih branik v nobenem režimu.

Poškodbe živih tkiv skorje in kambija povzročijo izsušitev poškodovanega tkiva, nekrozo kambija in nediferenciranih lesnih celic, nastanek kalusa in poranitvenega lesa. Pri iglavcih nastanejo še travmatski smolni kanali, ki so razporejeni v tangencialnih nizih. Pri manjših poškodbah je obseg ranitvenega tkiva manjši, struktura poškodovanega tkiva pa je neodvisna od velikosti rane. Poranitveni les mesto poškodbe preraste. Celice poranitvenega lesa, ki nastanejo nad kalusom, so dezorientirane in nepravilnih oblik (Gričar 2007). V lumnih celic se pogosto pojavijo tile in depoziti, ki jih opazimo z obarvanjem (slika 1d). Naštete strukturne spremembe so pomembne pri omejevanju območja rane in širitve patogenov (Torelli et al. 1990). Znatno večja pogostost tovrstnih poškodb v letu 2010 kaže vpliv manipulacije sadik pri presaditvi za potrebe poskusa. Vse te spremembe lesa pa negativno vplivajo na njegovo kakovost.

4 ZAKLJUČKI

V predhodnji analizi debelinske in višinske rasti sadik rdečega bora in navadne bukve smo zaključili, da je bil vpliv različnih okoljskih razmer na debelinsko rast dreves bolj opazen pri sadikah bora kot pri sadikah bukve. Na debelinsko rast sadik bora je hladnejše okolje negativno vplivalo, saj se je rast pri teh sadikah zaključila prej kot pri sadikah na prostem in v rastlinjaku. Pri sadikah bukve, ki so bile izpostavljene različnim okoljskim razmeram, nismo opazili razlik v dinamiki debelinske rasti. Rezultati kažejo na vrstno specifičen odziv pionirskega rdečega bora in sencovzdržne bukve na različne okoljske razmere v smislu debelinske rasti (Gričar 2014).

V pričujoči raziskavi ugotavljamo, da je bila pojavnost lesno-anatomskih značilnosti v splošnem večja v letu 2010 kot v 2011. To bi lahko pojasnili s presaditvenim šokom in z večjo verjetnostjo povzročitve mehanskih poškodb ob manipulaciji sadik, ki so negativno vplivali na kakovost lesa. Razlike v strukturnih posebnosti lesnih prirastkov v obeh proučevanih letih tudi kažejo na nujnost večletnih tovrstnih poskusov v nadzorovanih razmerah. Nenazadnje se nekateri odzivi lahko pokažejo šele v daljšem obdobju. Rezultati nadalje nakazujejo, da širina lesnega prirastka in lesno-anatomske značilnosti niso nujno povezane, zato na podlagi priraščanja ne moremo sklepati o kakovosti lesa. Ugotovitev opravljenih na mladostnem lesu mladih sadik ni mogoče neposredno prenesti na zreli les, vendar pa tovrstne raziskave pokažejo vpliv okoljskih dejavnikov na strukturne značilnosti lesa. Sadike so pri tem še posebej primerne, saj so zaradi majhnosti, neposrednega stika z dinamično mikro-klimo površja zelo občutljive na stresne razmere. Informacije o ranljivost sadik na spreminjajoče se okoljske razmere so tako pomembne z ekološkega in ekonomskega razlika, saj je mladostni les gospodarsko zelo pomemben, zato je nujno poznavanje njegovih lastnosti (Torelli et al. 1998). Poznavanje vzrokov za nastanek glavnih napak pri pomembnejših drevesnih vrstah, ustrezna gojitvena praksa ter izogibanje poškodbam drevja pri gozdnih posegih lahko tako veliko prispevajo h kakovosti lesa (Gričar 2011).

5 SUMMARY

Wood is used for various purposes and exploits it to its different properties. The quality of wood is the basic criterion for the suitability of wood for certain purposes, and is the result of tree growth, growth specifics and damage due to various factors. Thus, knowledge on structure and properties of wood is crucial for its optimal woodworking, processing and end-use. Wood anatomical features may be visible on the microscopic as well as on the macroscopic scale. While the former can often be quantified by detailed wood anatomical analyses, the latter are often treated as qualitative features or as binary variables (present/absent). Macroscopic tree-ring features can be quantified in terms of frequency, intensity, or classified according to their position within a xylem ring. In the paper, we describe and compare characteristics of wood structure of three-year-old pine (*Pinus sylvestris*) and beech (*Fagus sylvatica*) seedlings exposed to different temperature regimes in the growing seasons of 2010-2011: control (K, outdoors, mean temperature during the growing season = 17–19°C), greenhouse (G, mean temperature during the growing season = 22–24°C) and climatized room (C, mean temperature during the growing season = 15–17°C). On transverse-sections of xylem, presence and proportion of the reaction wood, presence of the density fluctuations, presence of callus tissue, and in the case of pine also density and position of the axial resin canals were evaluated. On transverse-sections of xylem, presence and proportion of the reaction wood, presence of the density fluctuations, presence of callus tissue, and in the case of pine also density and position of the axial resin canals were evaluated. A characteristic of tree species in the temperate climatic zone is a seasonal alternation of cambial activity and dormant (resting) periods, which is generally related to alternations of cold and hot or rainy and dry seasons Cambial activity usually starts in spring with cell division and ends in late summer with the completed development of the latest newly formed cells. Xylem rings are composed of early wood and late wood. Early wood cells are formed at the beginning of the growing season and are characterized by a large radial dimension and thin cell walls. The development of late wood cells with small radial dimensions and thick cell walls occurs in summer, resulting in its higher density. Intra-annual density fluctuations in xylem rings are generally considered structural anomalies in the normal structure of wood increments, such as earlywood-like cells in within latewood or latewood-like cells in earlywood. The formation of intra-annual density fluctuations can be triggered directly by environmental changes, especially in precipitation and temperature, that affect cambial activity and cell differentiation. It can also be the result of limited photosynthesis, due to defoliation induced by biotic or abiotic constraints. Normal resin canals are usually present in wood of Pinus genus. Axial and radial resin canals together form a network. In addition, traumatic resin canals can appear which form as a response of cambium to mechanical wounding. Intensive exploitation of trees with smaller diameter of logs will result in higher proportions of juvenile wood in the timber. The criteria for definition of the boundary between juvenile and mature wood are various and are mostly based on stabilising of anatomical dimensions. The juvenile period is very variable, depending on cambial activity, and usually occupies at least 10 to 20 growth rings, rarely even up to 60 years. Juvenile wood with shorter fibres, thinner cell walls, spiral grain and larger amounts of reaction wood poses a serious problem in performance of solid wood products. The juvenile wood has generally worse anatomical characteristics and physical properties as those in the mature wood of the same tree. Thus, structure and properties of juvenile wood need to be well characterized, to process and use the timber effectively. The formation of reaction wood is related to gravitropic signals and is formed in tilted trees because of external forces or mechanical stresses on the stems or crowns. In conifers, it is formed in lower part of the stem/ branches and is called compression wood while in angiosperms it is formed in upper part of the stem/ branches and is called tension wood. It is often present in juvenile wood and if present in higher proportions, it reduces wood quality. The mechanical damage of the cambium causes the formation of callus, wound-wood and traumatic resin canals. The structure of wounded tissue is independent of the size of the wound. Presence of such tissues in the wood reduces its quality. The results show species-specific response of pioneer Scots pine and late-successional beech to different environmental conditions in terms of radial growth and structural characteristics of wood. Incidence of wood-anatomical characteristics were generally higher in 2010 than in 2011. This may be explained by the transplant shock, and higher probability of mechanical wounding of cambium, which have a negative impact on the wood quality, when setting up the experiment. The differences in the structure of xylem increments of 2010 and 2011 demonstrate that a continuation of such observations over several growing seasons is necessary to capture the short- and long-term response of tree growth under changing environmental conditions. Finally, width of the wood increment and wood-anatomical characteristics are not necessarily linked, thus increment width cannot be an indicator of wood quality.

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6 LITERATURA - REFERENCES

Bigler, C., J. Gričar, H. Bugmann & K. Čufar, 2004: *Growth patterns as indicators of impending tree death in silver fir.* Forest Ecology and Management (Amsterdam) 199: 183-190. http://dx.doi.org/10.1016/j.foreco.2004.04.019

Bräuning, A., M. De Ridder, N. Zafirov, I. García-González, D. Petrov Dimitrov & H. Gärtner, 2016: *Tree-ring features: Indicators of extreme event impacts.* IAWA Journal (Leiden) 37: 206-231. http://dx.doi.org/10.1163/22941932-20160131

Čufar, K., 2006: *Anatomija lesa.* Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za lesarstvo. Ljubljana. (Univerzitetni učbenik,185 str.).

De Luis, M., J. Gričar, K. Čufar & J. Raventós, 2007: *Seasonal dynamics of wood formation in from dry and semi-arid ecosystems in Spain.* IAWA Journal (Leiden) 28: 389-404. http://dx.doi.org/10.1163/22941932-90001651

De Luis, M., K. Novak, J. Raventós, J. Gričar, P. Prislan & K. Čufar, 2011: *Climate factors promoting intra--annual density fluctuations in Aleppo pine (Pinus halepensis) from semiarid sites.* Dendrochronologia (Verona) 29: 163-169. http://dx.doi.org/10.1016/j.dendro.2011.01.005

De Micco, V., A. Balzano, K. Čufar, G. Aronne, J. Gričar, M. Merela & G. Battipaglia, 2016a: *Timing of false ring formation in Pinus halepensis and Arbutus unedo in southern Italy: Outlook from an analysis of xylogenesis and tree-ring chronologies.* Frontiers in Plant Science (Lausanne) 7: . http://dx.doi.org/10.3389/fpls.2016.00705

De Micco, V., A. Balzano, E. A. Wheeler & P. Baas, 2016b: *Tyloses and gums: A review of structure, function and occurrence of vessel occlusions.* IAWA Journal (Leiden) 37: 186-205. http://dx.doi.org/10.1163/22941932-20160130

De Micco, V., F. Campelo, M. De Luis, A. Bräuning, M. Grabner, G. Battipaglia & P. Cherubini, 2016c: *Intra-annual density fluctuations in tree rings: How, when, where, and why?* IAWA Journal (Leiden) 37: 232-259. http://dx.doi.org/10.1163/22941932-20160132

Gričar, J., 2007: *Xylo- and phloemogenesis in silver fir (Abies alba Mill.) and Norway spruce (Picea abies (L.) Karst.).* Ljubljana.

Gričar, J., 2011: *Lastnosti in kakovost lesa.* V: M. Medved (ur.): *Gospodarjenje z gozdom za lastnike gozdov.* Kmečki glas (Ljubljana), str. 252-257.

Gričar, J., M. De Luis, P. Hafner & T. Levanič, 2013: *Anatomical characteristics and hydrologic signals in tree--rings of oaks (Quercus robur L.).* Trees (Berlin) 27: 1669-1680. http://dx.doi.org/10.1007/s00468-013-0914-9

Gričar, J., 2014: Effect of temperature on radial growth of beech and pine saplings in the first and second year of the experiment: a comparison. Drvna Industrija (Zagreb) 65: 283-292. http://dx.doi.org/10.5552/drind.2014.1344

Grosser, D., 1977: *Die Hölzes Mitteleuropas.* Berlin, Heidelberg, New York.

Hölttä, T., H. Mäkinen, P. Nöjd, A. Mäkelä & E. Nikinmaa, 2010: *A physiological model of softwood cambial growth.* Tree Physiology (Victoria B.C.) 30: 1235-1252. http://dx.doi.org/10.1093/treephys/tpq068

Panshin, A.J. & C. De Zeeuw, 1980: *Textbook of wood technology.* New York.

Popović, M., V. Šuštar, J. Gričar, I. Štraus, G. Torkar, H. Kraigher & A. De Marco, 2015: *Identification of environmental stress biomarkers in seedlings of European beech (Fagus sylvatica) and Scots pine (Pinus sylvestris).* Canadian Journal of Forest Research (Ottawa Ont.) 46: 58-66. http://dx.doi.org/10.1139/cjfr-2015-0274

Rigling, A., H. Brühlhart, O. U. Bräker, T. Forster & F. H. Schweingruber, 2003: *Effects of irrigation on diameter growth and vertical resin duct production in Pinus sylvestris L. on dry sites in the central Alps, Switzerland.* Forest Ecology and Management (Amsterdam) 175: 285-296. http://dx.doi.org/10.1016/S0378-1127(02)00136-6

Steppe, K., F. Sterck & A. Deslauriers, 2015: *Diel growth dynamics in tree stems: linking anatomy and ecophysiology.* Trends in Plant Science (Oxford) 20: 335-343. http://dx.doi.org/10.1016/j.tplants.2015.03.015

Torelli, N., 1990: *Les & skorja. Slovar strokovnih izrazov.* Ljubljana.

Torelli, N., 1991: *Makroskopska in mikroskopska identifikacija lesa (ključi).* Ljubljana.

Torelli, N., 1998: *Lesna tekstura.* Les (Ljubljana) 50: 11-15.

Torelli, N., Ž. Gorišek, M. Zupančič & T. Logar, 1998: *Juvenilni les pri jelki (Abies alba Mill.) in smreki (Picea abies Karst.).* Les (Ljubljana) 50: 5-7.

Torelli, N., 2002: *Reakcijski les in njegova mehanika.* Les (Ljubljana) 54: 140-147.

Van Der Werf, G.W., U. Sass-Klaassen & G.M.J. Mohren, 2007: *The impact of the 2003 summer drought on the intra-annual growth pattern of beech (Fagus sylvatica L.) and oak (Quercus robur L.) on a dry site in the Netherlands.* Dendrochronologia (Verona) 25: 103-112. http://dx.doi.org/10.1016/j.dendro.2007.03.004

Vlada RS, 2015: *Slovenska strategija pametne specializacije S4.* Ljubljana.

Wimmer, R. & M. Grabner, 1997: *Effects of climate on vertical resin duct density and radial growth of Norway spruce [Picea abies (L.) Karst.].* Trees (Berlin) 11: 271-276. http://dx.doi.org/10.1007/pl00009673

Wimmer, R. & M. Grabner, 2000: *A comparison of tree-ring features in Picea abies as correlated with climate.* IAWA Journal (Leiden) 21: 403-416. http://dx.doi.org/10.1163/22941932-90000256

Wimmer, R., 2002: *Wood anatomical features in tree-rings as indicators of environmental change.* Dendrochronologia (Verona) 20: 21-36. http://dx.doi.org/10.1078/1125-7865-00005

FOSILNI RIBJI ZOBJE IZ NAJDIŠČ MED TRBOVLJAMI IN LAŠKIM

FOSSIL FISH TEETH FROM SITES BETWEEN TRBOVLJE AND LAŠKO, SLOVENIA

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IZVLEČEK

Fosilni ribji zobje iz najdišč med Trbovljami in Laškim

V prispevku so obravnavani ribji zobje oziroma njihove krone iz miocenskih plasti Centralne Paratetide, ki izdanjajo na območju med krajema Trbovlje in Laško oziroma na ozemlju med rekama Savo in Savinjo. Ugotovljeni so primerki štirih rodov hrustančnic *Carcharias, Carcharoides, Cosmopolitodus* in *Carcharhinus* ter dveh rodov kostnic *Diplodus* in *Pagrus*.

Ključne besede: ribe, miocen, Centralna Paratetida, Trbovlje – Laško, Slovenija

ABSTRACT

Fossil fish teeth from sites between Trbovlje and Laško, Slovenia

In this contribution we are dealing with fish remains found in Miocene beds in the area between Trbovlje and Laško. The fossil material consists of fish teeth, belonging to fossil shark genera *Carcharias*, *Carcharoides*, *Cosmopolitodus* and *Carcharhinus* and of two kinds of bony fish belonging to genera *Diplodus* and *Pagrus*.

Key words: fishes, Miocene, Central Paratethys, Trbovlje – Laško, Slovenia

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UVOD

Po večkratnem obiskovanju in pregledovanju kamnolomov Plesko – Retje in izdankov v okolici Hrastnika, Govc in Trnovega Hriba, smo v nekaj letih našli na terenu in zasebnih zbirkah več fosilnih ribjih zobnih kron hrustančnic in kostnic. Večina zob je najdenih v kamnolomu Plesko (1), posamezne najdbe so iz najdišč Dol pri Hrastniku (2), Govce (3) in Trnov Hrib pri Govcah (4) (slika 1). Vse zobne krone rib so najdene v miocenskih kamninah, nekaj v spodnje, največ v srednjemiocenskih – badenijskih laporovcih in biokalkarenitih.

Ker omenjene ribje krone še niso bile predstavljene, smo se odločili, da jim določimo ustrezno taksonomsko mesto in jih v krajšem prispevku predočimo širši javnosti. Tako bomo obogatili zbirko fosilnih vretenčarjev iz naših najdišč, ki je trenutno na slovenskih tleh izredno skromna in pomanjkljiva. V Sloveniji nimamo ustreznega fosilnega in recentnega primerjalnega materiala za razpoznavanje fosilnih rib in drugih vretenčarjev. Zato so njihove določitve večinoma otežkočene in včasih nezanesljive.

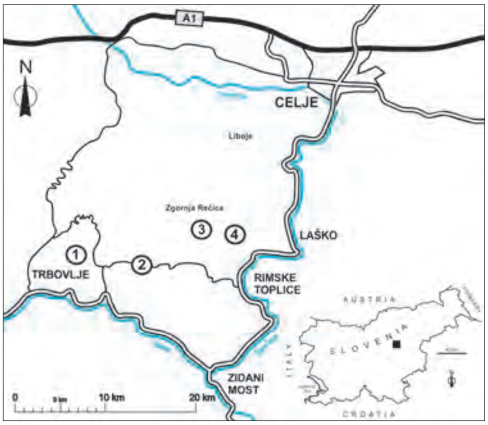
PALEONTOLOŠKI DEL

Sistematika po: Glikman 1964a, b, Cappetta 1987 in Schultz 2013

Classis Chondrichthyes Huxley, 1880
Subclassis Elasmobranchii Bonaparte, 1838
Cohort Euselachii Hay, 1902
Subcohort Neoselachii Compagno, 1977
Superordo Galeomorphii Compagno, 1973
Ordo Lamniformes Berg, 1958
Familia Odontaspididae Müller & Henle, 1839
Genus ***Carcharias*** Rafinesque, 1810

Carcharias taurus Rafinesque, 1810
Tab. 1, sl. 1-2, 4

1810 24. Sp. *Carcharias Taurus* – Rafinesque, 10
1959 *Odontaspis (Synodontaspis) acutissima* (Agassiz, 1844) – Kruckow, 85, Taf. 1, Figs. 4, 5a-c
1960 *Odontaspis acutissima* Agassiz, 1843 – Pawłowska, 421, Pl. 1, Figs. 1a-1c, 2a-2c
1969 *Odontaspis acutissima* (Agassiz) 1843 – Menesini, 10, Tav. 1, Figs. 11a-11c, 13a-13c
1972 *Odontaspis (Synodontaspis) acutissima acutissima* (Agassiz) – Schultz, Taf. 1, Fig. 2
1973 *Odontaspis (Synodontaspis) acutissima* (Agassiz) 1843 – Bauzá & Plans, 76, Lám. 4, Figs. 28-30
1974 *Odontaspis (Synodontaspis) acutissima* Agassiz 1843 – Menesini, 127, Tav. 45 (1), Figs. 1a-1c, 6a-6c
1978 *Odontaspis taurus* (Rafinesque, 1810) – Antunes, 67, Pl. 2, Fig. 16
1981 *Odontaspis taurus* Rafinesque – Antunes, Jonet & Nascimento, 17, Pl. 2, Figs. 4-6
1990 *Eugomphodus acutissimus* (Agassiz) – Rückert-Ülkümen, 34, Taf. 3, Figs. 7-8
1995 *Synodontaspis acutissima* (Agassiz, 1844) – Holec, Hornáček & Sýkora, 40, Pl. 10, Figs. 4a-b, 5a-b, Pl. 1, Figs. 1a-b
2001 *Carcharias taurus* Rafinesque, 1810 – Purdy et al., 101, Figs. 16. b, e-f



Slika 1. Geografski položaj najdišč miocenskih ribjih zob z območja med Trbovljami in Laškim
1 – kamnolom Plesko, 2 – Dol pri Hrastniku, 3 – Govce, 4 – Trnov Hrib
Figure 1. Geographical position of sites of Miocene fish teeth from the area between Trbovlje and Laško
1 – Plesko quarry, 2 – Dol at Hrastnik, 3 – Govce, 4 – Trnov Hrib

2003 *Carcharias* cf. *taurus* Rafinesque, 1810 – Vicens & Rodríguez-Perea, 120, Fig. 4. 1
2007 *Carcharias acutissima* (Agassiz, 1843) – Kocsis, 31, Figs. 4. 7-8, 11
2008 *Carcharias taurus* Rafinesque, 1810 – Portell et al., 280, Figs. 2 A-B
2011 *Carcharias taurus* Rafinesque, 1810 – Reinecke et al., 27, Pl. 11, Figs. 1a-c, 2a-c, 4a-c; Pl. 12, Figs. 10a-c; Text-Fig. 12. a-b
2012 *Carcharias acutissima* (Agassiz, 1833) – Ávila, Ramalho & Vullo, 174, Figs. 4. 1-3
2014 *Carcharias* cf. *acutissimus* Rafinesque, 1810 – Križnar & Mikuž, 99, Sl. 136-137, 139
2016 *Carcharias acutissima* (Agassiz, 1843) – Szabó & Kocsis, 580-582, Figs. 6. E-H

Material in opis: Tri zobne krone, dve iz badenijskih plasti kamnoloma Plesko, prva izolirana krona (tab. 1, sl. 1) in druga v laporastem apnencu (tab. 1, sl. 4) ter ena izolirana krona iz spodnjega miocena v okolici Govc (tab. 1, sl. 2). Za vse tri primerke je značilna labialno-lingvalna ukrivljenost ozke in suličaste krone. Njihovi rezalni robovi so gladki in ostri. Zobje so brez ohranjenih koreninskih delov.

Velikosti zob:

Carcharias taurus	**Višina in širina zoba (Height and width of tooth) mm**	**Višina krone (Crown height) mm**	**Debelina krone (Crown thickness) mm**	**Širina krone (Crown width) mm**
Tab. 1, sl. 1a-c	16 x 7	15,5	3,5	5
Tab. 1, sl. 2a-c	15 x 5	14,5	3	4,5
Tab. 1, sl. 4	27 x 7	24	?	6

Najdbe v Sloveniji: Mikuž in sod. (2014b: 28-29) predstavljajo manjšo zobno krono vrste *Carcharias* cf. *taurus* iz spodnjemiocenskih plasti v okolici Govc. Mikuž in Šoster (2014: 47) poročata, da je na ozemlju med Loko in Gorenjim Mokrim poljem v turitelnem laporovcu najden zob vrste *Carcharias taurus* Rafinesque, 1810. Pollerspöck in Beaury (2014: 25, 30) opisujeta in predstavljata ostanke vrste *Carcharias acutissimus* iz ottnangijskih plasti Bavarske v Nemčiji. Szabó in Kocsis (2016: 580-581) vrsto *Carcharias acutissima* opisujeta iz badenijskih plasti Madžarske (Nyirád). Ista avtorja (2016: 576) še navajata, da so njihovi ostanki zob najdeni v badenijskih skladih Dunajske kotline, Spodnjeavstrijske molase, v Štajerskem, Savskem, Panonskem in Transilvanskem bazenu ter ob vznožju Karpatov.

***Carcharias* sp.**

Tab. 1, sl. 7

Material in opis: Ena manjša krona v badenijskem biokalkarenitu iz kamnoloma Plesko (tab. 1, sl. 7). Krona je nizka, asimetrična in tipično karharidno suličasta, lingvalna stran je izbočena in izolirana, druga labialna stran je v kamnini. Koreninski del manjka.

Velikost zoba:

Carcharias sp.	**Višina in širina zoba (Height and width of tooth) mm**	**Višina krone (Crown height) mm**	**Debelina krone (Crown thickness) mm**	**Širina krone (Crown width) mm**
Tab. 1, sl. 7	?	5	2,5	6

Najdbe v Sloveniji: Mikuž in Šoster (2013: 201) poročata o zelo številnih zobnih kronah rodu *Carcharias* iz spodnjemiocenskih plasti okolice Žvarulj pri Mlinšah. Šoster in Mikuž (2013a: 76) opisujeta več zobnih kron morskega psa rodu *Carcharias* najdenih v miocenskih plasteh Višnje vasi pri Vojniku. Šoster in Mikuž (2013b: 154) poročata o najdbi dveh karharidnih kron iz miocenskih peščenjakov Pristove pri Dobrni. O najdbah zob ali samo njihovih kron morskih psov rodu *Carcharias* poroča Šoster (2014: 17-19) iz spodnjemiocenskih plasti Višnje vasi pri Vojniku. Mikuž in sod. (2014b: 28) poročajo o najdbi vretenca iz spodnjemiocenskih plasti v okolici Govc, ki najverjetneje pripada morskemu psu iz rodu *Carcharias*.

Familia Lamnidae Müller & Henle, 1838
Genus ***Carcharoides*** Ameghino, 1901

Carcharoides catticus (Philippi, 1846)

Tab. 1, sl. 10

1846 *Otodus catticus* – Philippi, 24, Tab. 2, Figs. 5-7
1968 *Lamna cattica* (Philippi, 1846) – Schultz, 82, Taf. 4, Fig. 58
1974 *Lamna cattica* (Philippi), 1846 – Menesini, 135, Tav. 1, Figs. 18a-18c
1987 *Carcharoides catticus* (Philippi, 1846) – Cappetta, 94-95
1990 *Lamna cattica* (Philippi, 1846) – Kruckow & Thies, 45
1995 *Carcharoides catticus* (Philippi, 1846) – Holec, Hornáček & Sýkora, 42, Pl. 12, Figs. 2a-b
2005 *Carcharoides catticus* (Philippi, 1846) – Holec & Krempaská, 560-561, Obr. 3

2005 *Carcharoides catticus* (Philippi, 1846) – Reinecke et al., 28, Taf. 19, Fig. 5
2007 *Carcharoides catticus* (Philippi, 1851) – Kocsis, 33, Figs. 5. 3a-3b
2011 *Carcharoides catticus* (Philippi, 1846) – Reinecke et al., 31, Pl. 28, Figs. 9a-b, 14a-c
2013 *Carcharoides catticus* (Philippi, 1846) – Schultz, 43
2016 *Carcharoides* cf. *catticus* (Philippi, 1846) – Szabó & Kocsis, 581, Figs. 7. C-G

Material in opis: Ohranjen je zelo majhen zob v celoti, dobra polovica je v kamnini, drugi manjši del je izoliran (tab. 1, sl. 10). Krona je majhna, nizka in triglava, sestoji iz glavne in velike osrednje simetrično trikotne konice ter dveh stranskih širokih in precej nižjih konic. Koreninski del je plitev in širok. Zob je najden v spodnjemiocenskem izdanku v Trnovem Hribu blizu Govc.

Velikost zoba:

Carcharoides catticus	Višina in širina zoba (Height and width of tooth) mm	Višina krone (Crown height) mm	Debelina krone (Crown thickness) mm	Širina krone (Crown width) mm
Tab. 1, sl. 10	4 x 5	3	?	5

Najdbe v Sloveniji in drugod: Šoster in Mikuž (2013a: 77) ter Šoster (2014: 20) predstavljajo skromno zobno krono vrste *Carcharoides catticus* iz spodnjemiocenskih plasti Višnje vasi pri Vojniku. Schultz (2013: 43) omenja ostanke vrste *Carcharoides catticus* iz ottnangijskih skladov Avstrije, iz spodnjemiocenskih plasti v preostali Paratetidi, iz oligocenskih Severnomorske kotline in spodnjega miocena Mediterana. Szabó in Kocsis (2016: 576) obliko *Carcharoides* cf. *catticus* predstavljata iz badenijskih plasti najdišča Nyirád na Madžarskem.

Genus ***Cosmopolitodus*** Glückman, 1964

Cosmopolitodus hastalis (Agassiz, 1843)
Tab. 1, sl. 3, 5-6

1838 *Oxyrhina hastalis* Agass. – Agassiz, 277, Ch. 27, Tab. 34, Figs. 1-1a, 2-2a,10-10a
1849 *Oxyrhina hastalis* Ag. – Sismonda, 40, Tav. 1. Figs. 45-47
1850 *Oxyrhina hastalis* Ag. – Costa, 196, Tav. 9, Figs. 10
1855 *Oxyrhina hastalis* – Giebel, 116, Taf. 47, Figs. 21a-b
1861 *Oxyrhina hastalis* Ag. – Sismonda, 473
1896 *Oxyrhina hastalis* Agassiz. – De Alessandri, 269, Tav. 1, Fig. 1b
1900 *Oxyrhina hastalis*, Agassiz. – Woodward, 4, Pl. 1, Figs. 6, 6a
1917 *Oxyrhina hastalis* Agass. – Stefanini, 21
1922 *Oxyrhina hastalis* Ag. – Vardabasso, Tav. 1, Figs. 6, 6a-6b
1957 *Oxyrhina hastalis* Agassiz. – Leriche, 27, Pl. 2 (Pl.45), Figs. 1, 2a-2b
1964a *Cosmopolitodus hastalis* (Agassiz) – Glikman, Tabl. 5, Fig. 5
1964b *Cosmopolitodus hastalis* (Ag.) – Glikman, 154, Ris. 75
1965 *Oxyrhina hastalis* Agassiz, 1843 – Radwański, 269, Pl. 1, Figs. 3a-3c
1966 *Oxyrhina hastalis* Ag. – Steininger, Taf. 4
1968 *Oxyrhina hastalis* Agassiz, 1843 – Schultz, 77, Taf. 2, Figs. 27-29
1969 *Isurus hastalis* (Agassiz) 1843 – Menesini, 15, Tav. 2, Figs. 5a-5c, 7a-7c
1971 *Isurus hastalis hastalis* (Agassiz, 1843) – Schultz, 321, Taf. 2, Fig. 14
1971 *Isurus hastalis escheri* (L. Agassiz, 1844) – Brzobohatý & Schultz, 732, Taf. 3, Fig. 1
1973 *Isurus oxyrhynchus hastalis* (Agassiz), 1843 – Caretto, 42 (30), Tav. 6, Figs. 1a-1c, 4a-4b,12a-12c
1973 *Isurus hastalis hastalis* (L. Agassiz, 1843) – Brzobohatý & Schultz, 666, Taf. 3, Figs. 13-14
1974 *Isurus hastalis* (Agassiz), 1843 – Menesini, 129, Tav. 55 (2), Figs. 4a-4c, 10a-10c
1977 *Isurus hastalis* Agassiz 1843 – Landini, 107, Tav. 13 (2), Figs. 4a-4c, 6a-6c
1978 *Isurus hastalis hastalis* (Ag.) – Brzobohatý & Schultz, 443, Taf. 2, Fig. 19
1987 *Isurus hastalis* (Agassiz 1843B) – Cappetta, 96
1990 *Isurus hastalis* (Agassiz, 1843) – Kruckow & Thies, 44
1995 *Isurus hastalis* (Agassiz, 1843) – Holec, Hornáček & Sýkora, 42, Pl. 12, Figs. 4a-b
1996 *Isurus hastalis* (Agassiz, 1843) – Hiden, 59-60, Abb. 7. B
1997 *Isurus oxyrhynchus hastalis* (Agassiz) – Majcen, Mikuž & Pohar, 115, Tab. 8, Sl. 2-4
1998 *Isurus hastalis* (Agassiz) – Schultz, 122-123, Taf. 55, Fig. 9
2001 *Isurus hastalis* (Agassiz, 1838) – Purdy et al., 116-117, Fig. 27, Fig. 28e
2003 *Isurus hastalis* (Agassiz, 1843) – Vicens & Rodríguez-Perea, 123, Fig. 4. 2a-b, 3
2005 *Isurus hastalis* (Agassiz, 1843) – Mikuž, 118, Tab. 3, Sl. 1a-b, 2a-b
2005 *Cosmopolitodus* aff. *hastalis* (Agassiz, 1838) – Reinecke et al., 33, Taf. 16, Fig. 1

2007 *Isurus hastalis* (Agassiz, 1843) – Kocsis, 34, Fig. 5. 7

2010 *Cosmopolitodus hastalis* (Agassiz, 1843) – Schultz, Brzobohatý & Kroupa, 500, Pl. 1, Figs. 9a-9b

2010 *Isurus hastalis* – Whitenack & Gottfried, 18, Figs. 1C

2011 *Cosmopolitodus hastalis* (Agassiz, 1838) – Reinecke et al., 36, Pl. 29, Figs. 6a-6b

2012 *Cosmopolitodus hastalis* (Agassiz, 1833) – Ávila, Ramalho & Vullo, 177, Figs. 5. 8-9, 12, 14-15

2013a*Cosmopolitodus hastalis* (Agassiz, 1838) – Šoster & Mikuž, 78, Tab. 3, Sl. 19-20

2013 *Cosmopolitodus hastalis* (Agassiz, 1838) – Mikuž & Šoster, 201, Tab. 2, Sl. 12-18

2013 *Cosmopolitodus hastalis* (Agassiz, 1838) – Mikuž, Šoster & Ulaga, 122, Tab. 1, 2a-2c

2013 *Cosmopolitodus hastalis* (Agassiz, 1843) – Schultz, 43, Taf. 4, Fig. 21

2014 *Cosmopolitodus hastalis* (Agassiz, 1838) – Križnar & Mikuž, 100, Sl. 140

2016 *Cosmopolitodus hastalis* (Agassiz, 1843) – Szabó & Kocsis, 582, 584, Fig. 7. I-K

Material in opis: Najdeni so trije zobje ali krone, prvi zob (tab. 1, sl. 3) je izoliran in najden v spodnjemiocenskih plasteh v Govcah. Krona je visoka in asimetrična, rezalna robova sta gladka. Koreninski del je odlomljen. Druga krona (tab. 1, sl. 5) je izolirana in najdena v badenijskih plasteh kamnoloma Plesko. Je tudi asimetrična z rahlo konkavno labialno stranjo in konveksno lingvalno stranjo, rezalna robova sta gladka, spodnji del krone širok. Koreninski del je odlomljen. Tretji izoliran zob (tab. 1, sl. 6) je iz spodnjega miocena Govc, našla ga je R. Verdel. Krona je asimetrična in malo ukrivljena, labialna stran je ravna do rahlo izbočena, lingvalna je bolj izbočena. Rezalna robova sta gladka in zašiljena. Koreninski del manjka.

Velikosti zob:

Cosmopolitodus hastalis	**Višina in širina zoba (Height and width of tooth) mm**	**Višina krone (Crown height) mm**	**Debelina krone (Crown thickness) mm**	**Širina krone (Crown width) mm**
Tab. 1, sl. 3	17 x 6,5	17	3,5	5,5
Tab. 1, sl. 5	?	35	8	24
Tab. 1, sl. 6	23 x ?	17	5	9,5

Najdbe v Sloveniji in drugod: Majcen in sod. (1997: 115) predstavljajo tri zobne krone iz okolice Laškega, ki pripadajo vrsti *Cosmopolitodus hastalis*. Žalohar in sod. (2010: 30) predstavljajo dve večji zobni kroni morskega psa iz srednjemiocenskih plasti pod Viševco v Tunjiškem gričevju. Kroni pripadata vrsti *Cosmopolitodus hastalis*. Majcen (2011: 27) piše, da so zobje morskih psov dokaj pogosti v peščenjakih pri Govcah in znova predstavlja tri kozmopolitodusove zobne krone. Mikuž in Šoster (2013: 201-203) poročata o razmeroma pogostnih najdbah zobnih kron vrste *Cosmopolitodus hastalis* iz spodnjemiocenskih kamnin okolice Žvarulj pri Mlinšah. Šoster in Mikuž (2013a: 78) opisujeta dve zobni kroni iz miocenskih plasti Višnje vasi pri Vojniku. Šoster in Mikuž (2013b: 155-156) predstavljata eno izolirano kozmopolitodusovo zobno krono iz miocenskih peščenjakov Pristove pri Dobrni. Mikuž in sod. (2013: 122-125) poročajo o dveh lepše ohranjenih zobnih kronah vrste *Cosmopolitodus hastalis* iz badenijskih plasti kamnoloma Plesko. Šoster (2014: 23-24) opisuje tri zobne krone morskega psa vrste *Cosmopolitodus hastalis* iz spodnjemiocenskih plasti najdišča Višnja vas pri Vojniku. Mikuž in Šoster (2014: 47) poročata, da so v badenijskih turitelnih laporovcih na ozemlju med Loko in Gorenjim Mokrim poljem našli zob vrste *Cosmopolitodus hastalis* (Agassiz, 1838). Schultz (2013: 45-47) tovrstne ostanke zob omenja iz številnih oligocenskih in miocenskih najdišč Centralne Paratetide, Severnomorske kotline, Atlantske province in Mediterana. Szabó in Kocsis (2016: 576) opisujeta vrsto *Cosmopolitodus hastalis* iz badenijskih plasti Madžarske. Nadalje še poročata, da je ugotovljena v celotni Centralni Paratetidi: v Dunajski kotlini, v Avstrijski molasi, Štajerkem, Savskem, Panonskem in Transilvanskem bazenu ter v vznožju Karpatov.

Ordo Carcharhiniformes Compagno, 1973
Familia Carcharhinidae Jordan & Evermann, 1896
Genus ***Carcharhinus*** Blainville, 1816

Carcharhinus priscus (Agassiz, 1843)
Tab. 1, sl. 8-9

1843 *Sphyrna prisca* Agass. – Agassiz, 234, Ch. 20, Vol. 3, Tab. 26a, Fig. 44

1968 *Carcharhinus (Hypoprion) acanthodon* (Le Hon, 1871) – Schultz, Taf. 4, Figs. 77-78

1971 *Carcharhinus priscus* (Agassiz, 1843) – Schultz, 328, Taf. 4, Figs. 18a-18c

1973 *Carcharhinus plumbeus priscus* (Agassiz), 1843 – Caretto, 71 (59), Tav. 12, Figs. 1a-1b, 5a-5b

1974 *Sphyrna prisca* Agassiz, 1843 – Menesini, Tav. 8, Figs. 4a-4c, 5a-5c

1978 *Carcharhinus* sp. II gr. »*priscus*« (Ag.) – Antunes, 70, Pl. 3, Figs. 85, 87

1981 *Carcharhinus priscus* (Agassiz) – Antunes, Jonet & Nascimento, 18, Pl. 2, Figs. 18a-18b
1990 *Carcharhinus priscus* (Agassiz 1843) – Kruckow & Thies, 52
1992 *Carcharhinus priscus* (Agassiz) – Solt, 500, Táb. 1, Fig. 5
1995 *Carcharhinus priscus* (Agassiz, 1843) – Holec, Hornáček & Sýkora, 46, Pl. 18, Figs. 1a-b, 2a-b
1996 *Carcharhinus priscus* (Agassiz, 1843) – Hiden, 65, Taf. 5, Fig. 2
1998 *Carcharhinus priscus* (Agassiz) – Schultz, 122-123, Taf. 55, Figs. 14a-14b
2001 *Carcharhinus priscus* (Agassiz, 1843) – Holec, 123, Tab. 2, 4a-4b, 6a-6b
2003 *Carcharhinus priscus* Agassiz, 1843 – Vicens & Rodríguez-Perea, 124, Fig. 4. 8a-b
2005 *Carcharhinus priscus* (Agassiz, 1843) – Fernandes dos Reis, 35, Figs. 4 A-B
2006 *Carcharhinus priscus* (Agassiz, 1843) – Holec, 75, 7a-7b
2007 *Carcharhinus priscus* (Agassiz, 1843) – Kocsis, 36, Figs. 6. 11-12
2009 *Carcharhinus gibbesi* (Woodward, 1889) – Cicimurri & Knight, 632-633, Figs. 5C-D
2010 *Carcharhinus priscus* (Agassiz, 1843) – Schultz, Brzobohatý & Kroupa, 502-503, Pl. 2, Figs. 11a-11b
2011 *Carcharhinus priscus* (Agassiz, 1843) – Reinecke et al., 63, Text-Fig. 22. a, k-o; Pl. 72, Figs. 7a-c; Pl. 73, Figs. 7a-c; Pl. 74, Figs. 1a-c; Pl. 76, Figs. 7a-d
2013 *Carcharhinus priscus* (Agassiz, 1843) – Schultz, 80, Taf. 7. Figs. 6a-6b, 7a-7b
2014 *Carcharhinus priscus* (Agassiz, 1843) – Pollerspöck & Beaury, 29, 25, Taf. 1, Figs. 2a-2b
2016 *Carcharhinus priscus* (Agassiz, 18439 – Szabó & Kocsis, 585-586, Fig. 8. F,G

Material in opis: Dva primerka, prvi je v sivem peščenem laporovcu s preseki koron morskih ježkov iz badenija kamnoloma Plesko (tab. 1, sl. 8), našla ga je Š. Ulaga. Drugi zob, ki ga je ob potoku blizu Dola pri Hrastniku našla osmošolka OŠ NH Rajka v Hrastniku (tab. 1, sl. 9) je v spodnjemiocenskem biokalkarenitu z dvema odtisoma kardiid in enim večjim delom lupine pektenidne školjke. Za oba zoba je značilna nizka trikotna osrednja krona, ki se razširi na vsako stran z nizkimi in drobnimi zobci. Koreninski del je nizek s široko razprtima rogljema.

Velikosti zob:

Carcharhinus priscus	Višina in širina zoba (Height and width of tooth) mm	Višina krone (Crown height) mm	Debelina krone (Crown thickness) mm	Širina krone (Crown width) mm
Tab. 1, sl. 8	7 x 10	5	?	9
Tab. 1, sl. 9	7 x 7,5	5	?	5

Najdbe v Sloveniji in drugod: Mikuž in Šoster (2013: 204) poročata o nekaj kronah in redkih celih zobeh vrste *Carcharhinus priscus* iz spodnjemiocenskih plasti okolice Žvarulj pri Mlinšah. Mikuž in Šoster (2014: 47) pišeta, da je na območju Šmarjete na Dolenjskem v badenijskem laporovcu najden zob vrste *Carcharhinus priscus* (Agassiz, 1843). Schultz (2013: 81-84) omenja ostanke vrste *Carcharhinus priscus* iz zgornjeoligocenskih in miocenskih plasti Centralne in Zahodne Paratetide ter miocenskih plasti Severnomorske kotline, Atlantske province in Mediterana. Pollerspöck in Beaury (2014: 29) vrsto *Carcharhinus priscus* predstavljajo iz ottnangijskih plasti Bavarske v Nemčiji. Szabó in Kocsis (2016: 585) pišeta, da je vrsta *Carcharhinus priscus* ugotovljena v badenijskih skladih Madžarske, v Dunajski kotlini in okolici, na območju Avstrijske molase, v Štajerskem, Savskem, Panonskem in Transilvanskem bazenu ter na vznožju Karpatov.

Sistematika po: Nelson 2006

Classis Actinopterygii Klein, 1885
Divisio Teleostei Müller, 1846
Ordo Perciformes Bleeker, 1859
Familia Sparidae Bonaparte, 1831

Genus ***Diplodus*** Rafinesque, 1810

Diplodus jomnitanus (Valenciennes, 1844)
Tab. 2, sl. 1-2

1844 *Sargus Jomnitanus* – Valenciennes, 103, Pl. 1, Figs. 1a-1b
1957 *Sargus jomnitanus* Valenciennes – Leriche, 46, Pl. 4, Figs. 19-22
1960 *Sargus jomnitanus* Valenciennes, 1844 – Pawłowska, 425, Pl. 3, Figs. 13-16
1973 *Diplodus jomnitanus* Valenciennes 1844 – Bauzá & Plans, 105, Lám. 8, Figs. 65-67
1973 *Diplodus jomnitanus* Valenc. – Obrador & Mercadal, 118, Fig. 3. 10
1981 *Diplodus jomnitanus* (Valenciennes) – Antunes, Jonet & Nascimento, 21, Pl. 5, Figs. 7a-7b

2003 *Diplodus jomnitanus* (Valenciennes, 1844) – Vicens & Rodríguez-Perea, 127, Fig. 4. 19a-b
2010 *Diplodus sitifensis* (Valenciennes, 1844) – Schultz, Brzobohatý & Kroupa, 504, Pl. 3, Figs. 6-7
2011 *Diplodus jomnitanus* – Križnar, 40-41, Sl. 4a-4b
2013 *Diplodus jomnitanus* (Valenciennes, 1844) – Mikuž, Šoster & Ulaga, 125, Tab. 1, Sl. 3a-3c
2013 *Diplodus jomnitanus* (Valenciennes, 1844) – Schultz, 300, Taf. 67, Figs. 1a-1b

Material in opis: Najdeni sta dve kroni, prva je skoraj cela (tab. 2, sl. 1), druga ima poškodovano zgornjo rezalno površino (tab. 2, sl. 2). Obe sta iz anteriornega dela čeljustnic, najdeni v badenijskih plasteh kamnoloma Plesko.

Velikosti zob:

Diplodus jomnitanus	**Višina (Height) mm**	**Širina (Width) mm**	**Debelina (Thickness) mm**
Tab. 2, sl. 1a-c	10,5	9	5
Tab. 2, sl. 2a-c	9	7	3

Najdbe v Sloveniji in drugod: Križnar (2011: 40) predstavlja eno zobno krono vrste *Diplodus jomnitanus* iz miocenskih plasti nad Trbovljami, omenja pa tudi najdbe iz Dola pri Hrastniku. Schultz (2013: 301) omenja vrsto *Diplodus jomnitanus* iz miocenskih plasti Avstrije, iz srednjemiocenskih preostale Centralne Paratetide in Atlantske province ter miocenskih in pliocenskih plasti Mediterana. Mikuž in sod. (2013: 125-126) poročajo o najdbi zobne krone vrste *Diplodus jomnitanus* iz badenijskih plasti kamnoloma Plesko.

Genus ***Pagrus*** Cuvier, 1817

Pagrus cinctus (Agassiz, 1839)
Tab. 2, sl. 3-15

1850 *Sphaerodus cinctus* Ag. – Costa, 197, Tav. 9, Fig. 24
1899 *Chrysophrys cincta* Ag. – Vinassa de Regny, 84, Tav. 2, Figs. 17a-17b
1902 *Chrysophrys cincta* Agass. – De Alessandri, 310, Tav. 5, Figs. 8, 8a-8b
1912 *Chrysophrys cincta* Ag. sp. – Gemmellaro, 142, Tav. 4, Figs. 35-43
1916 *Chrysophrys cincta* (Ag.) – Sacco, 173 (145)
1916 *Chrysophrys cicta* (Lawl.) var. *astensis* Sacc. – Sacco, 173 (145), Figs. 1a-1b
1917 *Chrysophrys cincta* (Agass.) – Stefanini, 16, Tav. 1, Figs. 9-10
1955 *Sparus cinctus* Agassiz – Veiga Ferreira, 37, Est. 4, Fig. 38
1960 *Chrysophrys* sp. (cf. *Sphaerodus cinctus* Münster, 1870) – Pawłowska, 426, Pl. 3, Figs. 1-6
1969 *Sparus cinctus* (Agassiz) 1843 – Menesini, 41, Tav. 7, Figs. 7-11
1973 *Sparus cinctus* (Agassiz) – Caretto, 77, Tav. 14, Figs. 5a-5b
1973 *Sparus cinctus* (Agassiz) 1843 – Bauzá & Plans, 102, Lám. 4, Figs. 32-33
1973 *Sparus cinctus* Ag. – Obrador & Mercadal, 118, Fig.3. 11
1974 *Sparus cinctus* (Agassiz), 1843 – Menesini, 156, Tav. 61 (8), Figs. 21-23
1981 *Sparus cinctus* (Agassiz) – Antunes, Jonet & Nascimento, Pl. 5, Figs. 19a-19b, 23a-23b
1998 *Pagrus cinctus* (Agassiz) – Schultz, 126-127, Taf. 57, Fig. 3
2002 *Sparus cinctus* (Agassiz, 1843) – Mas & Fiol, 110, Fig. 4. 3
2003 *Sparus cinctus* (Agassiz, 1843) – Vicens & Rodríguez-Perea, 126, Fig. 4. 16
2010 *Pagrus cinctus* (Agassiz, 1836) – Schultz, Brzobohatý & Kroupa, 504, Pl. 3, Figs. 8-9
2011 *Pagrus cinctus* – Križnar, 40-41, Sl. 1-3
2013a *Pagrus cinctus* (Agassiz, 1836) – Šoster & Mikuž, 79, Tab. 3, Sl. 21-25
2013 *Pagrus* cf. *cinctus* (Agassiz, 1839) – Mikuž & Šoster, 206, Tab. 4, Sl. 32-36
2013 *Pagrus cinctus* (Agassiz, 1836) – Mikuž, Šoster & Ulaga, 126, Tab. 1, Sl. 4a-4c, 5a-5c, 6-7
2013 *Pagrus cinctus* (Agassiz, 1839) – Schultz, 305, Taf. 67, Figs. 7a-7b, 8a-8c, 9, 10a-10b
2014 *Pagrus cinctus* (Agassiz, 1836) – Križnar & Mikuž, 105, Sl. 147-148
2014 *Pagrus cinctus* (Agassiz, 1836) – Šoster, 26, Tab. 3, sl. 21-27
2014 *Pagrus cinctus* (Agassiz, 1839) – Mikuž, Bartol & Šoster, 34, Tab. 1, Sl. 1a-1c

Material in opis: Najdenih je več kron, osem kron je v obodu okroglih do ovalnih različnih velikosti, te so iz stranskih delov čeljustnic. Sedem je izoliranih (tab. 2, sl. 8-13, 15) in ena v kamnini (tab. 2, sl. 14). Pet zobnih kron je koničastih iz sprednjega ali anteriornega dela čeljustnic, dve izolirani (tab. 2, sl 3, 5) in tri v ali s kamnino (tab. 2, sl. 4, 6-7). Tudi te so različnih oblik in velikosti. Vse so iz badenijskih plasti kamnoloma Plesko.

Velikosti zob:

Pagrus cinctus	**Višina (Height) mm**	**Premer (Diameter) mm**
Tab. 2, sl. 3	9	5 x 4
Tab. 2, sl. 4	9	5
Tab. 2, sl- 5	5	5
Tab. 2, sl. 6	8,5	5,5 x 5
Tab. 2, sl. 7	9,5	7,5 x 7
Tab. 2, sl. 8a-b	8,5	12 x 10
Tab. 2, sl. 9a-b	5,5	7
Tab. 2, sl. 10a-b	5,5	11 x 10
Tab. 2, sl. 11a-b	7	12 x 10
Tab. 2, sl. 12a-b	3	6
Tab. 2, sl. 13a-b	5,5	10 x 9
Tab. 2, sl. 14a-b	5	7
Tab. 2, sl. 15a-b	8,5	13 x 12

Najdbe v Sloveniji in drugod: Križnar (2011: 40) poroča o najdbah zobnih kron vrste *Pagrus cinctus* iz miocenskih plasti okolice Trbovelj, peskokopov Tomc in Drtija pri Moravčah ter iz kamnoloma Lipovica. Schultz (2013: 306-307) omenja tovrstne ostanke zob iz zgornjeoligocenskih in miocenskih skladov Avstrije, iz miocenskih preostale Centralne Paratetide, iz miocenskih in pliocenskih Atlantske province ter pliocenskih Mediterana. Mikuž in Šoster (2013: 206-207) poročata o redkih najdbah pagarjevih zob iz spodnjemiocenskih plasti okolice Žvarulj pri Mlinšah. Mikuž in sod. (2013: 126-127) opisujejo zobne krone vrste *Pagrus cinctus* iz srednjemiocenskih badenijskih plasti kamnoloma Plesko. Šoster in Mikuž (2013a: 79) opisujeta pet pagarjevih zobnih kron iz miocenskih plasti Pristove pri Vojniku. Iz spodnjemiocenskih plasti Višnje vasi pri Vojniku in Klanca nad Dobrno opisuje Šoster (2014: 26-27) najdbe zob vrste *Pagrus cinctus*. Mikuž in sod. (2014: 34-36) predstavljajo del pagarjeve čeljustnice z zobnimi kronami v badenijskem laporovcu z Mastnega hriba nad Škocjanom. Križnar in Mikuž (2014: 105) predstavljata pagarjeve zobne krone iz badenijskih plasti kamnoloma Lipovica nad Brišami. Šoster in Kovalchuk (2016: 418, Pl. 1) predstavljata zobne krone sparid iz neogenskih in pleistocenskih plasti južnovzhodnega dela Ukrajine.

ZAKLJUČKI

Raziskovali smo ostanke ribjih zob, najdenih v miocenskih skladih kamnolomov Plesko-Retje nad Trbovljami (sl. 1, 1) ter v najdiščih Dol pri Hrastniku (sl. 1, 2), Govce (sl. 1, 3) in Trnov Hrib (sl. 1, 4). Večinoma so ohranjene samo zobne krone hrustančnic in kostnic, nekaj zob je skoraj celih, tudi z delno ohranjenimi koreninskimi osnovami. Med hrustančnicami so ugotovljeni morski psi vrst: *Carcharias taurus* Rafinesque, 1810 (tab. 1, sl. 1-2, 4), *Carcharias* sp. (tab. 1, sl. 7), *Carcharoides catticus* (Philippi, 1846) (tab. 1, sl. 10), *Cosmopolitodus hastalis* (Agassiz, 1843) (tab. 1, sl. 3, 5-6) in *Carcharhinus priscus* (Agassiz, 1843) (tab. 1, sl. 8-9). Med kostnicami sta ugotovljeni dve obliki: *Diplodus jomnitanus* (Valenciennes, 1844) (tab. 2, sl. 1-2) in *Pagrus cinctus* (Agassiz, 1839) (tab. 2, sl. 3-15).

Zobje večine vrst ugotovljenih hrustančnic in kostnic v najdiščih z območja med rekama Savo in Savinjo oziroma med Trbovljami in Laškim, so najdeni tudi v nekaterih drugih slovenskih najdiščih miocenskih skladov. Registrirane oblike rib so najbolj primerljive z miocenskimi in deloma z oligocenskimi ribjimi ostanki iz nekdanjih sedimentacijskih prostorov Centralne Paratetide ter z območij Mediterana, Atlantika in Severnomorskega bazena, nekatere oblike tudi širše.

CONCLUSIONS

Fossil fish teeth from sites between Trbovlje and Laško, Slovenia

Fish remains from several localities between Trbovlje and Laško were considered in this contribution. Localities include Plesko-Retje quarry near Trbovlje (Fig. 1, 1), Dol near Hrastnik (Fig. 1, 2), Govce (Fig. 1, 3) and Trnov hrib (Fig. 1, 4). The studied material consists mostly of tooth crowns without basal parts. Entirely preserved teeth are rare. We have determined 5 species of fossil sharks: *Carcharias taurus* Rafinesque, 1810 (tab. 1, fig. 1-2, 4), *Carcharias* sp. (tab. 1, fig. 7), *Carcharoides catticus* (Philippi, 1846) (tab. 1, fig. 10), *Cosmopolitodus hastalis* (Agassiz, 1843) (tab. 1, fig. 3, 5-6) and *Carcharhinus priscus* (Agassiz, 1843) (tab. 1, fig. 8-9) and 2 species of bony fish *Diplodus jomnitanus* (Valenciennes, 1844) (tab. 2, fig. 1-2) and *Pagrus cinctus* (Agassiz, 1839) (tab. 2, fig. 3-15).

Teeth of most determined species of cartilaginous and bony fish from localities between Trbovlje and Laško were also found in other Slovenian Miocene fossil sites. The specimens are comparable with Miocene and partially Oligocene fish remains from paleogeographical areas of the Central Paratethys, Mediterranean, Atlantic and North Sea basins.

ZAHVALE

Učiteljici Romani Verdel iz Hrastnika in učenki Špeli Zupančič OŠ NH Rajka Hrastnika, Podružnica Dol pri Hrastniku se zahvaljujemo za posojena in v prispevku uporabljena fosilna zoba morskih psov.

LITERATURA – REFERENCES

Agassiz, L., 1833-1843: *Recherches sur les poissons fossiles*. Tome III. Imprimerie de Petitpierre (Neuchatel, Suisse): VIII, 1-390 + Tab. 1-47.

Antunes, M. T., 1978: *Faunes ichthyologiques du Néogène supérieur d`Angola, leur âge, remarques sur le Pliocène marin en Afrique australe*. Ciências da Terra (UNL) (Lisboa) 4: 59-90 + (Pl. 1-3).

Antunes, M. T., S. Jonet & A. Nascimento, 1981: *Vertébrés (Crocodiliens, Poissons) du Miocène marin de l`Algarve occidentale*. Ciências da Terra (UNL) (Lisboa) 6: 9-38 + (Pl. 1-5).

Ávila, S. P., R. Ramalho & R. Vullo, 2012: *Systematics, palaeoecology and palaeobiogeography of the Neogene fossil sharks from the Azores (Northeast Atlantic)*. Annales Paléontologie (Paris, New York, Barcelona) 98: 167-189. https://doi.org/10.1016/j.annpal.2012.04.001

Bauzá, J. & J. Plans, 1973: *Contribucion al conocimiento de la fauna ictiologica del Neogeno Catalano Balear*. Bolet. Soc. Hist. Natur. Baleares (Palma de Mallorca) 18: 72-131 + (Lám. 1-8).

Brzobohatý, R. & O. Schultz, 1971: *Die Fischfauna der Eggenburger Schichtengruppe*. In: J. Seneš (Ed.), Chronostratigraphie und Neostratotypen, Miozän der zentralen Paratethys. Bd. 2, M_1 Eggenburgien. Vydavatelstvo Slovenskej akadémie vied (Bratislava): 719-759 + (Taf. 1-8).

Brzobohatý, R. & O. Schultz, 1973: *Die Fischfauna der Innviertler Schichtengruppe und der Rzehakia Formation*. In: J. Seneš (Ed.), Chronostratigraphie und Neostratotypen, Miozän der zentralen Paratethys. Bd. 3, M_2 Ottnangien. Vydavatelstvo Slovenskej akadémie vied (Bratislava): 652-693 + (Taf. 1-5).

Brzobohatý, R. & O. Schultz, 1978: *Die Fischfauna des Badenien*. In: J. Seneš (Ed.), Chronostratigraphie und Neostratotypen, Miozän der Zentralen Paratethys. Bd. 4, M_4 Badenien. Verlag der Slowakischen Akademie der Wissenschaften (Bratislava): 441-464 + (Taf. 1-5).

Cappetta, H., 1987: *Chondrichthyes II. Mesozoic and Cenozoic Elasmobranchii*. In: H. P. Schultze (Ed.), Handbook of Paleoichthyology, Vol. 3B. Gustav Fischer Verlag (Stuttgart-New York): 1-193.

Caretto, P. G., 1973: *Osservazioni tassonomiche su alcuni Galeoidei del Miocene piemontese*. Boll. Soc. Paleont. Italiana 1972 (Modena) 11 (1):14-85 (3-73) + Tav. 1-14.

Cicimurri, D. J. & J. L. Knight, 2009: *Late Oligocene sharks and rays from the Chandler Bridge Formation, Dorchester County, South Carolina, USA*. Acta Palaeont. Polonica (Warszawa) 54 (4): 627-647. http://dx.doi.org/10.4202/app.2008.0077

Costa, O. G., 1850: *Paleontologia del Regno di Napoli contenente la descrizione e figura di tutti gli avanzi organici fossili*. Parte 1. (Napoli): 1-203 + Tav. 1-15.

De Alessandri, G. 1896: *Avanzi di Oxyrhina hastalis del Miocene di Alba*. Atti Soc. Italiana Sci. Natur. Mus. Civ. Stor. Natur. Milano (Milano) 36: 263-269 + Tav. 1-2.

De Alessandri, G., 1902: *Sopra alcuni odontoliti pseudomiocenici dell`istmo di Suez*. Atti Soc. Ital. Sci. Natur., Mus. Civ. Stor. Natur. Milano (Milano) 41 (3): 287-312 + Tav. 5.

Fernandes dos Reis, M. A., 2005: *Chondrichthyan Fauna from the Pirabas Formation, Miocene of Northern Brazil, with Comments on Paleobiogeography*. Anuário Inst. Geociências (UFRJ) (Rio de Janeiro) 28 (2): 31-58.

Gemmellaro, M. 1912: *Ittiodontoliti del Miocene medio di alcune regioni delle provincie di Palermo e di Girgenti*. Giorn. Sci. Natur. Econ. (Palermo) 29: 117-156 + Tav. 1-4.

Giebel, C. G., 1855: *Odontographie. Vergleichende darstellung des Zahnsystemes der lebenden und fossilen Wirbelthiere*. Verlag von Ambrosius Abel (Leipzig): XX, 1-129 + Taf. 1-52.

Glikman, L. S., 1964 a: *Podklass Elasmobranchii. Akylovie*. In: D. V. Obručev (redaktor), Osnovi paleontologii. Spravočnik dlja paleontologov i geologov SSSR. Besčeljustnie, ribi. Izdatelstvo »Nauka« (Moskva): 196-265 + Tabl. 1-6.

Glikman, L. S., 1964 b: *Akuli paleogena i ih stratigrafičeskoe značenie*. Akademija nauk SSSR, Otdelenie nauk o Zemle, otdel monografičeskih kollekcij. Izdatelstvo »Nauka« (Moskva – Leningrad): 1-227 + (Tabl. 1-31).

Hiden, H. R., 1996: Elasmobranchier (Pisces, Chondrichthyes) aus dem Badenium (Mittleres Miozän) des Steirischen Beckens (Österreich). Mitt. Abt. Geol. Paläont. Landesmuseum Joanneum, 1994/95 (Graz) 52/53: 41-110 + (Taf. 1-10).

Holec, P., 2001: *Miocénne drsnokožce a kostnaté ryby (Chondrichthyes et Osteichthyes, Vertebrata) z viedenskej panvy pri Bratislave (Slovensko)*. Mineralia Slovaca (Bratislava) 33: 111-134.

Holec, P., 2006: *Žraloky (Chondrichthyes, Vertebrata) z Hajnáčky*. Mineralia Slovaca (Bratislava) 38: 71-76.

Holec, P., M. Hornáček & M. Sýkora, 1995: *Lower Miocene Shark (Chondrichthyes, Elasmobranchii) and Whale Faunas (Mammalia, Cetacea) near Mučín, Southern Slovakia*. Geologické práce (Bratislava) 100: 37-52 + Pl. 8-22.

Holec, P. & Z. Krempaská, 2005: *Nález zuba žraloka Carcharoides catticus (Philippi, 1846) (Chondrichthyes, Vertebrata) na Slovensku z lokality Hlinisko v Spišskej Novej Vsi (paleogén)*. Mineralia Slovaca (Bratislava) 37: 559-562.

Kocsis, L., 2007: *Central Paratethyan shark fauna (Ipolytarnóc, Hungary)*. Geol. Carpathica (Bratislava) 58 (1): 27-40.

Križnar, M., 2011: *Miocenski zobje rib kostnic iz Zasavja*. Društvene novice (Tržič) 44: 40-41.

Križnar, M. & V. Mikuž, 2014: *Kamnolom Lipovica in njegove paleontološke zanimivosti. (Lipovica quarry and its interesting paleontological characteristics)*. Scopolia (Ljubljana) 82: 1-120.

Kruckow, T., 1959: *Eine untermiozäne Haifisch-Fauna in Schleswig-Holstein*. Meyniana (Kiel) 8: 82-95 + Taf. 1-2.

Kruckow, T. & D. Thies, 1990: *Die Neoselachier der Paläokaribik (Pisces: Elasmobranchii)*. Cour. Forsch.-Inst. Senckenberg Frankfurt am Main (Frankfurt am Main) 119: 1-102.

Landini, W., 1977: *Revisione degli »Ittiodontoliti pliocenici« della collezione Lawley*. Palaeontographia Italica (Pisa) 70, n. ser., 40: 92-134 + Tav. 12 (1)-16 (5).

Leriche, M., 1957: *Les Poissons Néogènes de la Bretagne de l`Anjou et de la Touraine*. Mémoires Soc. Géol. France 36, Nouv. ser. Mém. (Paris) 81:1-64 + Pl. 1-4.

Majcen, T., 2011: *Geološka učna pot na Govce. Že spet ali še vedno?* Društvene novice (Tržič) 44: 26-28.

Majcen, T., V. Mikuž & V. Pohar, 1997: *Okamnine v paleontološki zbirki laškega muzeja*. Geološki zbornik (Ljubljana) 13: 104-118 + (Tab. 1-11).

Mas, G. & G. Fiol, 2002: *Ictiofauna del Messinià de la plataforma sedimentària de Llucmajor (Illes Balears, Mediterrània occidental). Aspectes paleoambientals*. Boll. Soc. Hist. Nat. Balears (Palma de Mallorca) 45: 105-116.

Menesini, E., 1969: *Ittiodontoliti miocenici di Terra d`Otranto (Puglia)*. Palaeontographia Italica 1969 (Pisa) (n. ser. 35), 65: 1-61 + Tav. 1-7.

Menesini, E., 1974: *Ittiodontoliti delle formazioni terziarie dell`Arcipelago maltese*. Palaeontographia Italica 1971 (Pisa) (n. ser. 37), 67: 121-162 + Tav. 54-61 (1-8).

Mikuž, V., 2005: *Miocenski selahiji (Chondrichthyes) iz opuščenega peskokopa Tomc pri Moravčah. (Miocene selachians (Chondrichthyans) from abandoned sand pit Tomc near Moravče, Slovenia)*. Razprave 4. razreda SAZU (Ljubljana) 46 (1): 111-131 + (Tab. 1-4).

Mikuž, V., M. Bartol & A. Šoster, 2014a: *Zobje miocenskega špara v laporovcu z Mastnega hriba nad Škocjanom. (Porgy fish teetht in Miocene marl from Mastni hrib near Škocjan, Slovenia)*. Geologija (Ljubljana) 57 (1): 33-38 + (Tab. 1).

Mikuž, V., M. Bartol & Š. Ulaga, 2014b: *Ribje vretence iz miocenskih plasti v okolici Govc. (Fish vertebra from Miocene beds at Govce, Slovenia)*. Geologija (Ljubljana) 57 (1): 27-32 + (Tab. 1).

Mikuž, V., & A. Šoster, 2013a: *Spodnjemiocenske ribe in želva iz Žvarulj pri Mlinšah (Centralna Paratetida). (Lower Miocene fishes and turtle from Žvarulje near Mlinše, Slovenia (Central Paratethys)*. Geologija (Ljubljana)56 (2): 199-218 + (Tab. 1-4).

Mikuž, V., A. Šoster & Š. Ulaga, 2013b: *Miocenski ribji zobje iz kamnoloma Plesko. (Miocene fish teeth from the Plesko quarry, Slovenia)*. Folia biologica et geologica (Ljubljana) 54 (1): 121-133 + (Tab. 1-2).

Mikuž, V. & A. Šoster, 2014: *Miocenski neoselahiji Dolenjske in primerjava z drugimi slovenskimi najdišči*. In: B. Rožič, T. Verbovšek & M. Vrabec (uredniki), 4. Slovenski geološki kongres Ankaran, 8. – 10. oktober 2014. Povzetki in ekskurzije. Univerza v Ljubljani, Naravoslovnotehniška fakulteta (Ljubljana): 1-121 (46-47).

Nelson, J. S., 2006: *Fishes of the World*. Fourth Edition. John Wiley & Sons, Inc. (Hoboken, New Jersey): XV, 1-601.

Obrador, A. & B. Mercadal, 1973: *Nuevas localidades con fauna ictiológica para el Neógeno menorquín*. Acta Geológica Hispánica (Barcelona) 4: 115-119.

Pawłowska, K., 1960: *Szczatki ryb z wapieni mioceńskich Pińczowa*. Acta Palaeontologica Polonica (Warszawa) 5 (4): 421-432 + Pl. 1-3.

Philippi, R. A., 1846: *Ueber Tornatella abbreviata, Otodus mitis, Otodus catticus und Myliobatis Testae*. Palaeontographica (1851) (Cassel) 1 (1): 23-25 + Tab. 2.

Pollerspöck, J. & B. Beaury, 2014: *Eine Elasmobranchierfauna (Elasmobranchii, Neoselachii) aus der Oberen Meeresmolasse (Ottnangium, Unteres Miozän) des Heigelsberger Grabens bei Teisendorf, Oberbayern*. Zitteliana A (München) 54: 23-37, (Taf. 1-2).

Portell, R. W., G. Hubbel, S. K. Donovan, J. L. Green, D. A. T. Harper & R. Pickerill, 2008: *Miocene sharks in the Kendeace and Grand Bay formation of Carriacou, The Grenadines, Lesser Antilles*. Caribbean Journ. Sci. (Puerto Rico) 44 (3): 279-286. http://dx.doi.org/10.18475/cjos.v44i3.a2

Purdy, R. W., V. P. Schneider, S. P. Applegate, J. H. Mc Lellan, R. L. Meyer & B. H. Slaughter, 2001: *The Neogene Sharks, Rays, and Bony Fishes from Lee Creek Mine, Aurora, North Carolina*. Smithsonian Contributions Paleobiology (Washington) 90: 71-202.

Radwański, A., 1965: *A contribution to the knowledge of Miocene Elasmobranchii from Pińczów (Poland)*. Acta Palaeont. Polonica (Warszawa) 10 (2): 267-276 + Pl. 1-2.

Rafinesque Schmaltz, C. S., 1810: *Caratteri di alcuni nuovi generi e nuove specie di animali e piante della Sicilia con varie osservazioni sopra i medesimi*. Stampe di Sanfilippo: 3-105.

Reinecke, T., S. Louwye, U. Havekost & H. Moths, 2011: *The elasmobranch fauna of the late Burdigalian, Miocene, at Werde-Uesen, Lower Saxony, Germany, and its relatioships with Early Miocene faunas in the North Atlantic, Central Paratethys and Mediterranean*. Palaeontos (Antwerpen) 20: 1-170 + Pl. 1-101.

Reinecke, T., H. Moths, A. Grant & H. Breitkreuz, 2005: *Die Elasmobranchier des norddeutschen Chattiums, insbesondere des Sternberger Gesteins (Eochattium, Oberes Oligocän)*. Palaeontos (Antwerpen) 8: 1-135 + Taf. 1-60.

Reinecke, T., H. Stapf & M. Raisch, 2001: *Selachier und Chimären des Unteren Meeressandes und Schleichsandes im Mainzer Becken (Alzey- und Stadecken-Formation, Rupelium, Unteres Oligocän)*. Palaeontos (Antwerpen) 1: 1-73 + Taf. 1-63.

Rückert-Ülkümen, N., 1990: *Neue Ergebnisse zum Alter der miozänen Fisch-Schichten in Nord-Thrakien (Türkei). Stratigraphie I*. Mitt. Bayer. Staatsslg. Paläont. hist. Geol. (München) 30: 27-37 + (Taf. 1-3).

Sacco, F., 1916: *Apparati dentali di »Labrodon« e di »Chrysophrys« del Pliocene italiano*. Atti Acad. Sci. Torino (Torino) 51: 172 (144) – 177 (149) + Tav. 1.

Schultz, O., 1968: *Die Selachierfauna (Pisces, Elasmobranchii) aus den Phosphoritsanden (Unter-Miozän) von Plesching bei Linz, Oberösterreich. Naturkundl.* Jb. Stadt Linz (Linz) 14: 61-102 + Taf. 1-4.

Schultz, O., 1971: *Die Selachier-Fauna (Pisces, Elasmobranchii) des Wiener Beckens und seiner Randgebiete im Badenien (Miozän)*. Ann. Naturhist. Mus. Wien (Wien) 75: 311-341 + Taf. 1-4.

Schultz, O., 1972: *Eine Fischzahn.Brekzie aus dem Ottnangien (Miozän) Oberösterreichs*. Ann. Naturhistor. Mus. Wien (Wien) 76: 485-490 + Taf. 1.

Schultz, O., 1998: *Tertiärfossilien Österreichs. Wirbellose, niedere Wirbeltiere und marine Säugetiere*. Goldschneck-Verlag (Korb): 1-159 + (Taf. 1-65).

Schultz, O., 2013: *Pisces*. In: W. E. Piller (Ed.), Catalogus Fossilium Austriae. Ein systematisches Verzeichnis aller auf österreichischem Gebiet festgestellten Fossilien. Bd. 3. Verlag der Österreichischen Akademie der Wissenschaften (Wien): I-XXXVIII, 1-411 + Taf. 1-71.

Schultz, O., R. Brzobohatý & O. Kroupa, 2010: *Fish teeth from the Middle Miocene of Kienberg at Mikulov, Czech Republic, Vienna Basin*. Ann. Naturhist. Mus. Wien, Ser. A (Wien) 112: 489-506 + (Pl. 1-3).

Sismonda, E., 1849: *Descrizione dei pesci e dei crostacei fossili nel Piemonte*. Memorie Reale Accad. Sci. Torino (Torino) ser. 2, 10: 1-88 + Tav. 1-3.

Sismonda, E., 1861: *Appendice alla descrizione dei pesci e dei crostacei fossili nel Piemonte*. Memorie Reale Accad. Sci. Torino (Torino) ser. 2, 19: 453-474 + Tav. 1.

SOLT, P., 1992: *A Kazári cápafogas réteg halmaradványai*. A Magyar Áll. Földtani Intézet, Évi Jelentése 1990 (Budapest): 495-500 + (1 táb.).

STEFANINI, G., 1917: *Fossili del Neogene Veneto*. Mem. Ist. Geol. Univ. Padova 1916 (Padova) 4: 1-198 + Tav. 1-7.

STEININGER, F., 1966: *Über eine Fossiliensammlung aus dem Stadtbereich von Linz*. Naturkundl. Jb. Stadt Linz (Linz) 12: 7-10 + Taf. 1-4.

SZABÓ, M. & L. KOCSIS, 2016: *A new Middle Miocene selachian assemblage (Chondrichthyes, Elasmobranchii) from the Central Paratethys (Nyirád, Hungary): implications for temporal turnover and biogeography*. Geologica Carpathica (Bratislava) 67/6, 573-594. https://doi.org/10.1515/geoca-2016-0036

ŠOSTER, A., 2014: *Miocenska ribja favna Hudinjskega gričevja in okolice. (Miocene fish fauna of Hudinja hills and its surroundings)*. Univerza v Ljubljani, Naravoslovnotehniška fakulteta, Oddelek za geologijo, Diplomsko delo (Ljubljana): 1-39 + (Tab. 1-3).

ŠOSTER, A. & O. M. KOVALCHUK, 2016: *Late Neogene and Pleistocene porgy fishes (Teleostei, Sparidae) of the Eastern Paratethys, with comments on their palaeoecology*. Vestnik zologii (Kiev) 50 (5): 415-422 + (Pl. 1). https://doi.org/10.1515/vzoo-2016-0048

ŠOSTER, A. & V. MIKUŽ, 2013a: *Ostanki rib iz miocenskih plasti Višnje vasi blizu Vojnika. (Fish remains from Miocene beds of Višnja vas near Vojnik, Slovenia)*. Geologija, (Ljubljana) 56 (1): 73-86 + (Tab. 1-3). https://doi.org/10.5474/geologija.2013.006

ŠOSTER, A. & V. MIKUŽ, 2013b: *Ostanki rib iz miocenskih peščenjakov Pristove pri Dobrni*. Geološki zbornik (Ljubljana) 22: 154-158.

VALENCIENNES, A., 1844: *Description de quelques dents fossiles de poissons trovées aux environs de Staoueli, dans la province d`Alger*. Annales sciences naturelles, 3eme ser., Zoologie (Paris) 1: 99-104 + Pl. 1.

VARDABASSO, S., 1922: *Ittiofauna delle arenarie mioceniche di Belluno*. Mem. Ist. Geol. Univ. Padova (Padova) 6: 1-23 + Tav. 1-2.

VEIGA FERREIRA, O., 1955: *A Fauna Miocénica da Ilha de Santa Maria (Açores)*. Comun. Serv. Geol. Portugal (Lisboa) 36: 9-40 + Est. 1-11.

VICENS, D., A. RODRÍGUEZ-PEREA, 2003: *Vertebrats fòssils (Pisces i Reptilia) del Burdigalià de cala Sant Vicenç (Pollença, Mallorca)*. Boll. Soc. Hist. Natur. Balears (Palma de Mallorca) 46: 117-130.

VINASSA DE REGNY, P., 1899: *Pesci neogenici del Bolognese*. Rivista Italiana Paleont. (Bologna) 5: 79-84 + Tav. 2.

WHITENACK, L. B. & M. D. GOTTFRIED, 2010: *A morphometric approach for addressing tooth-based species delimitation in fossil Mako shark, Isurus (Elasmobranchii: Lamniformes)*. Journ. Vertebr. Paleont. (Norman, Oklahoma) 30 (1): 17-25. http://dx.doi.org/10.1080/02724630903409055

WOODWARD, A. S., 1900: *On some Fish-remains from the Parana Formation, Argentine Republic*. Ann. Mag. Nat. Hist. (London) Ser. 7, 6: 1-7 + Pl. 1.

ŽALOHAR, J., M. KRIŽNAR, T. HITIJ & E. GRMŠEK, 2010: *Fosili iz okolice Kamnika*. Uredila J. Železnikar. Medobčinski muzej Kamnik (Kamnik): 1-48.

TABLE – PLATES

TABLA 1 – PLATE 1

Sl. 1 *Carcharias taurus* Rafinesque, 1810; a – pogled z jezične strani, b – pogled s strani, c – pogled z ustnične strani, kamnolom Plesko, povečano
Fig. 1 *Carcharias taurus* Rafinesque, 1810; a – lingual view, b – lateral view, c – labial view, Plesko quarry, enlarged

Sl. 2 *Carcharias taurus* Rafinesque, 1810; a – pogled z jezične strani, b – pogled s strani, c – pogled z ustnične strani, Govce, povečano
Fig. 2 *Carcharias taurus* Rafinesque, 1810; a – lingual view, b – lateral view, c – labial view, Govce, enlarged

Sl. 3 *Cosmopolitodus hastalis* (Agassiz, 1843); a – pogled z jezične strani, b – pogled s strani, c – pogled z ustnične strani, Govce, povečano
Fig. 3 *Cosmopolitodus hastalis* (Agassiz, 1843); a – lingual view, b – lateral view, c – labial view, Govce, enlarged

Sl. 4 *Carcharias taurus* Rafinesque, 1810; pogled z jezične strani, kamnolom Plesko, povečano
Fig. 4 *Carcharias taurus* Rafinesque, 1810; lingual view, Plesko quarry, enlarged

Sl. 5 *Cosmopolitodus hastalis* (Agassiz, 1843); a – pogled z jezične strani, b – pogled s strani, c – pogled z ustnične strani, kamnolom Plesko, povečano
Fig. 5 *Cosmopolitodus hastalis* (Agassiz, 1843); a – lingual view, b – lateral view, c – labial view, Plesko quarry, enlarged

Sl. 6 *Cosmopolitodus hastalis* (Agassiz, 1843); a – pogled z jezične strani, b – pogled s strani, c – pogled z ustnične strani, Govce, najditeljica Romana Verdel, povečano
Fig. 6 *Cosmopolitodus hastalis* (Agassiz, 1843); a – lingual view, b – lateral view, c – labial view, Govce, finder Romana Verdel, enlarged

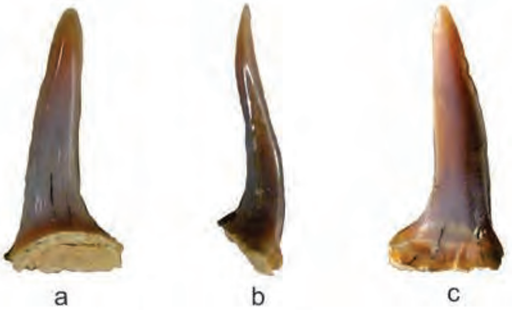
Sl. 7 *Carcharias* sp.; pogled z jezične strani, kamnolom Plesko, povečano
Fig. 7 *Carcharias* sp.; lingual view, Plesko quarry, enlarged

Sl. 8 *Carcharhinus priscus* (Agassiz, 1843); pogled z jezične strani, kamnolom Plesko, povečano
Fig. 8 *Carcharhinus priscus* (Agassiz, 1843); lingual view, Plesko quarry, enlarged

Sl. 9 *Carcharhinus priscus* (Agassiz, 1843); pogled z jezične strani, najditeljica Špela Zupančič, Dol pri Hrastniku, povečano
Fig. 9 *Carcharhinus priscus* (Agassiz, 1843); lingual view, finder Špela Zupančič, Dol pri Hrastniku, enlarged

Sl. 10 *Carcharoides catticus* (Philippi, 1846); pogled z ustnične strani, Trnov Hrib blizu Govc, povečano
Fig. 10 *Carcharoides catticus* (Philippi, 1846); labial view, Trnov Hrib near Govce, enlarged

TABLA 1 – PLATE 1



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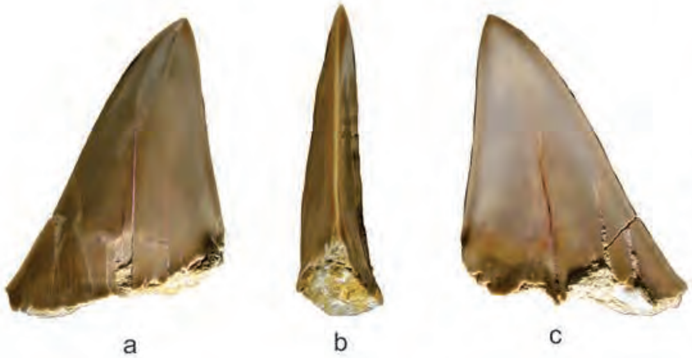

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TABLA 2 – PLATE 2

Sl. 1 *Diplodus jomnitanus* (Valenciennes, 1844); a – pogled z ustnične strani, b – pogled s strani, c – pogled z jezične strani, kamnolom Plesko, povečano
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Sl. 2 *Diplodus jomnitanus* (Valenciennes, 1844); a – pogled z ustnične strani, b – pogled s strani, c – pogled z jezične strani, kamnolom Plesko, povečano
Fig. 2 *Diplodus jomnitanus* (Valenciennes, 1844); a – labial view, b – lateral view, c – lingual view, Plesko quarry, enlarged
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Sl. 5 *Pagrus cinctus* (Agassiz, 1839); konica zoba s strani, kamnolom Plesko, povečano
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Sl. 6 *Pagrus cinctus* (Agassiz, 1839); pogled s strani, kamnolom Plesko, povečano
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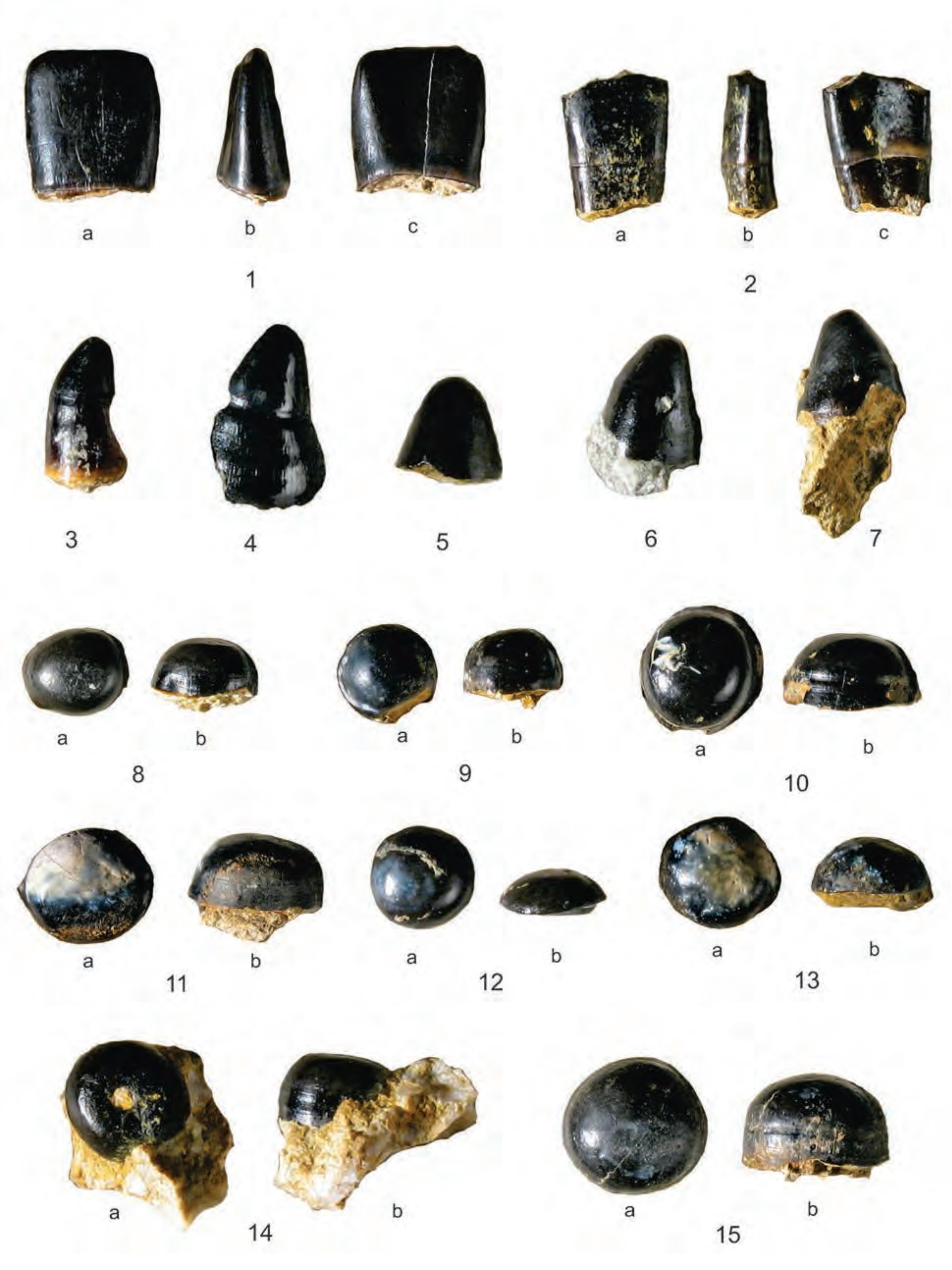
Sl. 8 *Pagrus cinctus* (Agassiz, 1839); a – pogled od zgoraj, b – pogled s strani, kamnolom Plesko, povečano
Fig. 8 *Pagrus cinctus* (Agassiz, 1839); a – occlusal view, b – lateral view, Plesko quarry, enlarged
Sl. 9 *Pagrus cinctus* (Agassiz, 1839); a – zgornja površina zoba, b – pogled s strani, kamnolom Plesko, povečano
Fig. 9 *Pagrus cinctus* (Agassiz, 1839); a – occlusal view, b – lateral view, Plesko quarry, enlarged
Sl. 10 *Pagrus cinctus* (Agassiz, 1839); a – zgornja površina zoba, b – pogled s strani, kamnolom Plesko, povečano
Fig. 10 *Pagrus cinctus* (Agassiz, 1839); a – occlusal view, b – lateral view, Plesko quarry, enlarged
Sl. 11 *Pagrus cinctus* (Agassiz, 1839); a – zgornja površina zoba, b – pogled s strani, kamnolom Plesko, povečano
Fig. 11 *Pagrus cinctus* (Agassiz, 1839); a – occlusal view, b – lateral view, Plesko quarry, enlarged
Sl. 12 *Pagrus cinctus* (Agassiz, 1839); a – zgornja površina zoba, b – pogled s strani, kamnolom Plesko, povečano
Fig. 12 *Pagrus cinctus* (Agassiz, 1839); a – occlusal view, b – lateral view, Plesko quarry, enlarged
Sl. 13 *Pagrus cinctus* (Agassiz, 1839); a – zgornja površina zoba, b – pogled s strani, kamnolom Plesko, povečano
Fig. 13 *Pagrus cinctus* (Agassiz, 1839); a – occlusal view, b – lateral view, Plesko quarry, enlarged
Sl. 14 *Pagrus cinctus* (Agassiz, 1839); a – zgornja površina zoba, b – pogled s strani, kamnolom Plesko, povečano
Fig. 14 *Pagrus cinctus* (Agassiz, 1839); a – occlusal view, b – lateral view, Plesko quarry, enlarged
Sl. 15 *Pagrus cinctus* (Agassiz, 1839); a – zgornja površina zoba, b – pogled s strani, kamnolom Plesko, povečano
Fig. 15 *Pagrus cinctus* (Agassiz, 1839); a – occlusal view, b – lateral view, Plesko quarry, enlarged

Primerki ribjih zob na tabli 1, slike 1-5, 7-8 in na tabli 2, slike 1-15 so iz zbirke Špele Ulaga iz Hrastnika (The specimens of fish teeth on plate 1, figures 1-5, 7-8 and plate 2, figures 1-15 are from collection of Špela Ulaga from Hrastnik)

Vse fotografije (All photos): Aleš Šoster

TABLA 2 – PLATE 2



RAZŠIRJENOST LIŠAJEV IZ SKUPINE *LOBARIA* S. LAT. V SLOVENIJI

DISTRIBUTION OF LICHENS FROM THE *LOBARIA* S. LAT. GROUP IN SLOVENIA

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IZVLEČEK

Razširjenost lišajev iz skupine *Lobaria* s. lat. v Sloveniji

V Sloveniji iz skupine *Lobaria* s. lat. zasledimo najdbe petih vrst, in sicer *Lobaria pulmonaria* (L.) Hoffm. in *Lobaria linita* (Ach.) Rabenh., *Lobarina scrobiculata* (Scop.) Nyl. ter *Ricasolia virens* (With.) H.H. Blom. & Tønsberg in *Ricasolia amplissima* (Scop.) De Not. Epifitske vrste iz skupine *Lobaria* s. lat. se pojavljajo v združbi *Lobarion*, ki je zelo občutljiva na gozdarske posege in zračno onesnaženje. Za naštete vrste smo pregledali zgodovinske in sodobne vire, in izrisali njihove karte razširjenosti. Hkrati smo pregledali, na katerih substratih uspevajo ter v katerih habitatih oz. združbah. Preverili smo status teh vrst v bližnjih evropskih državah, kjer je lihenologija bolje razvita. Naštete vrste so v Sloveniji vezane na območja z veliko količino padavin, največ najdb je z območja alpsko-dinarske pregrade. Za vse vrste, razen za navadnega pljučarja (*L. pulmonaria*), smo uspeli najti zelo majhno število navedb. Status populacij vrst ni znan. Izpostavili smo možne dejavnike, ki ogrožajo obstoj vrst iz skupine *Lobaria* s. lat. v Sloveniji.

Ključne besede: lihenizirane glive, epifitski lišaji, karte razširjenosti, *Lobaria*

ABSTRACT

Distribution of lichens from the *Lobaria* s. lat. group in Slovenia

In Slovenia, findings of five species from the *Lobaria* s.lat. group of lichens are recorded, namely *Lobaria pulmonaria* (L.) Hoffm. and *Lobaria linita* (Ach.) Rabenh., *Lobarina scrobiculata* (Scop.) Nyl., *Ricasolia virens* (With.) H. H. Blom. & Tønsberg and *Ricasolia* amplissima (Scop.) De Not. Epiphytic species from the *Lobaria* s. lat. group occur in *Lobarion* community, which is very sensitive to forestry interventions and air pollution. For these species, the historical and contemporary sources were investigated and distribution maps produced. At the same time, it was examined which substrates, habitats and forest communities are preferred by the species. The status of these species in neighbouring lichenologically better developed European countries, was checked. Listed species are related to areas of high mean annual precipitation areas in Slovenia, most of the finds are from the area of the Alpine-Dinaric barrier. For all species except for *L. pulmonaria*, we managed to find a very small number of entries. The status of populations is unknown. The potential factors that threaten the existence of species from the group *Lobaria* s. lat. in Slovenia are highlighted.

Keywords: lichenized fungi, epiphytic lichens, distribution maps, *Lobaria*

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1 UVOD

Lobaria s. lat. je skupina lišajev iz družine Lobariaceae. V družino Lobariaceae spadajo največji lišaji na svetu, ki lahko v premeru dosežejo tudi več decimetrov. Filogenetske raziskave so pokazale, da skupino *Lobaria* s. lat. tvori sedem manjših ločenih skupin, ki so taksonomsko na ravni rodu. Od teh rodov v Sloveniji najdemo tri, in sicer *Lobaria* s. str. z vrstama *L. pulmonaria* (L.) Hoffm. in *L. linita* (Ach.) Rabenh., *Lobarina* z vrsto *L. scrobiculata* (Scop.) Nyl. ter *Ricasolia* z vrstama *R. virens* (With.) H.H. Blom. & Tønsberg in *R. amplissima* (Scop.) De Not. Za rod *Lobaria* s. str. so značilne steljke s satastimi vdolbinami, pri katerih je tomentum razvit v obliki žil med izboklinami na spodnji površini. Spore so kratke in široko vretenaste. Rod *Lobarina* je podoben rodu *Lobaria* s. str. po obliki krp (lobulov), ima pa gostejši tomentum na spodnji površini, med katerimi so bela gladka območja, ki pa se ne ujemajo z mesti izboklin na spodnji površini. Askospore so ozko vretenaste do iglaste in veliko daljše. Za rod *Ricasolia* so značilne steljke z gladkimi krpami ter enakomeren tomentum po celotni spodnji površini. Rodovi se razlikujejo tudi po vsebnosti lišajskih snovi (Moncada s sod. 2013).

Epifitske vrste iz skupine *Lobaria* s. lat. se pojavljajo v združbah iz zveze *Lobarion*, ki so glavne epifitske lišajske klimaksne združbe gozdnega drevja na območju Evrope. Poleg vrst iz skupine *Lobaria* s. lat. te združbe gradijo tudi velike listaste vrste iz rodov *Sticta* in *Pseudocyphellaria*, manjši listasti lišaji iz rodov *Parmeliella*, *Pannaria*, *Nephroma*, *Peltigera* in *Parmelia*, številni skorjasti lišaji ter mahovi. Združbe iz zveze *Lobarion* niso vedno izključno epifitske, lahko se pojavljajo tudi na skalovju. Najbolj značilna in stalna vrsta združb je vrsta *L. pulmonaria*. Bogat herbarijski material ter notice v lokalnih naravoslovnih revijah potrjujejo nekdanjo široko razširjenost združb iz zveze *Lobarion* v večini Zahodne Evrope, kjer so imele oceansko-montanski značaj (Rose 1988).

Zgodovinski podatki kažejo, da so druge vrste iz združb zveze *Lobarion* upadle celo bolj drastično kot sama *L. pulmonaria*, posebno rodovi s cianobakterijskimi fotobionti, kot so *Collema*, *Leptogium*, *Nephroma*, *Pannaria*, *Parmeliella* in *Sticta* ter tudi vrsta *L. scrobiculata* (Rose 1988).

Vzroki za propadanje združb iz zveze *Lobarion* so spremembe v načinu gospodarjenja z gozdovi (npr. zamenjava listnatih vrst z iglastimi, vzdrževanje gostih sestojev brez osončenih vrzeli, selektivna sečnja dreves, ki merijo v premeru 30-40 cm, prekratka obhodna doba sečnje) (Gauslaa 1995, Rose 1988). Sprememba zgradbe gozda v smislu fragmentacije lahko vpliva na epifitske vrste z lokalnimi spremembami klime ter z vplivom na učinkovitost razširjanja med ustreznimi gozdnimi fragmenti (Ellis & Coppins 2007). V drugi polovici 20. stoletja so združbe iz zveze *Lobarion* propadale tudi zaradi onesnaženja z žveplovim dioksidom (Gauslaa 1995, Rose 1988).

2 MATERIAL IN METODE

Zbrani so bili podatki za vse vrste iz skupine *Lobaria* s. lat., za katere obstaja kakršnakoli informacija o njihovem pojavljanju na območju Slovenije: *Lobaria pulmonaria*, *L. linita*, *Lobarina scrobiculata*, *Ricasolia amplissima* (vključujoč »*Dendriscocaulon umhausense*«) ter *R. virens*. Nomenklatura je povzeta po Nimisu (2016), kratki opisi ob slikah pa po Wirthu (1995). Podatke smo zbrali s pomočjo Kataloga liheniziranih in lihenikolnih gliv Slovenije (Suppan s sod. 2000), podatkovne zbirke Boletus informaticus (Ogris 2008) ter objavljenih popisov lišajev oz. omemb navedenih vrst za območje Slovenije v literaturi. Za vse navedbe smo izpisali lokacijo pojavljanja, nadmorsko višino, substrat, na katerem je bila lišajska vrsta zabeležena, ter podatke o habitatih ali združbah, v katerih je bila vrsta najdena, v kolikor so bili ti podatki navedeni. Kjer so bile gozdne združbe poimenovane z neveljavnimi imeni, smo poiskali veljavna imena s pomočjo literature (Kutnar s sod. 2012, Šilc & Čarni 2012). Lokacije pojavljanja smo izrisali v obliki karte razširjenosti na MTB mreži. Znotraj vsakega MTB kvadranta, v katerem je bila vrsta zabeležena, je lahko več lokacij pojavljanja. Posebej smo izrisali podatke za obdobje pred letom 1950 in po njem. Pri virih izpred leta 1950 so podatki o nahajališčih zelo skopi, zato smo vrisali približne lokacije. Npr. če vir navaja, da se lišaj pojavlja v okolici Idrije, smo poiskali, v kateri MTB kvadrant spada mesto Idrija. Pri vrsti *L. pulmonaria* je bilo v nekaterih primerih nahajališče podano tako široko, da ga ni bilo mogoče vrisati v karto. Kot avtorji kart razširjenosti so navedeni določitelji vrst (po abecednem redu), v kolikor ta podatek ni znan, pa avtorji vira, v katerem je najdba objavljena.

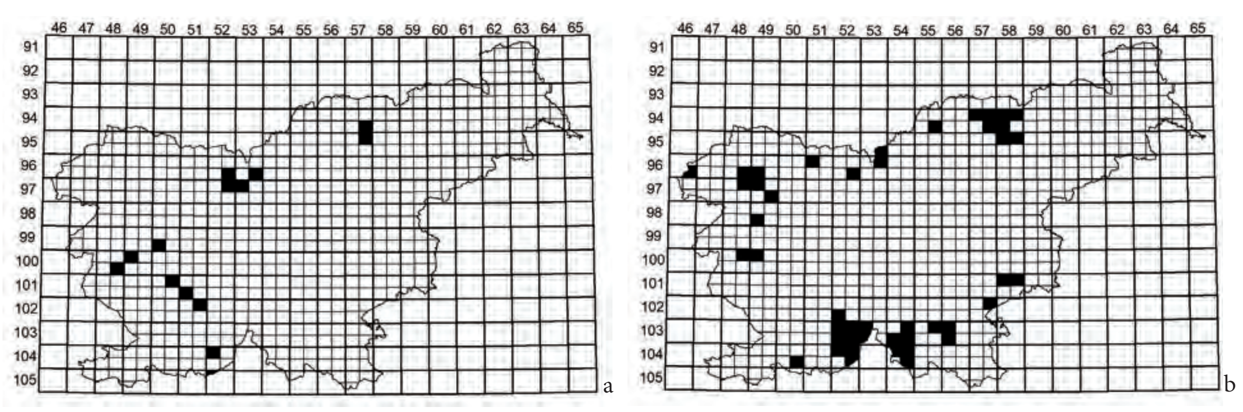
3 IZSLEDKI

3.1 *Lobaria pulmonaria* (L.) Hoffm.

V Sloveniji je bila vrsta po letu 1950 zabeležena 158x, največkrat na gorskem javorju (46,8 %), sledila je bukev (15,2 %), na ostalih podlagah se je pojavljala v manj kot 5 % (*Ulmus glabra*, *Fraxinus excelsior* > *Abies alba* > *Picea abies*, *Tilia* sp. > *Quercus* sp. > *Coryllus avellana* > *Juglans regia*, *Pyrus communis*, *Salix caprea*, *Sorbus*

Slika 1: Lobaria pulmonaria; navadni pljučar – steljka je v navlaženem stanju intenzivno zelena (zgoraj), saj je primarni fotobiont zelena alga, v posušenem stanju pa olivno zelena do rjava (spodaj levo). Zgornja stran steljke je mrežasto-vdolbinasta, z razvitimi sorali in/ali izidiji, občasno tudi z apoteciji (razvidni na sliki zgoraj). Spodnji del prekriva temno rjav tomentum, ki se razrašča na izboklinah v obliki žil, proti robu prehaja v svetlo rjavo barvo (spodaj desno).
Figure 1: Lobaria pulmonaria; tree lungworth, lung lichen – thallus in wet condition intensively green (above), as primary photobiont is green algae, and olive-green to brown in dry condition (below to the left). Upper side of the thallus with the comb-like structure, with soralia and/or isidia, apothecia infrequent (visible on picture above). Lower side of the thallus covered by dark brown tomentum on vein like ridges, getting light brown towards the edges.

aucuparia, *Populus tremula*). V 12,7 % je bila podlaga nedefinirana. Uspeva na skorji, dnišču debla, mahovih na deblu, mahovih na dnišču debla, mahovih na lesu, štorih, skalah. Najdemo jo predvsem v bukovih gozdovih (*Omphalodo-Fagetum* (Tregubov 1957) Marinček et al. 1993, *Anemono trifoliae-Fagetum* Tregubov 1962, *Ranunculo platanifoli-Fagetum* Marinček et al. 1993, *Polysticho lonchitis-Fagetum* (Horvat 1938) Marinček in Poldini et Nardini 1993, *Stellario montanae-Fagetum* (Zupančič 1969) Marinček et al. 1993, mešanih listnatih gozdovih, smrekovih gozdovih s primesjo listavcev (*Hacquetio-Piceetum* Zupančič (1980) 1999, *Lonicero ceruleae-Piceetum* Zupančič (1976) 1994, *Stellario montanae-Piceetum* Zupančič (1980) 1999, *Adenostylo glabrae-Piceetum* M. Wraber ex Zukrigl 1973), na gozdnih robovih, na gozdnih jasah z osamelimi drevesi in na osamelih drevesih v zaselkih.



Slika 2: Karta razširjenosti vrste Lobaria pulmonaria v Sloveniji: (a) pred letom 1950 (Arnold F., Biasoletto B., Glowacki J., Kernstock E., Lämmermayr L., Pötsch J.S., Schuler J., Scopoli I.A.) (b) po letu 1950 (Arup U., Batič F., Bilovitz P., Christensen S.N., Grube M., Koch M., Kruhar B., Mayrhofer H., Mrak T., Primožič K., Prügger J., Suppan U., Surina B.)
Figure 2: Distribution map of Lobaria pulmonaria in Slovenia: (a) before 1950 (Arnold F., Biasoletto B., Glowacki J., Kernstock E., Lämmermayr L., Pötsch J.S., Schuler J., Scopoli I.A.) (b) after 1950 (Arup U., Batič F., Bilovitz P., Grube M., Koch M., Kruhar B., Mayrhofer H., Mrak T., Primožič K., Prügger J., Suppan U., Surina B.)

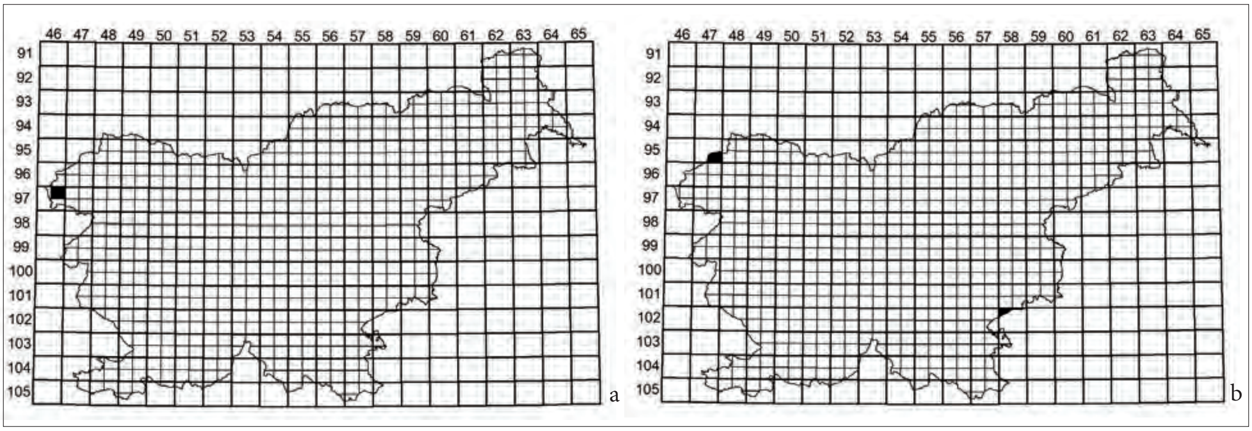
Karta razširjenosti vrste *L. pulmonaria* kaže, da je tudi vrsta vezana na območja z večjo količino padavin, v nasprotju z ostalimi epifitskimi vrstami iz skupine *Lobaria* s. lat. pa jo najdemo tudi na Pohorju. Od vseh vrst iz skupine *Lobaria* s. lat. je tudi najbolj razširjena. Najmanjša nadmorska višina, na kateri je bila vrsta zabeležena je bila 150 m (Krakovski gozd), največja pa 1460 m v Julijskih Alpah.

Vrsta je še prisotna na večini območij, kjer se je pojavljala tudi v preteklosti oz. je bila najdena na območjih, ki v preteklosti niso bila lihenološko raziskana. Historična navedba z Javornikov ni bila ponovno potrjena. Historični viri so jo navajali kot pogosto, npr. Glowacki & Arnold (1871): »posebno v okolici Idrije pogosta«. V nekaterih predelih Slovenije (npr. območje Snežnika) je status vrste še vedno zadovoljiv, steljke so velike in zdrave, na mnogih nahajališčih pa najdemo samo po par primerkov ali celo eno samo steljko, steljke pa so slabo razvite ali poškodovane.

3.2 *Lobaria linita* (Ach.) Rabenh.

V celotni zgodovini lihenoloških raziskav vemo na Slovenskem samo za tri najdbe (Glowacki 1874, Hočevar s sod. 1985, priprave na BLAM ekskurzijo l. 2003 - neobjavljeno), od tega je ena (Hočevar s sod. 1985) dvomljiva. Pri tej najdbi gre verjetno za mlado steljko vrste *L. pulmonaria*, ki še nima razvitih soralov in/ali izidijev (Suppan s sod. 2000). Obe zanesljivi najdbi izvirata iz gora v okolici Bovca (nad gozdno mejo), kjer med apnencem najdemo silikatne vložke. Najdba iz leta 2003 je z nadmorske višine 1880 m. Glede na to, da gre za vrsto, ki običajno uspeva nad gozdno mejo na svežih, kislih humoznih tleh, na mahovih, med silikatnimi skalnatimi bloki (Wirth 1995), je v Sloveniji je možnih rastišč vrste *L. linita* malo, saj zaradi prevlade karbonatnih kamnin primanjkuje substratov zanjo. Poznavanje lišajske flore nad gozdno mejo je v Sloveniji izjemno slabo, tako da ne poznamo njene dejanske pogostnosti ter velikosti populacij. Poleg tega so steljke na alpskih tratah izjemno težko

Slika 3: Lobaria linita; mali pljučar – steljka mrežasto nagubana, zeleno-rjave barve, v navlaženem stanju intenzivneje zelena (primarni fotobiont je zelena alga), brez soralov in izidijev. Apoteciji se pojavljajo redko. Tomentum svetlo rjav, prisoten med izboklinami na spodnjem delu steljke.
Figure 3: Lobaria linita; cabbage lung lichen – thallus with net-like structure of ridges, greenish-brown, intensively green when wet (primary photobiont is green algae), without soralia or isidia. Apothecia rarely present. Tomentum of light brown colour, developed between protrusions on the lower side of the thallus.



Slika 4: Razširjenost vrste Lobaria linita v Sloveniji: a) pred letom 1950 (Glowacki J.) in b) po letu 1950 (Batič F., Mayrhofer H.)
Figure 4: Distribution of Lobaria linita in Slovenia: a) before 1950 (Glowacki J.) and b) after 1950 (Batič F., Mayrhofer H.)

opazne, sploh v suhem stanju. Glede na pogostnost silikatnih kamnin nad gozdno mejo v slovenskem prostoru lahko domnevamo, da je zelo redka ter da so populacije zelo majhne.

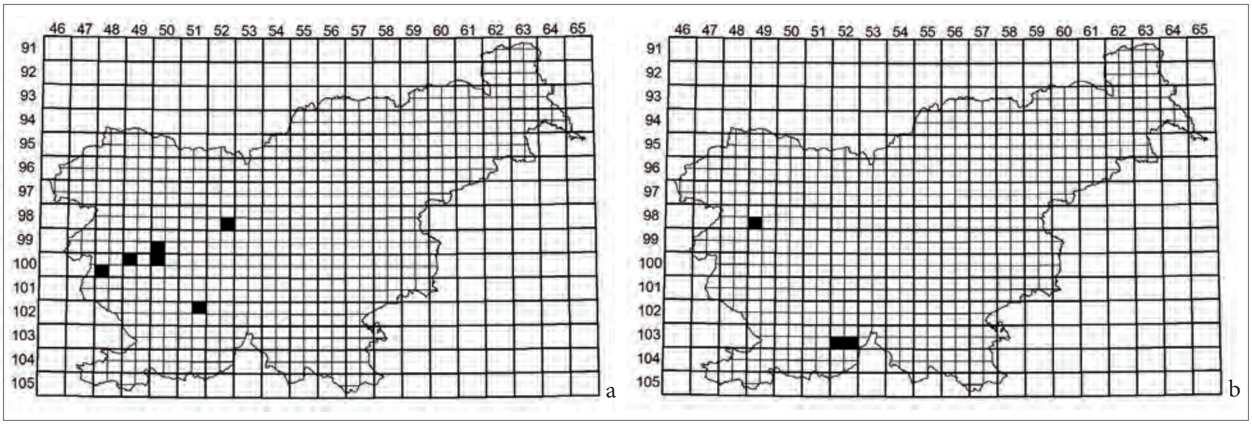
3.3 *Lobarina scrobiculata* (Scop.) Nyl.

Vrsto je prvi opisal Scopoli v svojem delu Flora Carniolica iz leta 1772 pod imenom *Lichen scrobiculatus*, in sicer iz okolice Idrije. Tipski Scopolijev material je izgubljen, zato so za lektotip izbrali primerek, ki odgovarja Dilleniusovemu opisu (Lichenoides pulmoneum villosum, superficie scrobiculata et peltata) in ilustraciji »Lichenoides no. 114« v delu Historia Muscorum iz leta 1741 (navaja ju že Scopoli), in je shranjen v oxfordskem herbariju (Yoshimura & Isoviita 1969).

Število najdb vrste *L. scrobiculata* je majhno tako pred letom 1950, kot tudi po njem. Najdbe po l. 1950 so zabeležene na substratih: *Ulmus glabra*, *Acer pseudoplatanus*, *Populus tremula* ter *Quercus robur*, historični viri poleg hrasta navajajo tudi vrsti *Fagus sylvatica* in *Abies alba*. Uspeva na deblih ali dniščih debla. Podatki o habitatih, kjer se vrsta pojavlja v Sloveniji, so zelo skopi. Vrsta naj bi uspevala v mešanih listopadnih gozdovih in na osamelih drevesih. Zabeležena je bila na nadmorskih višinah med 600 in 880 m.

Slika 5: Lobarina scrobiculata; sivi pljučar - steljka plitvo vdolbinasta, svetlo zeleno-siva, v navlaženem stanju svinčeno siva, saj so primarni fotobiont cianobakterije. V herbariju postane bledo rumene ali sivo-rumene barve (slika levo). Na površini s točkastimi sivo obarvani sorali, ki se med seboj združujejo, na robovih pa so sorali črtalasti (slika v sredini). Izidijev ni. Apoteciji so zelo redko razviti. Tomentum s posameznimi majhnimi belimi golimi mesti (slika desno), na robovih svetlo rjav, v sredini temno rjav.

Figure 5: Lobarina scrobiculata; textured lungworth - thalli with shallow indentations, pale green-grey, lead grey when wet (primary photobiont cyanobacteria). In herbarium, colour changes to pale yellow or grey-yellow (figure to the left). With roundish grey coloured soralia on the surface, which are getting confluent, and edge soralia (figure in the middle). Isidia are not developed. Apothecia rarely developed. Lower side with distinct small tomentum-free spots of white colour (figure to the right). Tomentum light brown on edges and dark brown in the middle.



Slika 6: Razširjenost vrste Lobarina scrobiculata v Sloveniji: a) pred letom 1950 (Arnold F., Dolšak F. Glowacki J., Pötsch J.S., Scopoli I.A.), in b) po letu 1950 (Batič F., Mayrhofer H., Primožič K., Prügger J., Suppan U.).

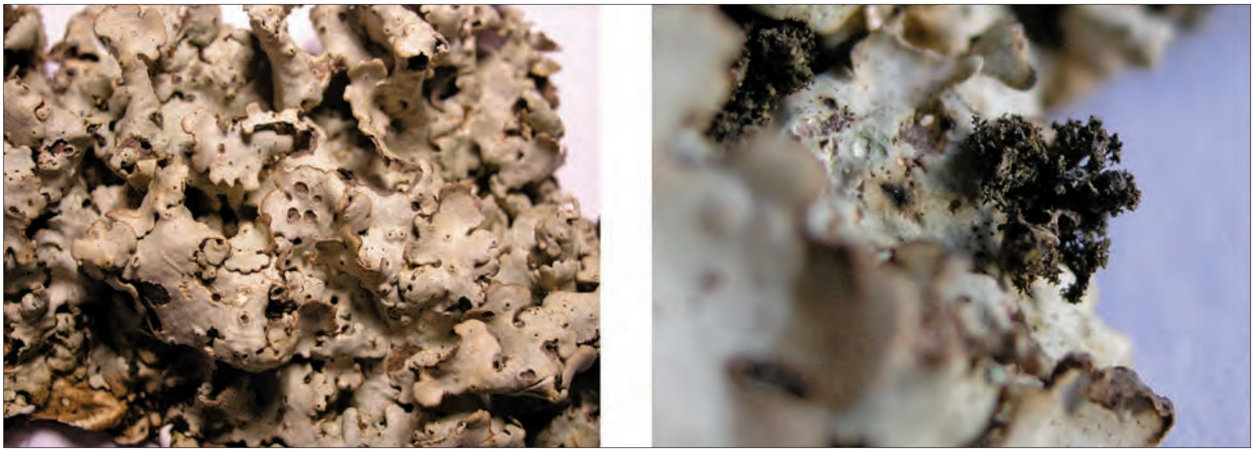
Figure 6: Distribution map of Lobarina scrobiculata in Slovenia: a) before 1950 (Arnold F., Dolšak F. Glowacki J., Pötsch J.S., Scopoli I.A.) and b) after 1950 (Batič F., Mayrhofer H., Primožič K., Prügger J., Suppan U.).

Razširjenost vrste se ujema z območji največje količine padavin na padavinski karti Slovenije. Nekatera območja, kjer bi vrsto lahko pričakovali glede na veliko količino padavin, bodisi niso bila nikoli v zadostni meri raziskana (npr. Kamniško-Savinjske Alpe, Karavanke) bodisi so bila podvržena korenitim gozdarskim posegom (npr. Pohorje). V Panovcu, okolici Idrije in Medvod, na Javornikih in Trnovskem gozdu po letu 1950 *L. scrobiculata* ni bila več najdena, kljub temu, da so na tem območju potekale intenzivne raziskave lišajske flore. Štiri od petih najdb po letu 1950 so z območja Snežnika.

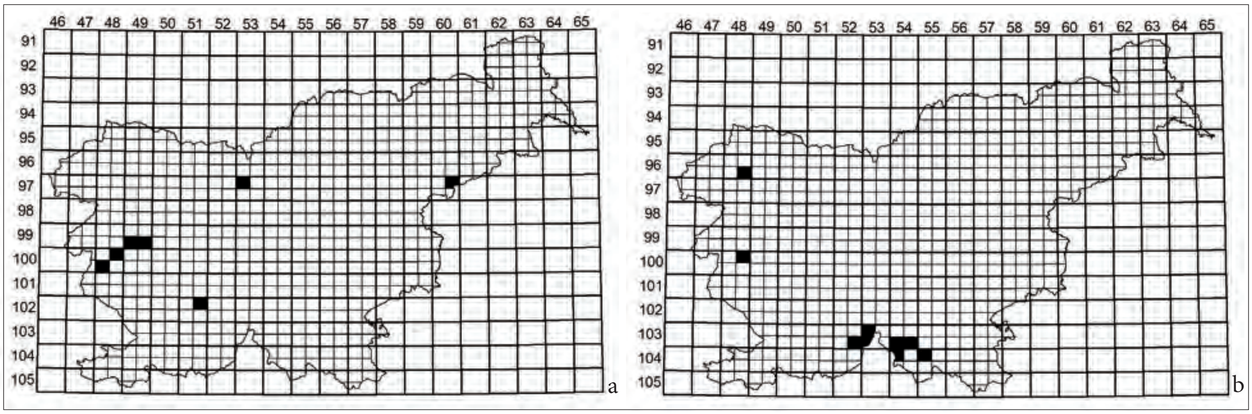
3.4 *Ricasolia amplissima* (Scop.) De Not. & »Dendriscocaulon umhausense«

Pri vrsti *R. amplissima* naletimo na taksonomsko in nomenklaturno težavo. »Cefalodiji« te vrste namreč lahko uspevajo samostojno in so bili obravnavani kot samostojen takson z imenom *Dendriscocaulon umhausense* (Auersw.) Degel. Pogosto jih najdemo skupaj z listasto obliko na istem rastišču. Z molekularnimi raziskavami so dokazali, da »*Dendriscocaulon umhausense*« gradi ista gliva kot listasto obliko z zelenim primarnim fotobiontom. Ker lišaj nosi ime po glivi, dveh imen preprosto ne more biti, saj oba rastna tipa gradi ista gliva. Za poimenovanje cianobakterijske različice je predlagano citiranje nepravilnega imena v narekovajih: »*Dendriscocaulon umhausense*« ali pa dodajanje pridevka cyan. ali chlor. za nomenklaturno pravilnim imenom, npr. *R. amplissima* cyan., kar nam prav tako poda informacijo o rastni obliki (Jorgensen 1998).

Kot podlage *R. amplissima* so po letu 1950 zabeležene naslednje drevesne vrste: *Ulmus glabra* > *Acer pseudoplatanus* > *Fagus sylvatica*, *Pyrus communis*, v



Slika 7: Ricasolia amplissima; bledi pljučar - Lobuli so gladki do valoviti (niso mrežasto nagubani). Primarni fotobiont je zelena alga. Zgornja površina je svetlo siva, v navlaženem stanju zeleno-siva; v herbariju postane svetlo rjava (slika levo). Izidiji in soral niso razviti, apoteciji pa so razmeroma pogosti. Skoraj vedno so prisotni 0,2-1 cm veliki olivno rjavi do črni zunanji grmičasti cefalodiji (desno). Tomentum je rjav, enakomerno razporejen.
Figure 7: Ricasolia amplissima – Thalli with smooth to wavy lobules (not with net-like ridges). Primary photobiont green algae. Upper surface pale grey when dry and green-grey when wet; light brown in herbarium (to the left). Isidia and soralia developed, apothecia relatively common. Upper surface with 0.2-1 cm olive brown to black external ramified cephalodia (to the right). Tomentum brown, even.



Slika 8: Razširjenost vrste Ricasolia amplissima v Sloveniji pred (Arnold F., Glowacki J., Lettau G., Pötsch J.S., Scopoli I.A., Suza J., Zahlbruckner A.) in po letu 1950 (Arup U., Batič F., Grube M., Mayrhofer H., Mrak T., Prügger J., Spribille T., Surina B.).
Figure 8: Distribution of Ricasolia amplissima in Slovenia before (Arnold F., Glowacki J., Lettau G., Pötsch J.S., Scopoli I.A., Suza J., Zahlbruckner A.) and after 1950 (Arup U., Batič F., Grube M., Mayrhofer H., Mrak T., Prügger J., Spribille T., Surina B.).

Slika 9: Ricasolia virens; zelenkasti pljučar – Temno olivno rjava do zeleno-siva, v namočenem stanju zelena. Herbarijski material je svetlo rjave barve. Primarni fotobiont je zelena alga. Zgornja površina gladka, starejši deli rahlo nagubani. V sredini steljke primarni lobuli pogosto tvorijo majhne sekundarne lobule, ki se medsebojno prekrivajo. Spodnji del steljke svetlo rjav z zelo kratkim tomentumom. Apoteciji razviti na lamini steljke.

Figure 9: Ricasolia virens – Thallus dark olive brown to green-grey; green when wet. Herbarium material light brown. Primary photobiont green algae. Upper surface smooth, older parts slightly wrinkled. In the middle of the thallus, primary lobules often form small secondary lobules which are overlapping. Lower part of the thallus light yellow-brown with very short tomentum. Apothecia developed on thallus lamina.

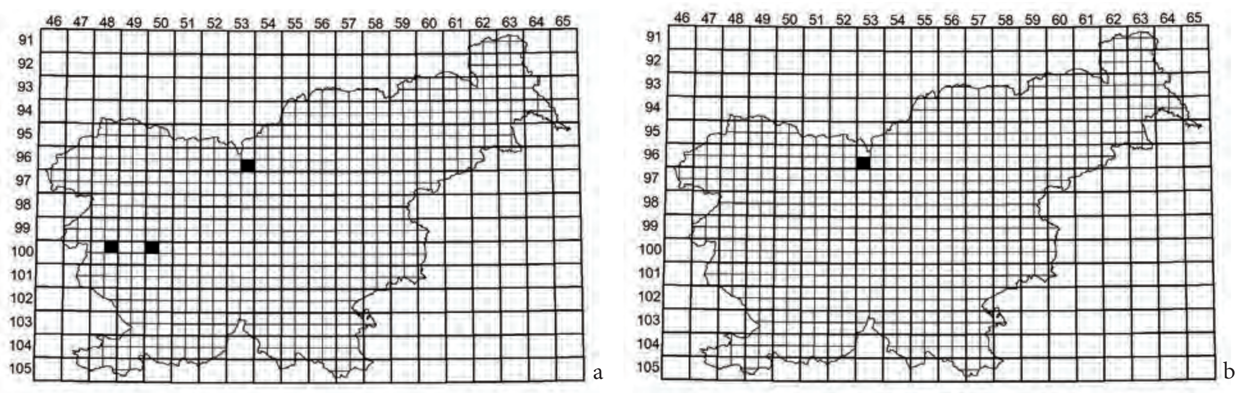
nekaterih primerih podatka o podlagi ni. V preteklosti so kot podlage omenjeni tudi *Abies alba*, *Castanea sativa*, *Quercus* sp., *Picea abies* ter iglavci. Uspeva na drevesni skorji ali na lesu, na gozdnih robovih, gozdnih jasah z osamelimi listavci, prostostoječih drevesih na območjih, kjer je gospodarska raba omejena na košnjo in krmljenje divjadi (Prügger 2005), mešanih gozdovih. Zabeležena je bila na nadmorskih višinah med 720 m (Babno polje) ter 1400 m (Julijske Alpe).

Razširjenost vrste (razen historičnega nahajališča na Donački gori) se ujema z območji največje količine padavin. Nekatera območja, kjer bi vrsto lahko pričakovali glede na veliko količino padavin, bodisi z lihenološkega vidika niso bila nikoli v zadostni meri raziskana (npr. Kamniško-Savinjske Alpe, Karavanke) bodisi so bila v preteklosti podvržena korenitim gozdarskim posegom (npr. Pohorje). Po letu 1950 je znanih dvanajst najdb. Raziskave lišajske flore v 90. letih 20. stol. in začetku 21. stol. so pokazale, da vrsta *R. amplissima* ne uspeva več na območju Panovca, Javornikov, Trnovskega gozda, Šenturške in Donačke gore. Za Panovec že Glowacki (1871), navaja, da je vrsta zelo redka. V Julijskih Alpah, za katere ni historičnih zapisov, ki bi poročali o tej vrsti, je bil po letu 1950 najden samo en primerek. Vsi ostali primerki so bili najdeni na Snežniku ali Goteniški gori.

3.5 *Ricasolia virens* (With.) H.H. Blom. & Tønsberg

V Sloveniji je bila vrsta *R. virens* najdena na drevesnih vrstah *Abies alba* in *Fagus sylvatica*. Podatkov o habitatih ali gozdnih združbah, v katerih se pojavlja, ni.

Za Slovenijo obstaja samo pet historičnih navedb o pojavljanju vrste *L. virens*, od tega je ena neobjavljena (herbarij F. Dolšak). Po letu 1950 je navedba samo ena, vendar potrjuje širše območje pojavljanja v preteklosti. Glede na to, da naj bi bila *R. virens* vrsta zmernega pasu z blago klimo ter vlažnih subtropskih predelov (Wirth 1995), je zanimivo, da se te navedbe nanašajo na območje Kamniško-Savinjskih Alp. Ker je v ostalih območjih, ki bi glede na ohranjenost gozdnih ekosistemov in količino padavin lahko bile potencialni habitat vrste, novejše lihenološke raziskave niso zabeležile, je v Sloveniji verjetno blizu izumrtja oz. je že izumrla.



Slika 10: Karta razširjenosti vrste Ricasolia virens v Sloveniji pred (Arnold F., Degelius G., Dolšak F., Glowacki J.) in po letu 1950 (Batič F.).
Figure 10: Distribution of Ricasolia virens before (Arnold F., Degelius G., Dolšak F., Glowacki J.), and after 1950 (Batič F.) in Slovenia.

4 RAZPRAVA

Vrste iz skupine *Lobaria* s. lat. so v Sloveniji večinoma omejene na območje z veliko količino padavin (alpsko-dinarska pregrada, Pohorje). Nekateri predeli Slovenije, kjer bi bile klimatske razmere lahko ustrezne za vrste iz skupine *Lobaria* s. lat. (Kamniško-Savinjske Alpe, Karavanke) lihenološko še vedno niso v zadostni meri raziskani. Na Pohorju je bila zabeležena samo vrsta *L. pulmonaria*, kar je najverjetneje povezano s korenitimi gozdarskimi posegi v preteklosti. Za območja pojavljanja velikosti populacij večinoma niso poznane, v nekaterih primerih pa gre za najdbo samo ene lišajske steljke oz. so steljke slabo razvite ali poškodovane, nobenega podatka pa ni o genski pestrosti, razen za dve lokaciji vrste *L. pulmonaria*, ki so bile zajete v raziskavo Scheideggerja s sod. (2012). V tej raziskavi so ugotovili, da sta slovenski populaciji v Rajhenavskem Rogu in Notranjskem Snežniku mešani saj sta vsebovali gene iz dveh različnih genetskih bazenov, kar prispeva k večji genetski pestrosti. Majhne populacije so ne glede na genetsko pestrost močno ogrožene, saj jih lahko uniči že en sam katastrofični dogodek (Zoller s sod. 1999). Sicer je Zoller s sod. (1999) na švicarskih populacijah vrste *L. pulmonaria* ugotovil, da genetska pestrost in velikost populacije nista povezani. Večjo genetsko pestrost so zasledili v populacijah, kjer se je glivni simbiont razmnoževal spolno. Vendar pa je za vrsto *L. pulmonaria* znano, da naj bi bil delež spolnega razmnoževanja še manjši od 30 % (dal Grande s sod. 2012), po nekaterih podatki pa še precej manj (Scheidegger s sod. 2012). Tudi v primerih, ko so apoteciji razviti, so pogosto okuženi z glivnim parazitom in nefunkcionalni (Jordan 1973). Poleg vrste *L. pulmonaria* naj bi se tudi vrsti *L. scrobiculata* in *L. linita* razmnoževali predvsem vegetativno (Nimis 2016). Za vrsto *L. pulmonaria* so ugotovili, da se njene vegetativne propagule lahko razširjajo le na kratke razdalje, identične genotipe so ugotovili le na največ 230 m oddaljenosti med seboj (Walser 2004). Pri populacijah, ki se razmnožujejo le vegetativno, ob fragmentaciji habitatov torej zelo hitro lahko pride do stanja, kjer se sosednji fragmenti ne morejo kolonizirati, kljub temu, da so razmere za uspevanje vrste tam ugodne. Za vrsto *L. pulmonaria* je bilo ugotovljeno, da celo blago gospodarjenje z gozdovi znatno zmanjšajo genetsko pestrost, še preden se pojavijo spremembe v pogostnosti vrste, kar naj bi bilo povezano ravno s fragmentacijo populacije v več manjših prostorsko izoliranih populacij, zaradi česar se prostorsko mešanje genotipov zmanjša (Scheidegger s sod. 2012). Podobno je tudi v primeru, ko vrsta naseljuje prosto stoječa, osamela drevesa. Ker se kulturna krajina s prosto stoječimi osamelimi drevesi ne vzdržuje več, v bližini ni novih ustreznih substratov za kolonizacijo. Za lokacijo vrste *L. amplissima*, kjer je vrsta uspevala na gorskem brestu, je bilo ugotovljeno, da so prav vsa drevesa, ki jih je bilo 15, v letih 2006-2009 odmrla zaradi okužbe z glivo *Ophiostoma novo-ulmi* (Obermayer 2011), s tem pa tudi vrsta *L. amplissima* na tej lokaciji. Vrste iz skupine *Lobaria* s. lat. ogroža tudi intenziviranje kmetijstva s povečanim vnosom dušikovih spojin, saj vrste bodisi ne prenesejo evtrofikacije ali pa le v majhni meri (*L. amplissima* in *L. pulmonaria*; Wirth 1995, Nimis 2016), pa tudi zaraščanje, saj za uspevanje potrebujejo večinoma zadostno količino difuzne svetlobe (Nimis 2016). Ker so vrste higrofilne, jih lahko prizadene tudi lokalno zmanjšana vlažnost zaradi gozdarskih posegov. Vrsta *L. linita*, za katero je potencialnih habitatov v Sloveniji zelo malo, bi bila lahko prizadeta zaradi globalnega segrevanja ozračja, saj gre za arktično-alpsko vrsto, daljinskega onesnaženja z dušikovimi spojinami ter uničevanja habitatov zaradi športnih dejavnosti v gorah. Glede na navedeno ni presenetljivo, da so v številnih evropskih državah vrste iz rodu *Lobaria* umeščene na rdeči seznam ogroženih vrst. V Italiji imajo vrste *R. amplissima*, *L. virens* in *L. scrobiculata* status potencialno ogrožene vrste, *L. pulmonaria* pa status najmanj ogrožene vrste (Nimis 2016). V Nemčiji je vrsta *L. virens* veljala za izumrlo, a so pred cca. desetletjem odkrili eno lokacijo, kjer se je ohranila (Fischer & Killman 2008), tudi v Švici velja za izumrlo (Scheidegger s sod. 2002), v Avstriji pa se ne pojavlja (H. Mayrhofer, os. komunikacija). *R. amplissima* je v Avstriji zelo redka, prav tako *L. scrobiculata*. *R. amplissima* in *L. scrobiculata* sta v Švici ogroženi (Scheidegger s sod. 2002). *L. pulmonaria* velja za ranljivo vrsto v Švici (Scheidegger s sod. 2002). O terikolnih vrstah (*L. linita*) je podatkov manj, Scheidegger s sod. 2002 jo opredeljuje kot vrsto zunaj nevarnosti, kar gre na račun velike površine, ki ga v Švici zavzemajo kristalinske Alpe. V Italiji je vrsta odsotna povsod, razen v alpski in predalpski regiji, kjer velja za zelo do ekstremno redko (Nimis 2016).

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SUMMARY

5 INTRODUCTION

Lobaria s. lat. is a group of lichens from Lobariaceae family. Lobariaceae family includes some of the largest lichens in the world that can reach several decimetres in diameter. Phylogenetic studies have shown that the group *Lobaria* s. lat. is formed from seven distinct groups that were given the genus level. Of these genera, three are found in Slovenia, namely *Lobaria* s. str. with species *L. pulmonaria* (L.) Hoffm. and *L. linita* (Ach.) Rabenh., *Lobarina* with *L. scrobiculata* (Scop.) Nyl. and *Ricasolia* with *R. virens* (With.) H. H. Blom. & Tønsberg and *R. amplissima* (Scop.) De Not. *Lobaria* s. str. is characterized by thalli with a honeycomb structure where tomentum is developed in the form of veins between the protrusions on the lower surface. Spores are short and broadly fusiform. Genus *Lobarina* is similar to genus *Lobaria* s. str. in the shape of lobes, but has a dense tomentum on the lower surface, leaving out smooth circular white areas that do not match with the position of protrusions on the lower surface. Ascospores are narrowly fusiform to acicular and much longer than in *Lobaria* s. str. For genus *Ricasolia*, plane lobe surface with smooth and uniform tomentum on the lower side is characteristic. Genera also differ in the content of lichen substances (Moncada et al. 2013).

Epiphytic species from the group *Lobaria* s. lat. form a *Lobarion* alliance, which communities are the main lichen climax communities of forest trees in Europe. In addition to species of *Lobaria* s. lat. group, large foliose species from *Sticta* and *Pseudocyphellaria* genera are present in these communities, as well as smaller foliose lichens from *Parmeliella*, *Pannaria*, *Nephroma*, *Peltigera* and *Parmelia* genera, and many crustose lichens and mosses. Communities from the *Lobarion* alliance are not always exclusively epiphytic and may also occur on rocks. The most significant and permanent species in communities of the *Lobarion* alliance is *L. pulmonaria*. A rich herbarium material and notices in the local scientific journals confirmed the former wide prevalence of *Lobarion* communities in most of Western Europe, where they had an oceanic-montane character (Rose 1988).

Historical data show that other species of *Lobarion* alliance declined even drastically than *L. pulmonaria* itself, specifically genera with cyanobacterial fotobionts, such as *Collema*, *Leptogium*, *Nephroma*, *Pannaria*, *Parmeliella* and *Sticta*, as well as *L. scrobiculata* (Rose 1988).

The causes for decline of communities from the *Lobarion* alliance are changes in forest management (eg. the replacement of deciduous for coniferous species, maintenance of dense stands with no forest gaps, selective logging of trees, which measure 30-40 cm in diameter, too short rotation period) (Gauslaa 1995, Rose 1988). Changes in the structure of the forest in terms of fragmentation can affect the epiphytic lichen species due to local climate changes and due to impact on the effectiveness of dispersion between the respective forest fragments (Ellis & Coppins 2007). In the second half of the 20th century, strong decline in communities from the *Lobarion* alliance was observed due sulphur dioxide pollution (Gauslaa 1995, Rose 1988).

6 MATERIAL AND METHODS

Data for all species from *Lobaria* s. lat. group, for which there is any information about their occurrence in Slovenia, were collected: *Lobaria pulmonaria*, *L. linita*, *Lobarina scrobiculata*, *Ricasolia amplissima* (including "*Dendriscocaulon umhausense*") and *R. virens*. The nomenclature is following Nimis (2016). Short descriptions accompanying figures are based on Wirth (1995). Data were collected with the help of Catalogue of the lichenized and lichenicolous fungi of Slovenia (Suppan et al. 2000), Boletus informaticus database (Ogris 2008) and published inventories of lichen or references of those species for the territory of Slovenia in the literature. For each reference, the following information was gathered, where available: location, altitude, the substrate on which the lichen species was recorded and habitat or community where the species was found. Invalid names of forest communities were substituted with corresponding valid names according to Kutnar et al. (2012) and Šilc & Čarni (2012). Locations were translated into MTB network distribution maps. Within each MTB quadrant, where the species was recorded, there might be several locations included. Data for the period before and after 1950 were mapped separately. For the period before 1950, data for locations were very scarce, therefore only approximate locations could have been drawn, eg. if it was referred that the lichen was occurring in the vicinity of Idrija, the MTB quadrant was assigned to the town of Idrija. In the case of *L. pulmonaria*, sometimes the location was given so widely that it was not possible to plot it.

As authors of distribution maps, determinators of lichens are given in alphabetical order. Where information on determinator was not known, author of the reference was given.

7 RESULTS

7.1 *Lobaria pulmonaria* (L.) Hoffm.

After 1950, there were 158 records for *L. pulmonaria* in Slovenia, in 46.8 % it was reported from *Acer pseudoplatanus*, followed by *Fagus sylvatica* (15.2 %). Other substrates were occurring in less than 5 % (*Ulmus glabra*, *Fraxinus excelsior* > *Abies alba* > *Picea abies*, *Tilia* sp. > *Quercus* sp. > *Coryllus avellana* > *Juglans regia*, *Pyrus communis*, *Salix caprea*, *Sorbus aucuparia*, *Populus tremula*). In 12.7 % of cases, the substratum was not defined. The species was growing on bark, tree bases, mosses on trunks and trunk bases, mosses on wood, stumps and rocks. It is reported mainly from beech forests (*Omphalodo-Fagetum* (Tregubov 1957) Marinček et al. 1993, *Anemono trifoliae-Fagetum* Tregubov 1962, *Ranunculo platanifoli-Fagetum* Marinček et al. 1993, *Polysticho lonchitis-Fagetum* (Horvat 1938) Marinček in Poldini et Nardini 1993, *Stellario montanae-Fagetum* (Zupančič 1969) Marinček et al. 1993), mixed broadleaved forests, spruce forests with admixed broadleaved trees (*Hacquetio-Piceetum* Zupančič (1980) 1999, *Lonicero ceruleae-Piceetum* Zupančič (1976) 1994, *Stellario montanae-Piceetum* Zupančič (1980) 1999, *Adenostylo glabrae-Piceetum* M. Wraber ex Zukrigl 1973), from forest edges, forest clearings with solitary treed and solitary trees in small settlements.

From distribution map of *L. pulmonaria* it is evident that this species is present in areas with high amount of precipitation. In contrast to other species from *Lobaria* s. lat. group, *L. pulmonaria* was found also in Pohorje area. It is the most widespread of all species from *Lobaria* s.lat. group. It was reported from 150 m a.s.l. in Krakovski gozd to 1460 m a.s.l. in Julian Alps.

It is still occurring in areas where it was present in the past and additionally in some areas that were lichenologically not investigated before. Historical record from Javorniki in Dinaric mountains was not confirmed any more. In historical records, L. pulmonaria was referred as common, e. g. as in Glowacki & Arnold (1871): »especially in the vicinity of Idrija common«. Nowadays, in some areas of Slovenia (eg. Snežnik), the status of the species is still satisfactory, thalli are big and healthy, while on many locations only some specimens or even single thallus is evidenced, thalli are badly developed or damaged.

7.2 *Lobaria linita* (Ach.) Rabenh.

In the whole history of lichenological investigations there are only three findings known for Slovenia (Glowacki 1874, Hočevar et al. 1985, BLAM excursion preparations in 2003 - unpublished), one of them is regarded as doubtful (Hočevar et al. 1985). This record may refer to young poorly developed thallus of *L. pulmonaria*, with no developed isidia or soralia (Suppan et al. 2000). Both reliable findings are from the mountains near Bovec (above tree line), where siliceous inclusions are found in carbonaceous rocks. The finding from 2003 is from 1880 m a.s.l. As this species is occurring on acid soil rich in humus, on bryophytes and between siliceous blocks (Wirth 1995), there are few potential sites for *L. linita* in Slovenia, due to prevalence of carbonate rocks. Knowledge of lichen flora above tree line is extraordinary low, therefore its frequency and the size of populations are not known. Besides all, thalli are hardly noticeable between alpine vegetation, especially in dry condition. As siliceous rocks above tree line in Slovenia are rare, it can be assumed that it is very rare and that the populations are small.

7.3 *Lobarina scrobiculata* (Scop.) Nyl.

Species was first described by Scopoli in his Flora Carniolica from 1772 under the name *Lichen scrobiculatus*, it originated from the vicinity of Idrija. Type Scopoli‘s material was lost, therefore a lectotype was chosen, that corresponded to Dillenius‘s description (Lichenoides pulmoneum villosum, superficie scrobiculata et peltata) and to illustration »Lichenoides no. 114« in Historia Muscorum from 1741 (already referred by Scopoli), and is kept in Oxford herbarium (Yoshimura & Isoviita 1969).

The number of findings of *L. scrobiculata* is small, both before and after 1950. Findings after 1950 are from the substrates *Ulmus glabra*, *Acer pseudoplatanus*, *Po-*

pulus tremula and *Quercus robur*, in historical records also *Fagus sylvatica* and *Abies alba* are mentioned besides oak. *L. scrobiculata* is found on trunks or trunk bases. There is very little information on habitats where it was found. It was reported from mixed broadleaved forests and solitary trees from 600 to 880 m a.s.l.

Distribution of species corresponds to areas with the highest amount of precipitation in Slovenia. Some areas, where it could potentially occur based on amount of precipitation, either have not been investigated in detail (e.g. Kamniško-Savinjske Alps, Karavanke) either were intensively managed (e.g. Pohorje). In Panovec (close to Nova Gorica), vicinity of Idrija and Medvode, on Javorniki and Trnovski gozd *L. scrobiculata* has not been found any more after 1950, although these areas were thoroughly investigated by lichenologists.

7.4 *Ricasolia amplissima* (Scop.) De Not. & »Dendriscocaulon umhausense«

In *R. amplissima* species, there is taxonomic and nomenclature problem. »Cephalodia« of this species can grow independently and were treated as independent taxon named *Dendriscocaulon umhausense* (Auersw.) Degel. Often, they are found together with foliose form on the same site. Molecular studies have revealed that »*Dendriscocaulon umhausense*« is built by the same fungus as foliose form with green primary photobiont. As lichens are named after fungus, two names cannot exist as both growth types are formed by the same fungus. To name a cyanobacterial form, a citing of incorrect name in quotation marks was suggested: »*Dendriscocaulon umhausense*« or adding of a corresponding adjective cyan. or chlor. after the correct name, e.g. *R. amplissima* cyan. In this way, information on growth form is given (Jorgensen 1998).

As substrates for *R. amplissima*, the following tree species were recorded after 1950: *Ulmus glabra* > *Acer pseudoplatanus* > *Fagus sylvatica*, *Pyrus communis*, in some cases there was no record on the type of the substratum. In the past, it was reported also from *Abies alba*, *Castanea sativa*, *Quercus* sp., *Picea abies* and conifers. It grows on tree bark or wood on forest edges, forest clearings with solitary broadleaved trees, solitary trees in areas where management is limited to hay harvesting and feeding of wild animals (Prügger 2005), and in mixed forests. It was recorded between 720 m.s.l (Babno polje) to 1400 m (Julian Alps).

Distribution of the species (except for the historical record from Donačka gora) is matching the areas with the highest amount of precipitation in Slovenia. Some areas, where it could potentially occur based on amount of precipitation, either have not been investigated in detail (e.g. Kamniško-Savinjske Alps, Karavanke) either were intensively managed (e.g. Pohorje). After 1950, there are twelve findings known. Investigations of lichen flora in 90ties of 20th century and in the beginning of 21st century have shown that *R.amplissima* does not occur anymore in Panovec (close to Nova Gorica), Javorniki, Trnovski gozd, Šenturška and Donačka gora. For Panovec it was already noted by Glowacki (1871) that it is very rare. For Julian Alps, where there were no historical records, after 1950 only one specimen was found. All other specimens were found at Snežnik or Goteniška gora.

7.5 *Ricasolia virens* (With.) H.H. Blom. & Tønsberg

In Slovenia, *R. virens* was reported from tree species *Abies alba* and *Fagus sylvatica*. There is no information available on habitats or forest communities where it was found.

There are only five historical records on occurence of *R. virens* in Slovenia, one of them is unpublished (herbarium F. Dolšak). After 1950, there is only one record, but is confirming wider area of occurrence in the past. Considering that *R. virens* is a species of mild temperate to humid subtropic climate (Wirth 1995), it is interesting that these records are referring to alpine region – Kamniško-Savinjske Alps. As recent lichenological investigations have not discovered it in its potential habitats (areas with high amount of precipitation in combination with low disturbance of forest ecosystems), it can be assumed that it is close to extinction or it is already extinct in Slovenia.

8 DISCUSSION

Species from the *Lobaria* s. lat. group are mostly limited to an area with high annual amount of precipitation (Alpine-Dinaric barrier, Pohorje) in Slovenia. Some parts of Slovenia, where the climatic conditions may be appropriate for the species from the *Lobaria* s. lat. group (Kamniške Alpe, Karavanke) are lichenologically still understudied. At Pohorje, only *L. pulmonaria* was recorded, which is most likely related to the radical forest management measures in the past. The sizes of populations for locations are mostly not known. However, in some cases, a single lichen thallus of the species was found at a location or the thalli were badly developed and damaged. There is no data on genetic diversity, except for two locations of *L. pulmonaria*, which were included in the study of Scheidegger et al. (2012). This study found that the Slovenian populations from Rajhenavski Rog and Notranjski Snežnik are admixed i.e. contain genes from two different genetic pools, which contributes to greater genetic diversity. Anyway, small populations are highly endangered regardless of genetic diversity as they may be destroyed by a single catastrophic event (Zoller et al. 1999). Otherwise, Zoller et al. (1999) found out that in Swiss populations of *L. pulmonaria* genetic diversity and size of the population were not linked. Greater genetic diversity was observed in populations where the fungal simbiont reproduced sexually. However, *L. pulmonaria* is known that, the sexual reproduction occurs in even less than 30 % (dal Grande et al. 2012), furthermore, according to some data the percentage of sexual reproduction is even significantly smaller (Scheidegger et al. 2012). In general, it is known that even when apothecia are developed, they are often infected with a fungal parasite and therefore nonfunctional (Jordan 1973). Besides *L. pulmonaria*, also *L. scrobiculata* and *L. linita* reproduce primarily by vegetative means (Nimis 2016). For *L. pulmonaria* it was reported that its vegetative propagules may disperse only on a short distance and that identical genotypes are found only at a maximum distance of 230 m from each other (Walser 2004). In populations, which are propagated only vegetatively, fragmentation of habitats can lead to situations where neighbouring fragments cannot be colonized due to distance in between, although they might be ecologically suitable. Even mild forest management significantly reduces genetic diversity of *L. pulmonaria* populations before changes in frequency occur due to fragmentation of one population into several small populations isolated in space, resulting in reduced mixing of genotypes (Scheidegger et al. 2012). Similar effects occur in cases where species occupies free-standing isolated trees. As the cultural landscape of free standing isolated trees is not maintained anymore, there are no appropriate substrates for colonization in the vicinity. For the location, where *R. amplissima* was known to flourish on *Ulmus glabra* (Prügger 2002), it was found out that all 15 trees died in 2006-2009 due to infection with *Ophiostoma novo-ulmi* fungus (Obermayer 2011), as well as *R. amplissima* disappeared with from this location. As lichens from the *Lobaria* s.lat. group cannot tolerate eutrophication or only to a small extent (*L. pulmonaria* and *R. amplissima*) (Wirth 1995, Nimis 2016), they are also threatened by intensification of agriculture with increased levels of nitrogen compounds. They also need a sufficient amount of diffused light for their growth (Nimis 2016), therefore abandonment of extensive agricultural land use is not advantageous. All lichens from *Lobaria* s. lat. group are hygrophilous (Nimis 2016), so they can be affected by reduced air humidity as a result of forestry measures. *L. linita*, with only a small number of potential habitats in Slovenia could be affected by global warming, as it is arctic-alpine species, remote pollution with nitrogen compounds and destruction of habitats due to sports activities in the mountains. Taking all the presented issues into account, it is not surprising that in many European countries, species of the *Lobaria* s.lat. group are placed on the red list of endangered species. In Italy, *R. amplissima*, *R. virens* and *L. scrobiculata* have a status of potentially endangered species, whereas *L. pulmonaria* is least threatened (Nimis 2016). In Germany *L. virens* considered to be extinct, but before approx. a decade a location where it has preserved was discovered (Fischer & Killman 2008). It is also considered extinct in Switzerland (Scheidegger et al. 2002), whereas in Austria it does not occur (H. Mayrhofer, pers. communication). *R. amplissima* in Austria is very rare, as well as *L. scrobiculata*. *L. amplissima* and *L. scrobiculata* are endangered, and *L. pulmonaria* is considered as vulnerable in Switzerland (Scheidegger et al. 2002). Terricolous species *L. linita* is out of danger in Switzerland (Scheidegger et al. 2002), probably due to large area that is occupied by crystalline Alps. In Italy, the species is absent everywhere except in alpine and subalpine region, where it is very to extremely rare (Nimis 2016).

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9 LITERATURA - REFERENCES

Arso. Vreme in podnebje. Napovedi in podatki. Padavinska karta. Obdobje 1961-1990. Ministrstvo za okolje in prostor, Agencija za okolje. http://www.arso.gov.si/vreme/napovedi %20in%20podatki/padavinska_karta.html (april 2017)

Arup, U., A. Wilfling, J. Prügger & H. Mayrhofer, 2001: *Contributions to the lichen flora of SLovenia VIII. Lichenized and lichenicolous fungi from Veliki Snežnik*. Bibliotheca Lichenologica (Berlin & Stuttgart) 78: 17-25.

Batič, F., 1976: *Prispevek k flori lišajev (Lichenophyta) na Slovenskem I.* Biološki vestnik (Ljubljana) 24(1): 61-67.

Batič, F., 1976: *Prispevek k flori lišajev (Lichenophyta) na Slovenskem II.* Biološki vestnik (Ljubljana) 26(1): 1-8.

Batič, F., 2001: *Lišajska flora.* V: Papež J. (ur.): *Panovec.* Mestna občina Nova Gorica & Zavod za gozdove Slovenije, Območna enota Tolmin: 70-75.

Batič, F., K. Primožič, B. Surina, T. Trošt & H. Mayrhofer, 2003: *Contributions to the lichen flora of Slovenia X. Lichens from the Slovenian Julian Alps*. Herzogia (Halle (Saale)) 16: 143-154.

Bilovitz, P. O., U. Arup & H. Mayrhofer, 2010: *Contributions to the lichen biota of Slovenia XII. Some lichens from Logarska dolina*. Hladnikia (Ljubljana) 26: 15-20.

Bilovitz, P. O., F. Batič & H. Mayrhofer, 2011: *Epiphytic lichen mycota of the virgin forest reserve Rajhenavski Rog (Slovenia).* Herzogia (Halle (Saale)) 24(2): 315-324.

Christensen, S. N., 1987: *Contribution to the lichen flora of Yugoslavia.* Acta Bot. Croat. 46: 161-171.

Dal Grande, F., I. Widmer, H. H. Wagner & C. Scheidegger, 2012: *Vertical and horizontal photobiont transmission within populations of lichen symbiosis.* Molecular Ecology (Oxford) 21: 3159-3172. https://doi.org/10.1111/J.1365-294X.2012.05482.X

Elllis, C. J. & B. J. Coppins, 2007: *Changing climate and historic-woodland structure interact to control species diversity of the 'Lobarion' epiphyte community in Scotland.* Journal of Vegetation Science (Uppsala) 15: 725-734. https://doi.org/10.1111/J.1654-1103.2007.TB02587.X

Fischer, E. & D. Killmann, 2008: *Wiederfund von Lobaria virens in Deutschland*. Herzogia (Halle (Saale)) 21: 79–84.

Gauslaa, Y., 1995: *The Lobarion, an epiphytic community of ancient forests threatened by acid rain.* Lichenologist (London) 27(1): 59-76. https://doi.org/10.1006/lich.1995.0005

Glowacki, J., 1871: *Prodromus einer Flechten-Flora von Görz.* V: Gatti F. (ur.): *Elfter Jahresbericht der K. K.* Ober-Realschule in Görz: 1-31.

Glowacki, J., F. Arnold, 1870: *Flechten aus Krain und Küstenland.* Verh. K. K. Zool.- Bot. Ges. Wien, 20: 431-466.

Glowacki, J., 1874: *Die Flechten des Tommasini'schen Herbars, ein Beitrag zur Flechtenflora des Küstenlandes.* Verh. K. K. Zool. — Bot. Ges. (Wien) 24: 539-552.

Grube, M., F. Batič & H. Mayrhofer, 1995: *Contributions to the lichen flora of Slovenia I. Epiphytic lichens of the Snežnik Area.* Herzogia (Halle (Saale)) 11: 189-196.

Grube, M., H. Mayrhofer & F. Batič, 1998: *Contributions to the Lichen Flora of Slovenia III. Epiphytic lichens from Goteniški Snežnik and Krokar Area.* Herzogia (Halle (Saale)) 13: 181-188.

Jordan, W. P., 1973: *The Genus Lobaria in North America North of Mexico.* The Bryologist (College Station, TX) 76(2): 225-251. https://doi.org/10.2307/3241326

Jorgensen, P. M., 1998: *What shall we do with the blue-green counterparts?* The Lichenologist (London) 30(4-5): 351-356. https://doi.org/10.1006/lich.1998.0146

Kranner, I., 2002: *Glutathione status correlates with different degrees of desiccation tolerance in three lichens of desiccation tolerance in three lichens.* New Phytologist (London) 154: 451–460. https://doi.org/10.1046/j.1469-8137.2002.00376.x

Kutnar, L., Ž. Veselič, I. Dakskobler & D. Robič, 2012: *Tipologija gozdnih rastišč Slovenije na podlagi ekoloških in vegetacijskih razmer za potrebe usmerjanja razvoja gozdov = Typology of Slovenian forest sites according to ecological and vegetation conditions for the purposes of forest management.* Gozdarski vestnik (Ljubljana) 70(4): 195-214.

Mayrhofer, H., M. Koch & F. Batič, 1996: *Beiträge zur Flechtenflora von Slowenien II. Die Flechten des Pohorje*. Herzogia (Halle (Saale)) 12: 111–127.

Mayrhofer, H., M. Matzer & Z. Belec, 1998: *Beiträge zur Flechtenflora von Slowenien V. Nachträge zur Flechtenflora des Pohorje.* Hladnikia (Ljubljana) 10: 5-10.

Moncada, B., R. Lücking & L. Betancourt-Macuase, 2013: *Phylogeny of the Lobariaceae (lichenized Ascomycota: Peltigerales), with the reappraisal of the genus Lobariella.* The Lichenologist (London) 45(2): 203-263. https://doi.org/10.1017/S0024282912000825

Mrak, T., H. Mayrhofer & F. Batič, 2004: *Contributions to the lichen flora of Slovenia XI. Lichens from the vicinity of Lake Bohinj (Julian Alps).* Herzogia (Halle (Saale)) 17: 107-127.

Nimis, P. L., 2016: *The Lichens of Italy.* A Second Annotated Catalogue. EUT. Trieste.

Obermayer, W., 2011: *Dupla Graecensia Lichenum (2011, nos 681-800).* Fritschiana (Graz) 69: 17-53.

Ogris, N., 2008: *Podatkovna zbirka gliv Slovenije Boletus informaticus.* Računalniški program.

Pötsch, J. S., *Lichenes Welwitschiani. Aufzählung mehrerer von Dr. F. Welwitsch in österreich gesammelten Flechten.* Verh. K.K. Zool.-Bot. Ges. (Wien) 13: 581-583.

Prügger, J., 2005: *Lišajska flora Snežnika in Javornikov. Die Flechtenflora des Snežnik und der Javorniki mit besonderer Berücksichtigung der epiphytischen Arten.* Studia Forestalia Slovenica, Strokovna in znanstvena dela: 122, Gozdarski inštitut Slovenije. Ljubljana.

Prügger, J., H. Mayrhofefr & F. Batič, 2000: *Beiträge zur Flechtenflora von Slowenien IV. Die Flechten des Trnovski gozd.* Herzogia (Halle (Saale)) 14: 113–143.

Prügger, J., B. Surina & H. Mayrhofefr, 2000: *The lichens of the Ždrocle forest reserve.* Zbornik gozdarstva in lesarstva (Ljubljana), 63: 7-25.

Robič, S., 1895: *Kranjski lišaji (Lichenes).* Izvestja muzejskega društva za Kranjsko: 33-42, 83-85, 118-121, 153-159.

Rose, F., 1988: *Phytogeographical and ecological aspects of Lobarion communities in Europe.* Botanical Journal of the Linnean Society (London) 96: 69-79. https://doi.org/10.1111/j.1095-8339.1988.tb00628.x

Scheidegger, C., P. O. Bilovitz, S. Werth, I. Widmer & H. Mayrhofer, 2012: *Hitchhiking with forests: population genetics of the epiphytic lichen Lobaria pulmonaria in primeval and managed forests in southeastern Europe.* Ecology and Evolution (Oxford) 2(9): 2223-2240. https://doi.org/10.1002/ece3.341

Scheidegger, C., P. Clerc, M. Dietrich, M. Frei, U. Groner, C. Keller, I. Roth, S. Stofer & M. Vust, 2002: Rote Liste der gefährdeten Arten der Schweiz. Baum und erdbewohnende Flechten. BUWAL, Bern, WSL, Birmensdorf & CJBG Geneve: 124 str.

Suppan, U., J. Prügger & H. Mayrhofer, 2000: *Catalogue of the lichenized and lichenicolous fungi of Slovenia.* Bibliotheca Lichenologica, Band 76. J.Cramer. Berlin. Stuttgart.

Šilc, U. & M. Čarni, 2012: *Conspectus of vegetation syntaxa in Slovenia.* Hacquetia (Ljubljana) 11(1): 113–164. https://doi.org/10.2478/v10028-012-0006-1

Walser, J.-C., 2004: *Molecular Evidence for Limited Dispersal of Vegetative Propagules in the Epiphytic Lichen Lobaria pulmonaria.* American Journal of Botany (Ames, Iowa) 91(8): 1273-1276. https://doi.org/10.3732/ajb.91.8.1273

Wirth, V., 1995: *Flechtenflora, Bestimmung und ökologische Kennzeichnung der Flechten Südwestdeutschland und angrenzender Gebiete.* 2.Auflage. Ulmer. Stuttgart.

Yoshimura, I. & P. Isoviita, 1969: *Scopoli's lichen specimens and the typification of Lobaria scrobiculata (Scop.) DC.* Annales Botanici Fennici (Helsinki) 6(4): 348-352.

Zoller, S., F. Lutzoni & C. Scheidegger, 1999: *Genetic variation within and among populations of the threatened lichen Lobaria pulmonaria in Switzerland and implications for its conservation.* Molecular Ecology (Oxford) 8: 2049-2059. https://doi.org/10.1046/j.1365-294x.1999.00820.x

POMEN MAKROFITOV V JEZERSKEM EKOSISTEMU

THE IMPORTANCE OF MACROPHYTES IN LAKE ECOSYSTEM

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IZVLEČEK

Pomen makrofitov v jezerskem ekosistemu

V preglednem članku povzemamo temeljne značilnosti makrofitov v jezerskem ekosistemu. Makrofiti so povezovalni člen med sedimentom, vodo in ozračjem. Vodne rastline vplivajo na zgradbo habitata, prav tako pa so vir avtohtonih snovi, ki so osnova za prehranjevalni splet. Rast vodnih rastlin je odvisna od mnogih okoljskih dejavnikov, ki so med seboj povezani - svetloba, temperatura, vodni tok, globina ipd. Za prehod od velike kalnosti do prosojnosti vode v jezeru sta značilni spremembi v prevladi skupin primarnih producentov in vrst v celotnem prehranjevalnem spletu, kjer namesto prevladujočega fitoplanktona postanejo prevladujoči primarni producenti submerzni makrofiti ali perifitonske alge. Makrofiti so pomembni tudi za vrednotenje človekovega vpliva na jezerski ekosistem ter posredno pri izvajanju upravljavskih načrtov za vode.

Ključne besede: makrofiti, jezera, fitoplankton, ekološko stanje

ABSTRACT

The importance of macrophytes in lake ecosystem

In a review paper we summarized the basic features of macrophytes in lake system. Macrophytes present link between sediment, water and atmosphere. Primarily aquatic plants determine the structure of habitat and present the vital source of autochthonous matter as a base for food web. The growth of aquatic plants depends on a number of environmental factors, which are linked - light, temperature, water flow, depth etc. Transition from high turbidity to the transparency of the water in the lake is characterized by a change in the dominance of primary producers and species throughout the food web, where instead of the dominant phytoplankton the dominant primary producers becomes submerged macrophytes or periphytic algae. Macrophytes are important for evaluating human impact on lake ecosystems and indirectly in the management plans for water.

Key word: macrophytes, lakes, phytoplankton, ecological status

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UVOD

Makrofiti imajo pomembno vlogo v vodnih ekosistemih (Flint & Madsen 1995, Luo et al. 2016), saj so povezovalni člen med sedimentom, vodo in ozračjem. S tvorjenjem mikrohabitatov za perifiton, mest za odlaganja jajčec rib in skrivališč mnogih organizmov, vplivajo na večjo biodiverziteto in heterogenost vodnega ekosistema (Klaassen & Nolet 2007, Lampert & Sommer 2007). S svojim koreninskim sistemom in listi absorbirajo hranila in na ta način čistijo vodo (Zhou et al. 2017) ter istočasno povečujejo koncentracijo hranil ko odmrejo in razpadejo. Lahko delujejo kot indikatorji kakovosti vode in sodelujejo pri kroženju hranil. Vključeni so v ekosistemske procese kot so biomineralizacija, transpiracija, izpust biogenih plinov v ozračje in sedimentacija (Carpenter & Lodge 1986). Izločajo tudi alelopatske snovi, ki vplivajo na prehranjevalni splet. Zavirajo rast fitoplanktona, bakterioplanktona (Mulderij et al. 2006) in epifitskih alg (Hilt et al. 2006, Cerbin et al. 2007, Gross et al. 2007, Wu et al. 2007). Raziskovalci so ugotovili, da alelopatski učinki makrofitov lahko vplivajo na velik del sprememb razpoložljivega ogljika v jezerih (Hilt & Gross 2008, Hilt 2006, Jürgens & Jeppesen 1998, Cerbin et al. 2007).

Razpoložljiv ogljik je potencialno vir za prehranjevalni splet (Cole et al. 2000), zato so za ravnovesje jezerskih ekosistemov makrofiti ključnega pomena (Hutchninson 1975). S posrednimi in neposrednimi učinki vplivajo na delovanje jezerskega ekosistema. Potopljeni makrofiti igrajo pomembno vlogo pri vzdrževanju kakovosti vode v plitvih jezerih (Kuiper et al. 2017). Potopljeni makrofiti preprečujejo erozijo in premikanje mehkega sedimenta in vplivajo na odstranjevanje suspendiranih delcev iz vodnega stolpca (Madsen et al. 1996). Prisotnost plavajočih rastlin lahko močno vpliva na prehranjevalni splet s posrednim in neposrednim učinkom na združbe organizmov (npr. planktona, nevretenčarjev, rib) ki naseljujejo obrežna in pelagična območja (Meerhoff & Mazzeo 2004). Številne raziskave dokazujejo, da na podlagi prisotnosti in pogostosti makrofitov lahko ugotavljamo vplive človekovih dejavnosti na vodne ekosisteme (Poikane et al. 2015, Sudnitsyna 2015).

VPLIV OKOLJSKIH DEJAVNIKOV NA MAKROFITE

Makrofiti vključujejo semenke, praprotnice, mahove in nekatere makroskopske alge (Fox 1992). Razvrščamo jih glede na rastno obliko, način pritrjanja in položaj v vodnem stolpcu. Na podlagi morfoloških značilnosti in položaja v vodnem stolpcu, delimo makrofite v štiri skupine: potopljene (submerzne) makrofite, plavajoče (natantne) ukoreninjene makrofite (slike 1-3), plavajoče (natantne) neukoreninjene makrofite in emergentne makrofite (Hutchinson 1975, Fox 1992, Germ 2013). Prisotnost in razporeditev makrofitov je odvisna od izpostavljenosti različnim abiotskim (fizikalnim in kemijskim) in biotskim dejavnikom (npr. herbivorija) (Haslam 2006, Lacoul & Freedman 2006, Ali & Soltan 2006, Zelnik et al. 2012). Pogostost makrofitov je odvisna tudi od uspešnosti vrst, ki temelji na sposobnosti hitre prilagoditve na spremembe okoljskih dejavnikov in kompeticiji (Germ 2013).

Poleg svetlobe h ključnim abiotskim dejavnikom, ki vplivajo na uspevanje makrofitov, uvrščamo temperaturo, vodni tok, globino in obliko jezerske kotanje, izpostavljenost valovom in vetru, vrsto sedimenta v jezeru in kemizem vode (Dar et al. 2014). Makrofiti kot primarni producenti opravljajo fotosintezo, za katero je potrebno dovolj svetlobe. Globina, do katere sega svetloba, je odvisna od dejavnikov kot so barva vode, kalnost in osenčenost jezera, ter razvitost obrežnega pasu (Lacoul & Freedman 2006). Znano je, da se približno 10 % sevanja izgubi na meji med zrakom in vodo (Janauer & Englmaier 1986). V plitvih jezerih lahko pride do resuspenzije delcev (Blom et al. 1994), kar zmanjša prosojnost vode in posledično tudi rast makrofitov. V globokih jezerih je tudi v osončenih delih litorala pojavljanje makrofitov manjše zaradi valovanja (Kantrud 1990). Valovi in veter vplivajo na razpršenost sončnega sevanja v vodnem stolpcu in temperaturo vode. V obdobju nizkih temperatur, ki vpliva na uspešnost in stopnjo fotosinteze, je rastlinska proizvodnja manjša (Scheffer 1998, Pilon et al. 2003). Temperatura vode in sedimenta vplivata na fiziologijo makrofitov (npr. tvorba semen, začetek sezonske rasti in začetek dormance), medtem ko hitrost metabolizma, prenos razmnoževalnih organov in dostopnost hranil v večji meri določa vodni tok (Dodds & Biggs 2002, Haslam 2006).

Eden izmed ključnih dejavnikov, ki vpliva na vertikalno razporeditev združb submerznih makrofitov, je sestava sedimenta (povprečna velikost delcev, delež organske snovi, frakcija mulja). Sediment služi kot pritrjevalna podlaga za korenine in rizoide (Handley & Davy 2002) in kot vir hranil (Peralta et al. 2003). Schulthorpe (1967) je izpostavil, da je vpliv sestave sedimenta na razporeditev makrofitov večji kot sama kemijska sestava sedimenta. Raziskovalci interakcij med vegetacijo in sedimentom so jasno razlikovali med lastnostmi združb makrofitov na pesku z nizko vsebnostjo hranil in lastnostmi združb makrofitov, ki rastejo na glini, ki vsebuje veliko hranil (Lindner 1987, Selig et al. 2007). Na vsebnost organskih in anorganskih snovi v sedimentu vplivajo raba tal, vegetacijska pokrovnost in deloma geomorfologija (Lacoul & Freedman 2006). Od kamninske podlage je odvisen pH vode, ki se lahko zaradi fotosinteze, dihanja in asimilacije nitrata spreminja. Kjer je pH višji od 7 je vrstno bogastvo makrofitov veliko, v vodi kjer je pH manjši od 7, pa majhno (Lampert & Sommer 2007).

Zaradi posrednih, neposrednih vplivov in delovanja drugih dejavnikov (vrsta substrata, nihanje vodne gladine, svetlobne razmere) je povezavo med kemizmom vode in uspevanjem makrofitov težko opisati (Pip 1989, Germ 2013). Nedvomno je v stoječih vodah ključnega pomena vsebnost kisika, ki v veliki meri določa aktivnost organizmov (Allan 1995). Primarna proizvodnja fitoplanktona, makrofitov in bentoških alg, predstavlja avtohtono podlago prehranjevalnega spleta. Primarna proizvodnja in dihanje sta glavni metabolni poti, po katerih se organske snovi proizvedejo in razgrajujejo. Ekosistemi, v katerih stopnja fotosinteze presega stopnjo dihanja, predstavljajo vir kisika in organske snovi ter ponor za ogljikov dioksid. V nasprotnem primeru pa govorimo o ekosistemih, ki predstavljajo vir ogljikovega dioksida in porabnike organskega ogljika (Carignan et al. 2000).

VPLIV MAKROFITOV NA INTERAKCIJE FITOPLANKTONA IN BAKTERIJ

Velika prisotnost makrofitov je značilnost subtropskih plitvih jezer, kjer zaradi ugodne klime rastejo vse leto (Petr 2000). Zaradi visoke primarne proizvodnje makrofiti prispevajo velike količine organskih snovi v jezeru in po navadi celo presežejo primarno proizvodnjo alg (Wetzel 2001, Lauster et al. 2006). V nekaterih jezerih lahko makrofiti vzdržujejo velik del bakterijske proizvodnje (Stanley et al. 2003). Ker makrofiti v plitvih jezerih vplivajo tako na fitoplankton in bakterije (They et al. 2013) je pričakovano, da bodo vplivali tudi na interakcijo med fitoplanktonom in bakterijami. Povečanje biomase makrofitov je pozitivno povezano z razmerjem med bakterijami in fitoplanktonom (De Kluijver et al. 2015). Pozitivna povezanost pomeni, da se s povečanjem makrofitske prisotnost poveča bakterijska biomasa, ki je večja v primerjavi s fitoplanktonom. Večja bakterijska biomasa je verjetno posledica močnega negativnega vpliva makrofitov na fitoplankton. Na območjih z velikim vplivom makrofitov in nizko biomaso in proizvodnjo fitoplanktona, bakterijska proizvodnja verjetno temelji na starejših delih ali izločkih makrofitov (Wetzel & Søndergaard 1997, Rooney & Kalff 2003). Ta premik vira ogljika igra pomembno vlogo pri pojavu (Huss & Wehr 2004) in sestavi bakterioplanktonske združbe (Wu et al. 2007). V laboratorijskem poskusu, kjer so uporabili različne biomase makrofitov vrste dristavca *Potamogetom illinoensis*, bakterijska gostota in biomasa nista bili povezani s koncentracijo klorofila *a*, ampak z razpoložljivostjo ogljika in biomaso makrofitov. Koncentracija uporabljenega raztopljenega organske ogljika (DOC) pri bakterijah je izvirala iz obeh: vrste *P. illinoensis* in perifitonske združbe na dristavcu (Canterle 2011). They et al. (2013) so ugotovili, da je raztopljen organski ogljik, ki izvira iz makrofitov, še posebej pomemben za bakterije v litoralu jezer.

PRODUKTIVNOST JEZER

Makrofiti iz vodnega stolpca ali sedimenta pridobivajo hranila. Hranila so bistvena za zagotavljanje primarne produkcije, ki je izhodišče vsem ostalim trofičnim nivojem v ekosistemu. S primerno količino hranil in posledično ustrezajočo primarno produkcijo, se vzdržuje naravna dinamika ekosistema (Cis 2005). Negativni vplivi zelo velike vsebnosti hranil v vodnih ekosistemih so cvetenje strupenih alg, večja rast epifitskih alg, rast makro alg, izguba potopljene vegetacije zaradi senčenja, razvoj hipoksije (anoksičnih razmer) zaradi razgradnje organske biomase in spremembe v sestavi združb vodnih organizmov zaradi pomanjkanja kisika ali prisotnosti strupenih fitoplanktonskih vrst (Revilla et al. 2009).

Produktivnost znotraj celinskih voda je določena z različnimi dejavniki in kontrolnimi mehanizmi, ki delujejo na različnih prostorskih ravneh (Wetzel 2001). Osnovna lastnost vseh ekosistemov je stalno spreminjanje, razvoj in podvrženost sukcesiji. Razvoj jezera običajno poteka v smeri od nizke k visoki produktivnosti, vendar imajo lahko jezera obraten razvoj. S prehodom oligotrofnega jezera v evtrofično stanje se spremenijo značilnosti ekosistema (Rohlich 1969). Zato so oligotrofni ekosistemi posebnega pomena za raziskave o virih hranil in strategijah za preživetje makrofitov. V takšnih jezerih se ustvarjajo oblaki z veliko gostoto fitoplanktona, ki so soodvisni od prisotnosti makrofitov v litoralnih območjih (Fragoso et al. 2008). Razporeditev, številčnost in odziv fitoplanktona v plitvih jezerih brez makrofitov je drugačna od tistih, kjer so makrofiti prisotni (Moss 1990, Jasser 1995, O' Farrell et al. 2009).

Dejavniki, ki uravnavajo avtotrofno proizvodnjo in hitrost dekompozicije nastalih organskih snovi, vplivajo na nalaganje organskih snovi. Wetzel (2001) navaja, da avtohtona primarna proizvodnja temelji pretežno na planktonski združbi. Ko se poveča vsebnost hranil, pride v jezerskem ekosistemu do bistvenih sprememb. Razmere v vodnih ekosistemih, kjer prevladujejo makrofiti ter številne piscivore ribe, se s povečano koncentracijo hranil spremeni. Poveča se motnost vode, pojavi se velika gostota fitoplanktona in zmanjša gostota makrofitov (Søndergaard et al. 1990). Sočasno se s povečano količino hranil poveča biomasa rib, kjer prevladujejo ciprinidne ribe, še posebej vrsti rdečeoka (*Rutilus rutilus*) in ploščič (*Abramis brama*). Povečana biomasa zooplanktivornih rib se odraža v povečanem plenjenju zooplanktona in posledično zmanjšanje paše na fitoplanktonu. Povečana biomasa fitoplanktona zmanjša prodiranje svetlobe v nižje plasti vode. Povečano plenilstvo rib lahko zmanjša tudi število strgalcev (npr. polžev), ki se prehranjujejo z epifiti. Epifiti so pritrjeni na rastlinah in s preprečevanjem prodiranja svetlobe do rastlinskih delov spremenijo razmere za rast. Makrofiti lahko iz ekosistema izginejo in vir hrane za številne ptice se zmanjša. Rezultat je jezero z veliko biomaso ciprinidnih rib, veliko številčnostjo fitoplanktona, zmanjšano pristnostjo in številčnostjo potopljenih makrofitov in močno povečanim številom ptic, ki se prehranjujejo z ribami (Jeppesen et al. 2005).

Za prehod od velike kalnosti do prosojnosti vode sta značilni spremembi v prevladi skupini primarnih producentov in vrst v celotnem prehranjevalnem spletu. Namesto prevladujočega fitoplanktona postanejo prevladujoči primarni producenti submerzni makrofiti ali perifitonske alge (Scheffer et al. 1992, Vadeboncoeur et al. 2001, Liboriussen & Jeppesen 2003). Raziskovalci menijo, da se biomasa višjih prehranjevalnih ravni poveča zaradi učinkovitega prenosa energije v prehranjevalnem spletu. Svetloba v prosojni vodi lahko prodre do sedimenta in primarnih producentov, med tem ko je proizvodnja primarnih producentov v kalnih vodah omejena, bodisi zaradi hranil (zgornja plast vodnega stolpca) ali svetlobe (spodnje plasti vodnega stolpca in dno) (Wetzel 2001).

EKOLOŠKO STANJE

Evtrofikacija predstavlja enega poglavitnih problemov jezerskih ekosistemov (Nijboer & Verdonschot 2004). V mnogih jezerih prihaja do povečane produktivnosti, pogosto kot neposredna posledica povečanega vnosa hranil zaradi delovanja človeka (Bennett et al. 2001, Dong 2010). Termin »evtrofen« se tako nanaša na razmere, ko so naravne trofične razmere (vključno biološke) neuravnotežene zaradi antropogenih posegov (Cis 2005, Direktiva 2000). Makrofiti izboljšajo kakovost vode neposredno s proizvodnjo kisika in ponovno uporabo hranil ter posredno z zagotavljanjem površin algam, glivam in bakterijam (Holmes 1999). Vrstna sestava in številčnost makrofitov predstavljajo kakovost ekosistema kot celote. Iz tega razloga so makrofiti vključeni v Direktivo o vodah, in predstavljajo enega izmed štirih nepogrešljivih bioloških elementov za določanje ekološkega stanja jezer (Dodkins et al. 2005). Vodna direktiva uporablja vodne makrofite, njihovo vrstno sestavo in številčnost kot biološki element kakovosti po vsej Evropi. V skladu z direktivo bi morala podobna jezera imeti podobno sestavo združbe makrofitov, če so v podobnem ekološkem stanju. Okvirno, direktiva poudarja pomen vrstne sestave in številčnosti ampak dopušča svobodo pri izboru metodologije. V principu ocena stanja makrofitov temelji na odstopanju od referenčne skupine makrofitov, značilnih za določen tip vode. Indeksi služijo kot sredstva za količinsko prepoznavanje odstopanja od referenčnih razmer. Mnoge evropske države članice si prizadevajo za oblikovanje ocene stanja metod za jezera, ki temeljijo na združbah makrofitov (Pall & Moser 2009).

V Sloveniji so raziskovalci razvili Slovenski indeks za vrednotenje ekološkega stanja jezerskih ekosistemov na podlagi makrofitov (SMILE) (Pall et al. 2014, Metodologija Vrednotenja… 2016). Indeks je vrednotenje odziva predvsem na obremenitev jezer s hranili, v manjši meri pa tudi splošna degradacija. Indeks sestavljajo tri metrike: indeks makrofitov, maksimalna globina vegetacije, maksimalna globina har. S pomočjo tega indeksa se vodno telo uvrsti v razred ekološkega stanja po modulu trofičnosti na podlagi makrofitov. Makrofitska združba se na spremembe odziva s spremembo vrstne sestave in pogostosti posamezne vrste ter s spremembo globine, do katere se posamezne vrste še pojavljajo. V novih razmerah se gostota sestojev makrofitov spremeni razmeroma hitro, medtem, ko so spremembe v globinski razporeditvi in vrstni sestavi počasnejše, kar je zelo pomembno za vrednotenje izboljšanja stanja jezer (Metodologija Vrednotenja... 2016). Pri vodnih ekosistemih, ki so bogati s hranili, se pojavljajo težave pri ocenjevanju posledic vpliva človeka in spremembe trofičnega stanja (Bernez et al. 2004), saj se v jezerih z naraščajočo evtrofikacijo, makrofitske združbe pogosto odzovejo z velikim časovnim zamikom (Søndergaard et al. 2010).

ZAKLJUČEK

Makrofiti so vodni fotosintezni organizmi, vidni s prostim očesom. Predstavljajo pomemben element vodnih ekosistemov, saj omogočajo njihovo stabilnost. Na uspevanje makrofitov vplivajo abiotski in biotski dejavniki. Abiotski dejavniki so svetloba, temperatura, vodni tok, substrat, globina in oblika jezerske kotanje, izpostavljenost valovom in vetru ter kemizem vode. Med tem ko sta biotska dejavnika, ki vplivata na razporeditev in sestavo makrofitov v vodnem telesu, kompeticija in herbivorija. Makrofiti vplivajo na kemizem vode - znižajo ali povečajo koncentracijo hranil, povečajo vsebnost kisika in tako posredno vplivajo na živalstvo v vodnem okolju.

Številni raziskovalci obravnavajo vpliv evtrofikacije na makrofite kot primarne producente. V tovrstnih raziskavah so preučili tudi odnose in povezavo med makrofiti, fitoplanktonom in bakterijami. Proučevanje takšnih povezav prispeva k razumevanju procesov celotnega vodnega ekosistema. Vodne rastline so pokazatelji stanja in obremenitev v vodnih okoljih. Raziskave o makrofitih kot bioindikatorjih služijo kot izhodišče pri upravljanju z vodami.

SUMMARY

Macrophytes are important components of aquatic ecosystems (Flint & Madsen 1995, Luo et al. 2016), since they present links between sediment, water and atmosphere. By creating microhabitats for periphyton, fish eggs and shelter for many organisms, macrophytes contribute to higher biodiversity and greater heterogeneity of aquatic ecosystems (Laassen & Nolet 2007, Lampert & Sommer 2007). Macrophytes absorb nutrients from water and effectively purify water quality (Zhou et al. 2017). Additionally, they recycle nutrients when they die and decompose. They're involved in many ecosystems processes like biomineralisation, transpiration, release of biogenic gases and chemical precipitation (Carpented & Lodge 1986). Researchers discovered that macrophytes play an important role by contributing to available carbon in lakes (Hilt & Gross 2008). Macrophyte-derived carbon is a potential basal food source within food webs, thus macrophytes are crucial for lake ecosystem balance (Hutchninson 1975). Macrophytes have direct and indirect effects on lake ecosystems. Submergent macrophytes prevent erosion and movement of soft sediments, and reduce the resuspension of sediment in the water column (Madsen et al., 1996). Presence of floating plants can affect littoral and even pelagic food webs (Meerhoff & Mazzeo 2004). Macrophytes are commonly used for bioassessment, especially to assess human impacts on water ecosystems (Poikane et al. 2015).

Classification of macrophytes depends on their growth form and position in water column. Based on morphological characteristics and their position in lakes, we divide them in four basic groups: submerged, floating (natant) rooted macrophytes (Figures 1-3), floating (natant) unrooted and emergent macrophytes (Germ 2013). In addition to light, key abiotic factors influencing the growth of macrophytes include water temperature, flow, the depth and shape of lake basin, exposure to waves and wind, the nature of the lake sediment and water chemistry (Dar et al. 2014). Sediment is also one of the main factors, where researchers clearly distinguished between macrophyte communities on the sand with low nutrients and macrophyte communities that grow on clay with abundant nutrients (Selig et al. 2007). Due to the direct and indirect impacts of abiotic factors, the link between water chemistry and macrophyte's growth is not that clear (Pip 1989). However, macrophytes contribute large amounts of organic matter in the lake and usually exceed the primary production of algae (Wetzel 2001). Macrophytes in shallow lakes affect both the phytoplankton and bacteria and their interactions (They et al. 2013). Distribution, abundance and response of phytoplankton in shallow lakes without macrophytes is different from those in which the macrophytes are present (Moss 1990, O'farrell et al. 2009). When macrophytes are abundant in shallow lakes, significant changes appear in dominance of primary producers, and the shift from clear to turbid water occurs. Instead of macrophytes high densities of phytoplankton occur and instead of piscivorus fish, cyprinid fish dominate (Søndergaard et al. 1990). Eutrophication is one of the main stressors affecting lake ecosystems (Nijboer & Verdonschot 2004). The term "eutrophic" mostly refers to situations when the natural trophic conditions are unbalanced due to anthropogenic activities (Cis 2005, Direktiva 2000). Macrophytes improve the quality of water directly with production of oxygen and recycling of nutrients. Species composition and abundance of macrophytes can indicate the quality of the whole ecosystem. For this reason, macrophytes are included in the Water Framework Directive as one of the four biological elements for determination ecological status of lakes (Dodkins et al. 2005). In Slovenia, researchers developed a multimetric index evaluating ecological status of lakes based on macrophytes (SMILE) (Metodologija Vrednotenja… 2016). With their index, the primary evaluation is eutrophication and to a lesser extent general degradation. However, in nutrient reach lakes it is hard to assess the anthropogenic effect due to the slow response of macrophytes (Bernez et al. 2004). Research on macrophytes as bioindicators serves as a basis for water management plans, whereas research based on macrophytes and other biotic and abiotic factors contribute to understanding of aquatic ecosystems processes.

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LITERATURA - REFERENCES

Ali, M. M. & M. A. Soltan, 2006: *Expansion of Myriophyllum spicatum (Eurasian water milfoil) into Lake Nasser, Egypt: invasive capacity and habitat stability*. Aquatic Botany (Amsterdam) 84 (3): 239-244. http://doi.org/10.1016/j.aquabot.2005.11.002

Allan, J. D., 1995: *Structure and function of running waters*. Stream Ecology, Springer Science & Business Media, Dordrecht.

Bennett, E. M., S. R. Carpenter & N. F. Caraco, 2001: *Human Impact on Erodable Phosphorus and Eutrophication: A Global Perspective*. BioSicence (Oxford) 51 (3): 227-234. http://dx.doi.org/10.1641/0006-3568(2001)051[0227:HIOEPA]2.0.CO;2

Bernez, I., H. Daniel, J. Haury & M. T. Ferreira, 2004: *Combined effects of environmental factors and regulation on macrophyte vegetation along three rivers in Western France*. River Research and Applications (Hoboken) 20: 43-59. http://dx.doi.org/10.1002/rra.718

Blom, G., E. H. S. Van Duin & L. Lijklema, 1994: *Sediment resuspension and light conditions in some shallow Dutch lakes*. Water Science & Technology (London) 30 (10): 243-252.

Canterle, E. R. B., 2011: *Metabolismo mediado pelo bacterioplâncton em um lago raso subtropicale sua relação com a presença de macrófitas, sedimento e regime hídrico*. Ph.D. Thesis, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS.

Carignan, R., P. D'arcy & S. Lamontagne, 2000: *Comparative impacts of fire and forest harvesting on water quality in Boreal Shield lakes*. Canadian Journal of Fisheries and Aquatic Sciences (Ottawa) 57: 105-117. http://dx.doi.org/10.1139/cjfas-57-S2-105

Carpenter, S. R. & D. M. Lodge, 1986: *Effects of submersed macrophytes on ecosystem processes.* Aquatic Botany (Amsterdam) 26: 341-370. https://doi.org/10.1016/0304-3770(86)90031-8

Cerbin, S., E. Van Donk & R. D. Gulati, 2007: *The influence of Myriophyllum verticillatum and artificial plants on some life history parameters of Daphnia magna.* Aquatic Ecology (Amsterdam) 41: 263-271. http://dx.doi.org/10.1007/s10452-007-9091-5

Cis, Common Implementation Strategy for the Water Framework Directive, 2005: *Towards a Guidance Document on Eutrophication Assessment in the context of European water policies.* Interim document.

Cole, J. J., M. L. Pace, S. R. Carpenter & J. F. Kitchell, 2000: *Persistence of net heterotrophy in lake during nutrient and foob web manipulation*. Limnology and Oceanography (Hoboken) 45: 1718-1730. http://dx.doi.org/10.4319/lo.2000.45.8.1718

Dar, N. A., A. K. Pandit & B. A. Ganai, 2014: *Factors affecting the distribution patterns of aquatic macrophytes.* Limnological Review (Toruń) 14 (2): 75-81. https://doi.org/10.2478/limre-2014-0008

De Kluijver, A., J. Ning, Z. Liu, E. Jeppesen, R. D. Gulati & J. J. Middelburg, 2015: *Macrophytes and periphyton carbon subsidies to bacterioplankton and zooplankton in a shallow eutrophic lake in tropical China*. Limnology and Oceanography (Hoboken) 60: 375-385. http://dx.doi.org/10.1002/lno.10040

Direktiva 2000/60/ES Evropskega parlamenta in sveta Evrope, Directive of the European.

Dodds, W. K. & B. J. F. Biggs, 2002: *Water velocity attenuation by stream periphyton and macrophytes in relation to growth form and architecture.* Water Resources research (Hoboken) 43: 2-15. http://dx.doi.org/10.2307/1468295

Dodkins, I., B. Rippley & P. Hale, 2005: *An application of canonical correspondence analysis for developing ecological quality assessment metrics for river macrophytes.* Freshwater Biology (Hoboken) 50: 891-904. http://dx.doi.org/10.1111/j.1365-2427.2005.01360.x

Dong, H., H. Jiang, B. Yu & X. Liu, 2010: *Impacts of environmental change and human activity on microbial ecosystems on the Tibetan Plateau, NW China*. GSA Today Archive (Harrisonburg) 20 (6): 4-10. http://dx.doi.org/10.1130/GSATG75A.1

Flint, N. A. & J. D. Madsen, 1995: *Effect of temperature and daylength on the germination of Potamogeton nodosus tubers*. Journal of freshwater ecology (Abingdon) 10 (2): 125-128. http://dx.doi.org/10.1080/02705060.1995.9663426

Fox, A. M., 1992: *Macrophytes.* In: Calow P. & G. E. Petta (eds.). *The Rivers Handbook. Hydrological and ecological priciples.* Oxford.

Fragoso, C. R., D. M. L. Motta Marques, W. Collischonn, C. E. M. Tocci & E. H. Van Nes, 2008: *Modelling spatial heterogeneity of phytoplankton in Lake Mangueira, a large shallow subtropical lake in South Brazil*. Ecological Modelling (Amsterdam) 219: 125-137. http://doi.org/10.1016/j.ecolmodel.2008.08.004

Germ, M., 2013: *Biologija vodnih rastlin*. Učbenik, Ljubljana.

Gross, E. M., S. Hilt, P. Lombardo & G. Mulderij, 2007: *Searching for allelopathic effects of submerged macrophytes on phytoplankton- state of the art and open questions*. Hydrobiologia (Berlin) 584: 77-88. http://dx.doi.org/10.1007/s10750-007-0591-z

Handley, R. J. & A. J. Davy, 2002: *Seedling root establishment may limit Najas marina L. to sediment of low cohesive strength*. Aquatic Botany (Amsterdam) 73 (2): 129-136. http://doi.org/10.1016/S0304-3770(02)00015-3

Haslam, S. M., 2006. *River Plants. The Macrophytic Vegetation of Watercourses.* New York.

Hilt, S., 2006: *Allelopathic inhibition of epiphytes by submerged macrophytes*. Aquatic Botany (Amsterdam) 85 (3): 252-256. http://doi.org/10.1016/j.aquabot.2006.05.004

Hilt, S., M. G. N. Ghobrial & E. M. Gross, 2006: *In situ allelopathic potential of Myriophyllum verticillatum (Haloragaceae) against selected phytoplankton species*. Journal of Phycology (Hoboken) 42: 1189-1198. http://dx.doi.org/10.1111/j.1529-8817.2006.00286.x

Hilt, S. & E. M. Gross, 2008: *Can allelopathically active submerged macrophytes stabilise clear-water states in shallow eutrophic lakes?* Basic and Applied Ecology (Amsterdam) 9: 422-432. http://doi.org/10.1016/j.baae.2007.04.003

Holmes, N. T. H., 1999: *Recovery of headwater stream flora following the 1989-1992 groundwater drought.* Hydrological Processes (Hoboken) 13: 341-54. http://dx.doi.org/10.1002/(SICI)1099-1085(19990228)13:3<341::AID-HYP742>3.0.CO;2-L

Huss, A. A. & J. D. Wehr, 2004: *Strong indirect effects of a submersed aquatic macrophyte,Vallisneria americana, on bacterioplankton densities in a mesotrophic lake*. Microbial Ecology (Berlin) 47: 305-315. http://dx.doi.org/10.1007/s00248-003-1034-7

Hutchinson, G. E., 1975: *Limnological Botany.* New York.

Janauer, G. A. & P. Englmaier, 1986: *The effects of emersion on soluble carbohydrate accumulations in Hippuris vulgaris L.* Aquatic Botany (Amsterdam) 24 (3): 241-248. https://doi.org/10.1016/0304-3770(86)90060-4

Jasser, I., 1995: *The influence of macrophytes on a phytoplankton community in experimental conditions.* Hydrobiologia (Berlin) 306 (1): 21-32. http://dx.doi.org/10.1007/BF00007855

Jeppesen, E., M. Søndergaard, J. P. Jensen & T. L. Lauridsen, 2005: *Shallow Lakes: Effects of Nutrient Loading and How to Remedy Eutrophication. Vol. I. Oceans and aquatic ecosystems.* Encyclopedia of Life Support Systems (EOLSS). Paris.

Jürgens, K. & E. Jeppesen, 1998: *Cascading effects on microbial food web structure in a dense macrophyte bed. in the structuring role of submerged macrophytes in lakes.* In: Jeppesen, E., M. Søndergaard, M. Søndergaard & K. Christoffersen (eds.): *The Structuring Role of Submerged Macrophytes in Lakes.* New York. http://dx.doi.org/10.1007/978-1-4612-0695-8_16

Kantrud, H. A., 1990: *Sago Pondweed (Potamogeton pectinatus L.): A Literature Review.* Washington, DC.

Klaassen, M. & B. Nolet, 2007: *The role of herbivorous water birds in aquatic systems through interactions with aquatic macrophytes, with special reference to the Bewick's Swan-Fennel Pondweed system.* Hydrobiologia (Berlin) 584 (1): 205-213. http://dx.doi.org/10.1007/s10750-007-0598-5

Kuiper, J. J., M. J. J. M. Verhofstad, E. L. M. Louwers, E. S. Bakker, R. J. Brederveld, L. P. A. Van Gerven, A. B. G. Janssen, J. J. M. De Klein & W. M. Mooij, 2017: *Mowing Submerged Macrophytes in Shallow Lakes with Alternative Stable States: Battling the Good Guys?* Environmental Management (Berlin) 59 (4): 619-634. http://dx.doi.org/10.1007/s00267-016-0811-2

Lacoul, P. & B. Freedman, 2006: *Environmental influences on aquatic plans in freshwater ecosystems.* Environmental Reviews (Ottawa) 14 (2): 89-136.
http://dx.doi.org/10.1139/a06-001

Lampert, W. & U. Sommer, 2007: *Limnoecology: the Ecology of Lakes and Streams.* Oxford.

Lauster, G. H., P. C. Hanson & K. Kratz, 2006: *Gross primary production and respiration differences among littoral and pelagic habitats in northern Wisconsin lakes.* Canadian Journal of Fisheries and Aquatic Sciences (Ottawa) 63 (5): 1130-1141. http://dx.doi.org/10.1139/f06-018

Liboriussen, L. & E. Jeppesen, 2003: *Temporal dynamics in epipelic, pelagic and epiphytic algal production in a clear and a turbid shallow lake.* Freshwater Biology (Oxford) 48: 418–431.
http://dx.doi.org/10.1046/j.1365-2427.2003.01018.x

Lindner, A., 1987: *Soziologisch- ökologische Untersuchungen an der submersen Vegetation in der Boddenkette sudlich des Darß und Zingst.* Limnologica (Amsterdam) 11: 299-305.

Luo, J., X. Li, R. Ma, F. Li, H. Duan, W. Hu, B. Qin & W. Huang, 2016: *Applying remote sensing techniques to monitoring seasonal and interannual changes of aquatic vegetation in Taihu Lake, China.* Ecological Indicators (Amsterdam) 60: 503-513. http://doi.org/10.1016/j.ecolind.2015.07.029

Madsen, J. D., J. A. Bloomfield, J. W. Sutherland, W. L. Eichler & C.W. Boylen, 1996: *The aquatic macrophyte community of Onondaga Lake: field survey and plant growth bioassays of lake sediments.* Lake and Reservoir Management (Abingdon) 12: 73-79. http://dx.doi.org/10.1080/07438149609353998

Meerhoff, M. & N. Mazzeo, 2004: *Importancia de las plantas flotantes libres de gran porte en la conservación y rehabilitación de lagos someros de Sudamérica.* Revista Ecosistemas (Madrid) 13: 13-22.

Metodologija Vrednotenja Ekološkega Stanja Jezer Na Podlagi Fitobentosa In Makrofitov, 2016. Republika Slovenija, Ministrstvo za okolje in prostor, Ljubljana. http://www.mop.gov.si/fileadmin/mop.gov.si/pageuploads/podrocja/voda/ekolosko_stanje/metod_vredn_ekoloskega_st_jezer_fitobentosa_makrofitov.pdf

Moss, B., 1990: *Engineering and biological approaches to the restoration from eutrophication in which aquatic aquatic plant communities are important components.* Hydrobiologia (Berlin) 200 (1): 367-377. http://doi.org/10.1007/BF02530354

Mulderij, G., A. J. P. Smolders & E. Van Donk, 2006: *Allelopathic effect of the aquatic macrophyte, Stratiotes aloides, on natural phytoplankton.* Freshwater Biology (Hobok) 51: 554-561.
http://dx.doi.org/10.1111/j.1365-2427.2006.01510.x

Nijboer, R. C. & P. F. M. Verdonschot, 2004: *Variable selection for modelling effects of eutrophication on stream and river ecosystems.* Ecological modelling (Amsterdam) 177 (1-2): 17-39.
http://doi.org/10.1016/j.ecolmodel.2003.12.050

O’farrell, I., P. P. Tezanos, P. L. Rodriguez, G. Chaparro & H. N. Pizarro, 2009: *Experimental evidence of the dynamic effect of free-floating plants on phytoplankton ecology.* Freshwater Biology (Berlin) 54 (2): 363-375. http://dx.doi.org/10.1111/j.1365-2427.2008.02117.x

Pall, K. & V. Moser, 2009: *Austrian Index Macrophytes (AIM-Module 1) for lakes: a Water Framework Directive compliant assessment system for lakes using aquatic macrophytes.* Hydrobiologia (Berlin) 633: 83-104. http://dx.doi.org/10.1007/s10750-009-9871-0

Pall, K., V. Bertrin, F. Buzzi, S. Bountry, A. Dutartrem, M. Germ, A. Oggioni, J. Schaumburg & G. Urbanič, 2014: *Alpine Lake Macrophyte ecological assessment methods.* Water Framework Directive Intercalibration Technical Report, Luxembourg. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC88126/alpine%20lake%20macrophyte%20intercalibration.pdf

Peralta, G., T. J. Bouma, J. Van Soelen, J. L. Perez-Lorens & I. Hernandez, 2003: *On the use of sediment fertilization for seagrass restoration: a mesocosm study on Zostera marina L.* Aquatic Botany (Berlin) 75 (2): 95-110. http://doi.org/10.1016/S0304-3770(02)00168-7

Petr, T., 2000: *Interactions between fish and aquatic macrophytes in inland waters*. Rome.

Pilon, J. J., L. Santamaria, M. J. M. Hootsmans & W. Van Vierssen, 2003: *Latitudinal variation in life-cycle characteristics of Potamogeton pectinatus L.: vegetative and reproductive traits*. Plant Ecology (Berlin) 165 (2): 247-262. http://dx.doi.org/10.1023/A:1022252517488

Pip, E., 1989: *Water temperature and freshwater macrophyte distribution*. Aquatic Botany (Amsterdam) 34 (4): 367-373. https://doi.org/10.1016/0304-3770(89)90079-X

Poikane, S., S. Birk, J. Böhmer, L. Carvalho, C. De Hoyos, H. Gassner, S. Hellsten, M. Kelly, A. Lyche, M. Olin, K. Pall, G. Phillips, R. Portielje, D. Ritterbusch, L. Sandin, A. Schartau, A.G. Solimini, M. Berg, G.Wolfram & W. Van De, 2015: *A hitchhiker’s guide to European lake ecological assessment and intercalibration*. Ecological Indicators (Amsterdam) 52: 533-544. http://doi.org/10.1016/j.ecolind.2015.01.005

Revilla, M., J. Franco, J. Bald, Á. Borja, A. Laza, S. Seoane & V. Valencia, 2009: *Assessment of the phytoplankton ecological status in the Basque coast (northern Spain) according to the European Water Framework Directive.* Journal of Sea Research (Amsterdam) 6 (1-2): 60-67. http://doi.org/10.1016/j.seares.2008.05.009

Rohlich, G. A., 1969: *Eutrophication: Causes, Consequences, Correctives.* Washington.

Rooney, N. & J. Kalff, 2003: *Submerged macrophyte-bed effects on water-column phosphorus, chlorophyll a, and bacterial production*. Ecosystems (Berlin) 6 (8): 797-807. http://doi.org/10.1007/s10021-003-0184-2

Scheffer, M., M. R. De Redelijkheid & F. Noppert, 1992: *Distribution and dynamics of submerged vegetation in a chain of shallow eutrophic lakes.* Aquatic Botany (Amsterdam) 42 (3): 199-216. https://doi.org/10.1016/0304-3770(92)90022-BScheffer, M., 1998: *Ecology of Shallow Lakes.* London. https://doi.org/10.1007/978-1-4020-3154-0

Schultrope, C. D., 1967: *The Biology of Aquatic Vascular Plants.* London.

Selig, U., M. Schubert, A. Eggert, T. Steinhardt, S. Sagert & H. Schubert, 2007: *The influence of sediment on soft bottom vegetation in inner coastal waters of Mecklenburg-Vorpommern (Germany).* Estuarine, Coastal and Shelf Science (Amsterdam) 71 (1–2): 241-249. http://doi.org/10.1016/j.ecss.2006.07.015

Søndergaard, M., E. Jeppesen, E. Mortensen, E. Dall, P. Kristensen & O. Sortkjær, 1990: *Phytoplankton biomass reduction after planktivorous fish reduction in a shallow, eutrophic lake: a combined effect of reduced internal P-loading and increased zooplankton grazing.* Hydrobiologia (Berlin) 200 (1): 229-240. http://doi.org/10.1007/BF02530342

Søndergaard, M., L. S. Johansson, T. L. Lauridsen, T. B. Jørgensen, L. Liboriussen & E. Jeppesen, 2010: *Submerged macrophytes as indicators of the ecological quality of lakes.* Freshwater Biology (Hoboken) 55 (4): 893-908. http://dx.doi.org/10.1111/j.1365-2427.2009.02331.x

Stanley, E. H., M. D. Johnson & A. K. Ward, 2003: *Evaluating the influence of macrophytes on algal and bacterial production in multiple habitats of a freshwater wetland*. Limnology and Oceanography (Hoboken) 48 (3): 1101-1111. http://dx.doi.org/10.4319/lo.2003.48.3.1101

Sudnitsyna, D. N., 2015: *Anthropogenic Impact on the Macrophytes of Pskov Region Alkalitrophic Lakes.* Environment. Technology. Resources. Proceeding of the 10th International Scientific and Practical Conference 2 (Rezekne) 2: 303-306. http://dx.doi.org/10.17770/etr2015vol2.248

They, N. H., D. M. Marques, R. S. Souza & L. R. Rodrigues, 2013: *Short-term photochemical and biological unreactivity of macrophyte-derived Dissolved Organic Matter in a subtropical shallow lake.* Journal of Ecosystems (Berlin) 2013: 1-9. http://dx.doi.org/10.1155/2013/316709

Vadeboncoeur, Y., D. M. Lodge & S. R. Carpenter, 2001: *Whole-lake fertilization effects on distribution of primary production between benthic and pelagic habitats.* Ecology (Hoboken) 82 (4): 1065-1077. http://doi.org/10.2307/2679903

Wetzel R. G. & M. Søndergaard, 1997: *Role of submersed macrophytes for the microbial community and dynamics of dissolved organic carbon in aquatic ecosystems. In The Structuring Role of Submerged Macrophytes in Lakes*. Ecological Studies (Berlin) 131: 133-148. http://doi.org/10.1007/978-1-4612-0695-8_7

Wetzel, R. G., 2001: *Limnology*, 3rd ed. Orlando.

Wu, Q. L., G. Zwart, J. Wu, M. P. Agterveld, S. Liu & M. W. Hahn, 2007: *Submersed macrophytes play a key role in structuring bacterioplankton community composition inthe large, shallow, subtropical Taihu Lake, China.* Environmental Microbiology (Hoboken) 9 (11): 2765-2774.

Zelnik, I., M. Potisek & A. Gaberščik, 2012: *Environmental Conditions and macrophytes of Karst Ponds.* Polish Journal of Environmental Studies (Olsztyn) 21 (6): 1911-1920.

Zhou, Y., X. Zhou, R. Han, X. Xu, G. Wang, X. Liu, F. Bi & D. Feng, 2017: *Reproduction capacity of Potamogeton crispus fragments and its role in water purification and algae inhibition in eutrophic lakes.* Science of the total environment (Amsterdam) 580: 1421-1428. http://dx.doi.org/10.1016/j.scitotenv.2016.12.108

Slika 1: Vodni orešek (Trapa natans). Zadrževalnik Medvedce.
Figure 1: Water caltrop (Trapa natans). Accumulation Medvedce.

Slika 2: Beli lokvanj (Nymphaea alba). Zadrževalnik Medvedce.
Figure 2: European white water lily (Nymphaea alba). Accumulation Medvedce.

Slika 3: Rumeni blatnik (Nuphar luteum). Škalsko jezero
Figure 3: Nuphar luteum. Lake Škalsko jezero.

CULTIVABLE BACTERIAL MICROBIOTA FROM CHOANAE OF FREE-LIVING BIRDS CAPTURED IN SLOVENIA

KULTIVABILNA BAKTERIJSKA MIKROBIOTA IZ SAPIŠČ PROSTOŽIVEČIH PTIC, UJETIH V SLOVENIJI

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ABSTRACT

Cultivable bacterial microbiota from choanae of free-living birds captured in Slovenia

We have analysed the structure of cultivable choanal microbiota from free-living birds in relation to bird diet, its richness and the relative number of opportunistic bacteria acquired from the environment. For this purpose, we have taken choanal swabs from 25 free-living birds representing 13 different bird species captured in Slovenia. From the grown cultures, 98 bacterial colonies were isolated and their 16S rRNA genes sequenced. Most of the bacteria belonged to the phylum Actinobacteria (52 %), Proteobacteria (31 %), Firmicutes (15 %) and Bacteroidetes (4 %). Thirty-two percent of sampled birds were colonized by known human opportunists and 44 % of birds by at least one known plant pathogen. Hierarchical clustering of the analyzed microbiota grouped the birds according to their predominant diet. The richness of choanal microbiota from birds feeding mainly on insects was poorer compared to the birds feeding on diverse animal and plant material. The study has shown that the free-living birds carry an important reservoir of opportunistic human and plant pathogenic bacteria in their upper respiratory tract. To get a deeper insight into its composition, a bigger pool of birds will have to be analyzed in the future.

Keywords: birds, microbiota, choanae, pathogenic bacteria, diet

IZVLEČEK

Kultivabilna bakterijska mikrobiota iz sapišč prostoživečih ptic, ujetih v Sloveniji

Sestavo kultivabilne bakterijske mikrobiote v sapiščih prostoživečih ptic smo analizirali z vidika vpliva prehrane, bogatosti mikrobiote in prisotnosti oportunističnih bakterij. Petindvajsetim prostoživečim pticam, ki so bile ujete v Sloveniji in so pripadale 13 vrstam, smo odvzeli bris sapišča. Po nacepitvi brisov na mikrobiološka gojišča in gojenju, smo izolirali 98 bakterijskih kolonij in jim določili nukleotidno zaporedje gena za 16S rRNK. Večina izoliranih bakterij je pripadala deblu Actinobacteria (52 %), Proteobacteria (31 %), Firmicutes (15 %) in Bacteroidetes (4 %). Pri približno eni tretjini ptic (32 %) smo iz sapišča izolirali vsaj eno oportunistično bakterijsko vrsto, ki lahko povzroča okužbe pri ljudeh. Pri slabi polovici ptic (44 %) pa smo v sapišču našli vsaj eno bakterijsko vrsto, ki lahko okuži rastline. Z metodo hierarhičnega združevanja smo pokazali, da imajo ptice s podobno prehrano, podobno bakterijsko mikrobioto sapišč. Ptice, ki se prehranjujejo pretežno z žuželkami so imele manj bogato mikrobioto kot ptice, ki se prehranjujejo z bolj raznoliko živalsko in rastlinsko hrano. Raziskava je tudi pokazala, da so zgornja dihala prostoživečih ptic pomemben rezervoar oportunističnih bakterij, ki lahko okužijo ljudi in rastline. Da bi dobili globji vpogled v sestavo mikrobiote zgornjih dihal, bi v prihodnosti morali povečati število analiziranih ptic.

Ključne besede: ptice, mikrobiota, sapišče, patogene bakterije, prehrana

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1 INTRODUCTION

Free-living birds are recognized vectors for spreading pathogenic bacteria across long distances with well-known transmission of various respiratory infections to humans (Murthy et al. 2008, Pan et al. 2012, Tsiodras et al. 2008). Despite of this, our knowledge on the avian respiratory tract microbiota is very limited. While some data exist for the lower respiratory tract, almost nothing is known about the bacteria living in the upper respiratory regions.

Data on microbiota of the lower respiratory tract in domestic birds have shown that it harbors potentially pathogenic bacteria. Majority of cultured bacteria found in the lungs and trachea of birds belonged to phyla Proteobacteria, Firmicutes, Tenericutes, Actinobacteria, Bacteroidetes and Chlamydia/Verrucomicrobia (Murthy et al. 2008, Charlton et al. 1993, Byrum & Slemons 1995). Additionally, culture independent analyses detected groups of fastidious or poorly represented taxons belonging to Fusobacteria, Acidobacteria, Chloroflexi, Cyanobacteria and Deinococcus -Thermus in the lower respiratory tract of poultry. Among them were also potential pathogens (*Myroides* spp., *Collinsella aerofaciens*, *Bacteroides fragilis, Enterococcus cecorum, Kurthia zopfii, Kushneria* sp. and *Bordetella* sp.) (Shabbir et al. 2015). Even though the pathogen *Riemerella* sp. has been isolated from the upper respiratory tract of some species of domestic and free-living birds (Vancanneyt et al. 1999), a deeper insight into the structure of the upper respiratory microbiota in birds is lacking. Thus far, a very limited number of research attempted to analyze the bacterial composition of the upper respiratory tract in free-living birds, besides, they used selective media for culturing specific groups of pathogenic bacteria, and thus substantially limiting the overall view on microbial diversity of the upper respiratory tract (Lamberski et al. 2003, Stenkat et al. 2014). In such a way, Lamberski et al. (2003) analyzed two species of hawks which harbored pathogens like *Salmonella* sp. and *Pasteurella* sp.. Stenkat et al. (2014) focused more on water birds and also found potential avian and human pathogens (*Klebsiella pneumoniae*, *Escherichia coli* and *Pseudomonas aeruginosa* among others).

More knowledge about the microbiota of the upper respiratory tract of birds is necessary for better understanding the influence, positive or negative, of this microbiome on animal health and the risks of spreading potential infections between free-living birds, in the environment and subsequently to humans (Waldenstrom et al. 2003, Abulreesh et al. 2007).

2 MATERIALS AND METHODS

Bird sampling, culturing of bacteria and identification

All of the 25 healthy adult birds included in this study were captured in fine mist nets for bird ringing during fall, between September 18 and December 10, 2013 in Maribor and its surroundings (Slovenia). The birds were caught in the frame of bird ringing scheme coordinated by EURING.

Choanal swabs (pre moistened with sterile saline) were immediately taken from each bird and put in a transport medium (Amies agar gel medium transport swabs – no charcoal, Copan) until further processing. All samples were sent to the laboratory within 2 to 3 hours after sampling and inoculated on nutrient agar (NA, Sigma). Inoculated plates were incubated 4 - 7 days at 30°C. After incubation, each colony morphotype per bird was isolated and stored at -80°C until further processing. Colony morphotypes were differentiated based on form, margin and pigmentation of the colonies.

Total DNA was isolated and cleaned using a commercial kit (NucleoSpin Tissue, Macherey-Nagel). Full lengths of 16S rRNA genes were amplified with PCR. The final concentrations of the PCR reaction mix contained 0.2 mM dNTP (Thermo Scientific), 1x PCR buffer with KCl (Thermo Scientific), 2.5 mM $MgCl_2$ (Thermo Scientific), 1.0 µM of forward primer (5'-AAA TTG AAG AGT TTG ATC ATG GC-3'), 1.0 µM of reverse primer (5'-AAG GAG GTG ATC CAG CCG CA-3') and 0.025 units/µL of *Taq* polymerase (Thermo Scientific). Amplicons were obtained using the following PCR protocol: initial denaturation at 95°C for 5 min followed by 30 cycles of denaturation at 95°C for 30 s, annealing at 56°C for 30 s and elongation at 72°C for 1.5 min, followed by a final extension at 72°C for 10 min. The PCR product was purified with a commercial kit (GeneJET PCR Purification Kit, Thermo Scientific) and sequenced (Eurofins Genomics). The obtained sequences were compared to EMBL/GenBank/DDBJ databases and identified using BLAST. The closest hits to type strains, with 98.7 or higher % similarity, were identified at species level. In case of two or more different hits with similarity score above 98.7 %, the isolate was identified at the genus level.

Hierarchical clustering

Ward method with Euclidian distances was used for the clustering of the choanal microbiota of the investigated birds, for which the data on the presence or absence of bacterial species were included in the analysis.

Statistical analysis

To test the differences in the presence of microbial groups between different species of birds, we used Fisher's exact test, where $P < 0.05$ was considered significant. Where the differences in the frequencies of microbial groups were significant, odds ratio was calculated ($P < 0.05$).

The differences in species richness between the groups of birds were tested with Student - T test, $P < 0.05$ was considered significant.

3 RESULTS AND DISCUSSION

In this study we performed identification of bacteria isolated on a complex nutrient agar medium from birds' choanae with the aim to assess microbial diversity from this specific niche and find a possible correlation with birds' diet. For this, we have sampled 25 birds, from which 98 bacterial colonies were isolated and sequenced. The number of different bacterial species per bird ranged from 12 (Song thrush (*Turdus philomelos*) to 1 (Willow warbler (*Phylloscopus trochilus*)) (Table 1).

Table 1: Richness of choanal microbiota.
Preglednica 1: Bogatost mikrobiote sapišč.

Bird Species	Number of birds	Average number of different isolates per bird species
European robin (*Erithacus rubecula*)	4	2.8 ± 2.0[a]
Garden warbler (*Sylvia borin*)	1	4
Common reed bunting (*Emberiza schoeniclus*)	1	3
Willow warbler (*Phylloscopus trochilus*)	1	1
Dunnock (*Prunella modularis*)	4	2.5 ± 1.1[a]
Common redstart (*Phoenicurus phoenicurus*)	1	5
Common chiffchaff (*Phylloscopus collybita*)	1	3
Yellowhammer (*Emberiza citrinella*)	1	4
Eurasian blackcap (*Sylvia atricapilla*)	2	2.5 ± 1.5[a]
Song thrush (*Turdus philomelos*)	1	12
Pigeon (*Columba livia*)	4	3.3 ± 2.3[a]
Common chaffinch (*Fringilla coelebs*)	1	10
Eurasian tree sparrow (*Passer montanus*)	3	5.7 ± 1.9[a]

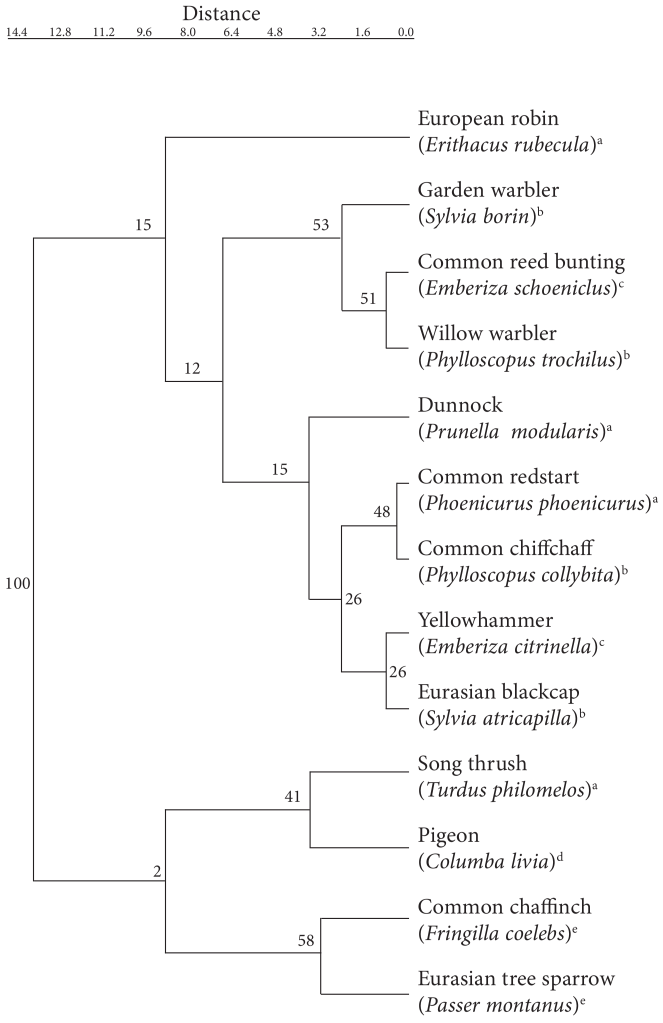
[a], standard deviation

Majority of isolates belonged to phyla Actinobacteria (52 %) and Proteobacteria (31 %). The phyla Firmicutes and Bacteroidetes were represented by only 15 % and 4 %, respectively. The isolates belonged to 22 families. The majority constituted families Microbacteriaceae (36 %), Pseudomonadaceae (11 %), Enterobacteriaceae (10 %), Micrococcaceae (7 %), Flavobacteriaceae, Xanthomonadaceae and Staphylococcaceae (all 4 %). Other families were found only sporadically. Of 13 different bird species, which have been sampled, 85 % were colonized with members of Microbacteriaceae. Pseudomonadaceae, Nocardiaceae and Enterobacteriaceae were found in 38 %, 31 % and 31 % of bird species, respectively. Xanthomonadaceae, Moraxellaceae, Staphylococcaceae were found in 23 % and Micrococcaceae in 15 % of analyzed bird species. Other isolates were found only per single bird. Although two previous studies analyzed choanal swabs from birds, there are some substantial differences in experimental approaches in comparison to our study and also in the birds analyzed. Lamberski et al. (2003) analyzed choanal swabs from captive and free-living red-tailed and Cooper's hawks, but the samples were grown on blood and MacConkey media. In this way they found the microbiota to be composed of *Bacillus* sp., *Corynebacterium* sp., *Escherichia* sp., *Salmonella* sp., *Pasteurella* sp., *Streptococcus* sp. and coagulase positive and negative staphylococci. Since we have performed the isolation on a complex nutrient medium in order to detect a wider range of environmental bacteria our results only partially overlapped. We have also isolated the genus *Bacillus* sp. and coagulase negative staphylococci, but otherwise the choanal microbiota of our birds greatly differed. This can be explained also by the fact that we have sampled different species of birds, with different diets (Cooper's hawk feeds exclusively on small and mid-sized birds and red-tailed hawk is opportunistic carnivorous feeder) and in different geographical locations (Slovenia vs. Unites States). The other group, Stenkat et al. (2014) used blood, MacConkey and Briliant green agar to investigate pharyngeal bacterial microbiota in water rails, spotted crakes, barn swallows, mute swans, reed warblers and black cormorants, and found numerous ubiquitous bacteria belonging predominantly to Enterobacteriaceae, Pseudomonadaceae, Aeromonadaceae, Bacillaceae, Staphylococcaceae and Streptococcaceae which are frequently present in the environment and on food. We have also found members of the forementioned bacterial families, except the family Aeromonadaceae, which is more associated with water habitats and the family Streptococcaceae, which was absent in our study, possibly due to different growth media (nutrient agar as opposed to blood agar).

Out of 98 isolates from choanal swabs, 13 (13.3 %) have been known to cause opportunistic infections in humans. Species previously described as being associated with human infections were *Acinetobacter calcoaceticus* (Nonaka et al. 2014), *Cellulosimicrobium funkei* (Petkar et al. 2011), *Curtobacterium citreum* (Rivera et al. 2012), *Curtobacterium flaccumfaciens* (Francis et al. 2011), *Exiguobacterium sibiricum* (Tena et al. 2014), *Hafnia alvei* (Gunthard & Pennekamp 1996), *Microbacterium oleivorans* (Kim & Lee 2012), *Microbacterium resistens* (Panackal 2013), *Pantoea agglomerans* (Rezzonico et al. 2010), *Pseudomonas aeruginosa* (Yamazaki et al. 2012), *Serratia grimesii* (Kumar et al. 2013), *Staphylococcus epidermidis* (Vuong & Otto 2002) and *Staphylococcus gallinarum* (Tibra et al. 2010). Eight out of 25 (32 %) sampled birds carried one or more human opportunistic bacteria in their choanae. Five out of 25 (20 %) birds were colonized by one, two birds were simultaneously colonized by two opportunists and the song thrush (*Turdus philomelos*) by three different putative pathogens. Pigeons also seemed to be frequent carriers of potential pathogens. Three out of four sampled pigeons were colonized by *Staphylococcus gallinarum* (in our study found only in pigeons) and the fourth bird was colonized by *Acinetobacter calcoaceticus*. Two out of three sampled eurasian tree sparrows which, as pigeons, also live in close proximity to humans, also carried opportunists (*Curtobacterium citreum*, *Curtobacterium flaccumfaciens* and *Exiguobacterium sibiricum*) in choanal microbiota.

In addition to human opportunistic bacteria, 7 potential plant pathogens were also isolated from choanae of 11 (44 %) sampled birds. These were *Agrobacterium larrymoorei* (Bouzar & Jones 2001), *Clavibacter michiganensis* (Xu et al. 2010), *Curtobacterium flaccumfaciens* (Francis et al. 2011), *Plantoea agglomerans* (Rezzonico et al. 2010), *Pseudomonas aeruginosa* (Yamazaki et al. 2012), *Pseudomonas flavescens* (Fett, Cescutti & Wijey 1996) and *Rhodococcus fascians* (Crespi et al. 1992). Ten (40 %) birds were colonized by one plant pathogen and only one tree sparrow by two (*Agrobacterium larrymoorei* and *Curtobacterium flaccumfaciens*). The most frequently isolated plant pathogen was *Rhodococcus fascians*, which was isolated from four different birds belonging to four different species (Eurasian tree sparrow, Common chaffinch, Yellowhammer and Dunnock) with different feeding habits (seeds/insects, seeds/insects, insects and insects), respectively. This suggests that it is commonly present in bird population.

Previous investigations have shown that the composition of intestinal microbiota in birds depends on



	DIET (winter)	DIET (breeding season)	DIET (summer)	DIET (autumn)
European robin (*Erithacus rubecula*)[a]	insects / seeds / fruit	insects	insects	insects
Garden warbler (*Sylvia borin*)[b]	berries	insects	berries	berries
Common reed bunting (*Emberiza schoeniclus*)[c]	seeds	invert.[f]	seeds	seeds
Willow warbler (*Phylloscopus trochilus*)[b]	insects	insects	insects	insects / berries
Dunnock (*Prunella modularis*)[a]	insects /seeds	insects	insects	insects
Common redstart (*Phoenicurus phoenicurus*)[a]	insects	insects	insects	insects
Common chiffchaff (*Phylloscopus collybita*)[b]	insects	insects	insects	insects
Yellowhammer (*Emberiza citrinella*)[c]	seeds	invert.[f]	seeds	seeds
Eurasian blackcap (*Sylvia atricapilla*)[b]	berries	insects	berries	berries
Song thrush (*Turdus philomelos*)[a]	invert.[f]	invert.[f]	invert.[f] / fruit	invert.[f] / fruit
Pigeon (*Columba livia*)[d]	invert.[f] / seeds / artif.[g]	invert.[f] / seeds / artif.[g]	invert.[f] / seeds / artif.[g]	invert.[f] / seeds / artif.[g]
Common chaffinch (*Fringilla coelebs*)[e]	seeds	invert.	seeds	seeds
Eurasian tree sparrow (*Passer montanus*)[e]	invert.[f] / seeds / berries	invert.[f] / seeds / berries	invert.[f] / seeds / berries	invert.[f] / seeds / berries

Figure 1: Clustering of sampled bird species based on bacterial (family level) composition of choanal microbiota. Top: Euclidian distance. Numbers at each node designate bootstrap value (bootstrap number 100). a (Cramp 1988); b (Cramp et al. 1992); c (Cramp & Perrins 1994); d (Cramp 1985); e (Cramp 1994); f (invertebrates); g (artificial man-made food).
Slika 1: Hierarhično združevanje vzorčenih vrst ptic glede na sestavo bakterijske (na nivoju družin) mikrobiote v sapiščih. Zgoraj: Evklidska razdalja. Številke pri razvejitvah so bootstrap vrednosti (število ponovitev 100). a (Cramp 1988); b (Cramp et al. 1992); c (Cramp & Perrins 1994); d (Cramp 1985); e (Cramp 1994); f (nevretenčarji); g (prehrana človeškega izvora).

Table 2: Identified bacterial isolates from choanae of free-living birds. The birds were grouped based on choanal microbiota composition with hierarchical clustering on group 1 (predominantly insectivorous birds) and group 2 (birds with mixed diet of invertebrates and seeds).
Preglednica 2: Identificirani bakterijski izolati iz sapišč prostoživečih ptic. Ptice smo s hierarhičnim zduževanjem združili v dve skupini, skupina 1 (pretežno žužkojede ptice) in skupina 2 (ptice z mešano prehrano sestavljeno iz nevretenčarjev in semen).

Bacterial isolates found in group 1	Bacterial isolates found in group 2	Bacterial isolates found in group 1 and 2
Aeromicrobium ponti/ *A. tamlense*	*Agrobacterium larrymoorei*	*Acinetobacter calcoaceticus*
Aeromicrobium sp. nov.[a]	*Agromyces terreus*	*Chryseobacterium indoltheticum*
Agrococcus versicolor	*Agromyces* sp. nov.[b]	*Frigoribacterium faeni*
Agromyces allii	*Arthrobacter aurescens*	*Microbacterium hydrocarbonoxydans/* *M. phyllosphaerae*
Bacillus aryabhattai	*Arthrobacter nitroguajacolicus/* *A. aurescens*	*Microbacterium phyllosphaerae*
Citrobacter gillenii	*Arthrobacter oxydans*	*Micrococcus* sp.
Clavibacter michiganensis	*Brochothrix campestris*	*Paenibacillus xylanexedens/* *P. amylolyticus/* *P. tundra*
Curtobacterium plantarum	*Cellulosimicrobium funkei*	*Pseudomonas flavescens*
Enterococcus plantarum	*Chryseobacterium daecheongense*	*Rathayibacter festucae*
Hafnia alvei	*Chryseobacterium* sp. nov.[c]	*Rhodococcus fascians*
Microbacterium hominis	*Curtobacterium citreum*	*Stenotrophomonas rhizophila*
Microbacterium oleivorans	*Curtobacterium flaccumfaciens*	
Microbacterium oxydans	*Exiguobacterium sibiricum*	
Microbacterium sp.	*Leucobacter exalbidus*	
Microbacterium xylanilyticum	*Microbacterium hydrocarbonoxydans*	
Micrococcus yunnanensis	*Microbacterium resistens*	
Ochrobactrum thiophenivorans	*Microbacterium testaceum*	
Pantoea agglomerans	*Oerskovia* sp.	
Pantoea anthophila	*Okibacterium fritillariae*	
Plantibacter flavus	*Pantoea agglomerans*	
Pseudomonas aeruginosa	*Pseudoclavibacter helvolus*	
Pseudomonas moraviensis	*Pseudomonas cedrina*	
Pseudomonas orientalis	*Pseudomonas extremorientalis*	
Pseudomonas psychrotolerans	*Pseudoxanthomonas koreensis*	
Sanguibacter keddieii	*Sphingobacterium faecium*	
Serratia grimesii	*Staphylococcus gallinarum*	
Staphylococcus epidermidis	*Staphylococcus* sp.	
Stenotrophomonas chelatiphaga		
Variovorax paradoxus		

[a,b,c,] potentially new species isolated from garden warbler (*Sylvia borin*)[a], song thrush (*Turdus philomelos*)[b] and Eurasian tree sparrow (*Passer montanus*)[c]

various factors, among them being the host species and feeding patterns. The differences extend to functional properties such as the greater capacity for amino acid metabolism and energy harvest in carnivores compared to herbivores (Waite & Taylor 2014). Therefore, since the gastrointestinal and respiratory tracts are connected, it is reasonable to assume that these factors also influence the composition of the respiratory microbiota. To assess the differences in the choanal microbiota of the sampled birds, we have performed hierarchical clustering which grouped the birds into two groups (Fig. 1). Choanal microbiota of the birds with similar diet grouped together. Birds which feed predominantly on insects or have more monotonous diet clustered in one group, those that have more mixed diet of animals (invertebrates) and seeds throughout the year formed a separate group (Fig. 1). The number of bacterial species was used to assess the difference in choanal microbiota richness between the two groups. The first group which contains the birds predominantly feeding on insects, or which have a more monotonous diet in general, had a significantly lower average number of species (2.9 ± 1.6) in comparison to birds enjoying a more mixed diet of animals and plants throughout the season (7.8 ± 3.4) ($P = 0.0002$) (Table 1). The choanal microbiota differed between the two groups not only in terms of species richness, but also in terms of bacterial composition. Majority of isolates were found in only one of the two groups of birds (29 – the first group, 27 – the second group) and only 11 bacterial species colonized choanae of birds belonging to both groups (Table 2).

Stenkat et al. (2014) have previously found correlations between certain bacterial families and feeding habits, although they targeted specific pathogenic groups of bacteria. Enterobacteriaceae and Aeromonadaceae were correlated to piscivores, Staphylococcaceae and Streptococcaceae to aerial insectivores, and Pseudomonadaceae and Bacillaceae to herbivores. Our findings corroborate this, as hierarchical clustering grouped the choanal microbiota of the sampled birds into two groups based on the bird diet.

When comparing the presence or absence of individual bacterial species, pigeons showed to be far more likely colonized with *Staphylococcus gallinarum* than other sampled birds (Fisher's exact test ($P = 0.013$); odds ratio (pigeons/other birds) = 31.5, $P = 0.012$). Furthermore, the presence of the genus *Staphylococcus* sp. was indicative of the birds with a more diverse diet throughout the season; these birds also clustered in one of the two groups (Fig. 1, Fisher's exact test ($P = 0.040$); odds ratio (second group/first group) = 12.0; $P = 0.044$).

Apart from finding numerous human and plant opportunists, we have also isolated one novel species from garden warbler (*Sylvia borin*) (*Aeromycrobium choanae* sp. nov.) (Ber et al. 2017), and two potentially novel species from song thrush (*Turdus philomelos*) (*Agromyces* sp., 16S rRNA gene sequence similarity < 97 %) and Eurasian tree sparrow (*Passer montanus*) (*Chryseobacterium* sp., 16S rRNA sequence similarity < 98.7 %). Their description is part of ongoing research.

4 CONCLUSIONS

Our study has shown that the choanal microbiota of free-living birds with a diet composed predominantly of insects, or with a generally monotonous diet, was poorer in terms of species richness, compared to birds with a more diverse diet during the year. Previously, correlation between selected bacterial families and diet has been determined, however our analyses have shown that the differences in microbiota extend beyond selected bacterial families. Hierarchical clustering of bacteria showed a correlation between the birds feeding patterns and the upper respiratory microbiota composition. Our study has also shown that free-living birds carry a wide array of known human and plant pathogens in their upper respiratory tract, but also possible novel species. Given the impact microbiota has on the bird´s health and bird´s potential for spreading pathogens in the environment, it will be necessary to extend the analysis of choanal microbiota and factors that shape its structure, on more free-living bird species.

5 POVZETEK

Da bi ocenili mikrobno diverziteto v sapiščih prostoživečih ptic, smo 25 pticam odvzeli brise sapišč, ki smo jih nacepili na hranilni agar. Po gojitvi smo izolirali 98 bakterijskih kolonij in jih na podlagi nukleotidnega zaporedja za 16S rRNK identificirali. Število različnih bakterijskih izolatov pri posamezni ptici se je gibalo med 12 (cikovt, *Turdus philomelos*) in 1 (severni kovaček, *Phylloscopus trochilus*). Večina izolatov je pripadala deblom Actinobacteria (52 %), Proteobacteria (31 %), Firmicutes (15 %) in Bacteroidetes (4 %). Izolati so večinoma pripadali družinam Microbacteriaceae (36 %), Pseudomonadaceae (11 %), Enterobacteriaceae (10 %), Micrococcaceae (7 %), in Flavobacteriaceae, Xanthomonadaceae in Staphylococcaceae (vse 4 %). Največ ptic (11) je bilo koloniziranih z bakterijami, ki so pripadale družini Microbacteriaceae, nato Pseudomonadaceae (pet ptic), Nocardiaceae (štiri ptice), Enterobacteriaceae (štiri ptice), Xanthomonadaceae (tri ptice), Moraxellaceae (tri ptice), Staphylococcaceae (tri ptice) in Micrococcaceae (dve ptici). Ostale družine bakterij smo detektirali le pri posamezni ptici.

Od skupno 98 bakterijskih izolatov, smo našli 13 (13,3 %) takih, ki lahko povzročajo okužbe pri ljudeh: *Acinetobacter calcoaceticus, Cellulosimicrobium funkei, Curtobacterium citreum, Curtobacterium flaccumfaciens, Exiguobacterium sibiricum, Hafnia alvei, Microbacterium oleivorans, Microbacterium resistens, Pantoea agglomerans, Pseudomonas aeruginosa, Serratia grimesii, Staphylococcus epidermidis* in *Staphylococcus gallinarum*. Pri osmih pticah (32 %) smo v sapišču našli vsaj eno oportunistično bakterijo. Petina ptic je bila koloniziranih z eno, dve ptici z dvema, cikovt pa hkrati s tremi oportunističnimi vrstami bakterij. Tudi ptice urbanih okolij (golob in domači vrabec) so bile kolonizirane s človeškimi oportunisti. Golobi s *Staphylococcus gallinarum* in *Acinetobacter calcoaceticus*, vrabci pa s *Curtobacterium citreum*, *Curtobacterium flaccumfaciens* in *Exiguobacterium sibiricum*.

Poleg oportunističnih bakterij, ki povzročajo okužbe pri ljudeh, smo pri 44 % vzorčenih ptic našli bakterije, ki so patogene za rastline: *Agrobacterium larrymoorei, Clavibacter michiganensis, Curtobacterium flaccumfaciens, Plantoea agglomerans, Pseudomonas aeruginosa, Pseudomonas flavescens* in *Rhodococcus fascians*. Največkrat smo detektirali bakterijo *Rhodococcus fascians*, ki je bila prisotna pri štirih različnih vrstah ptic (domači vrabec, ščinkavec, rumeni strnad in siva pevka). Prvi dve vrsti se prehranjujeta z raznovrstno hrano sestavljeno iz semen in žuželk, zadnji dve pa pretežno z žuželkami, kar bi lahko pomenilo, da je bakterija med pticami splošno prisotna.

Na sestavo in delovanje črevesne mikrobiote pri pticah vplivajo različni dejavniki, kot sta vrsta gostitelja in vrsta hrane (mesojedci/rastlinojedci). Ker so prebavila in dihala povezana, ti dejavniki verjetno vplivajo tudi na sestavo in delovanje mikrobiote v dihalih. Z metodo hierarhičnega združevanja smo ptice na podlagi sestave bakterijske mikrobiote sapišč združili v dve skupini. V prvi skupini so bile pretežno žužkojede ptice, v drugi pa ptice z bolj raznovrstno prehrano rastlinskega in živalskega izvora. Tudi bogatost mikrobiote, ki smo jo ocenili na podlagi števila prisotnih bakterijskih vrst, je med obema skupinama ptic bila različna. Pri žužkojedih pticah smo zaznali manjše število vrst (2,9 ± 1,6) v primerjavi s pticami, ki se hranijo z bolj raznovrstno hrano živalskega in rastlinskega izvora (7,8 ± 3,4) (P = 0,0002). Obe skupini ptic sta imeli tudi različno sestavo mikrobiote, saj smo večino bakterijskih vrst našli le pri eni ali drugi skupini (29 bakterijskih vrst pri žužkojedih pticah, 27 bakterijskih vrst pri pticah z raznoliko prehrano) in le 11 bakterijskih vrst smo detektirali pri obeh skupinah ptic. Pri vrtni penici (*Sylvia borin*), cikovtu (*Turdus philomelos*) in vrabcu (*Passer montanus*) smo v sosledju našli tudi novo in dve domnevno novi vrsti bakterij; *Aeromycrobium choanae* sp. nov., *Agromyces* sp. in *Chryseobacterium* sp..

Z metodo hierarhičnega združevanja smo pokazali, da imajo ptice s podobno prehrano, podobno bakterijsko mikrobioto sapišč. Ptice, ki se prehranjujejo pretežno z žuželkami, so imele manj bogato mikrobioto kot ptice, ki se prehranjujejo z bolj raznoliko živalsko in rastlinsko hrano. Raziskava je tudi pokazala, da so zgornja dihala prostoživečih ptic pomemben rezervoar oportunističnih bakterij, ki lahko okužijo ljudi in rastline, in tudi novih vrst bakterij. Da bi dobili globji vpogled v sestavo mikrobiote zgornjih dihal, bi v prihodnosti morali povečati število analiziranih ptic.

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REFERENCES - LITERATURA

Abulreesh, H. H., R. Goulder & G. W. Scott, 2007: *Wild birds and human pathogens in the context of ringing and migration*. Ringing Migration. (Oxford) 23: 193–200. http://dx.doi.org/10.1080/03078698.2007.9674363

Ber, P., S. Van Trappen, P. Vandamme & J. Trček, 2017: *Aeromicrobium choanae sp. nov., an actinobacterium isolated from the choana of a garden warbler.* Int. J. Syst. Evol. Microbiol. (Reading) 67: 357-361. https://doi.org/10.1099/ijsem.0.001632

Bouzar, H. & J. B. Jones, 2001: *Agrobacterium larrymoorei sp. nov., a pathogen isolated from aerial tumours of Ficus benjamina*. Int. J. Syst. Evol. Microbiol. (Reading) 51: 1023-1026. https://doi.org/10.1099/00207713-51-3-1023

Byrum, B. R. & R. D. Slemons, 1995: *Detection of proteolytic bacteria in the upper respiratory-tract flora of poultry*. Avian. Dis. (Ithaca) 39: 622-626. https://doi.org/10.2307/1591817

Charlton, B. R., S. E. Channing-Santiago, A. A. Bickford, C. J. Cardona, R. P. Chin, G. L. Cooper, R. Droual, J. S. Jeffrey, C. U. Meteyer, H. L. Shivaprasad & R. L. Walker, 1993: *Preliminary characterization of a pleomorphic Gram-negative rod associated with avian respiratory-disease*. J. Vet. Diagn. Invest. (Columbia) 5: 47-51. https://doi.org/10.1177/104063879300500111

Cramp, S., 1985: *Handbook of the birds of Europe, the Middle East and North Africa: the birds of the Western Palearctic. Volume 4: terns to woodpeckers*. Oxford.

Cramp, S., 1988: *Handbook of the birds of Europe, the Middle East and North Africa: the birds of the Western Palearctic. Volume 5: tyrant flycatchers to thrushes*. Oxford.

Cramp, S., D. J. Brooks, E. Dunn, R. Gillmor, J. Hall-Craggs, P. A. D. Hollom, E. M. Nicholson, M. A. Ogilvie & C. S. Roselaar, 1992: *Handbook of the birds of Europe, the Middle East and North Africa. The birds of the Western Palearctic. Volume 6: warblers*. Oxford.

Cramp, S., 1994: *Handbook of the birds of Europe, the Middle East and North Africa: the birds of the Western Palearctic. Volume 9: buntings and New World warblers*. Oxford.

Cramp, S. & C. M. Perrins, 1994: *Handbook of the birds of Europe, the Middle East and North Africa: the birds of the Western Palearctic. Volume 8: crows to finches*. Oxford.

Crespi, M., E. Messens, A. B. Caplan, M. V. Montagu & J. Desomer, 1992: *Fasciation induction by the phytopathogen Rhodococcus fascians depends upon a linear plasmid encoding a cytokinin synthase gene*. EMBO J. (Eynsham) 11: 795-804.

Fett, W. F., P. Cescutti & C. Wijey: 1996: *Exopolysaccharides of the plant pathogens Pseudomonas corrugata and Ps. flavescens and the saprophyte Ps. chlororaphis*. J. Appl. Bacteriol. (Oxford) 81: 181-187. http://dx.doi.org/10.1111/j.1365-2672.1996.tb04497.x

Francis, M. J., R. R. Doherty, M. Patel, J. F. Hamblin, S. Ojaimi & T. M. Korman, 2011: *Curtobacterium flaccumfaciens septic arthritis following puncture with a Coxspur Hawthorn thorn*. J. Clin. Microbiol. (Washington) 49: 2759-2760. https://doi.org/10.1128/JCM.00340-11

Gunthard, H. & A. Pennekamp, 1996: *Clinical significance of extraintestinal Hafnia alvei isolates from 61 patients and review of the literature*. Clin. Infect. Dis. (Chicago) 22: 1040-1045.

Kim, B. H. & M. Lee, 2012: *A Case of Bacteremia Due to Microbacterium oleivorans Identified by 16S rRNA Sequencing Analysis*. Korean J. Clin. Microbiol. (Iksan) 15: 110-113. https://doi.org/10.5145/KJCM.2012.15.3.110

Kumar, S., M. Bandyopadhyay, M. Chatterjee, P. Mukhopadhyay, S. Pal, S. Poddar & P. Banerjee, 2013: *Red discoloration of urine caused by Serratia rubidae: a rare case*. Avicenna J. Med. (Mumbai) 3: 20-22. https://doi.org/10.4103/2231-0770.112790

Lamberski, N., A. C. Hull, A. M. Fish, K. Beckmen & T. Y. Morishita, 2003: *A survey of the choanal and cloacal aerobic bacterial flora in free-living and captive red-tailed hawks (Buteo jamaicensis) and Cooper's hawks (Accipiter cooperii)*. J. Avian. Med. Sur. (Boca Raton) 17: 131-135. https://doi.org/10.1647/2002-025

Murthy, T. R. G. K., N. Dorairajan, G. A. Balasubramaniam, A. M. Dinakaran, & K. Saravanabava, 2008: *Pathogenic bacteria related to respiratory diseases in poultry with reference to Ornithobacterium rhinotracheale isolated in India*. Vet. Arhiv (Zagreb) 78: 131–140.

Nonaka, Y., M. Nagae, T. Omae, S. Yamamoto, R. Horitani, D. Maeda & T. Yoshinaga, 2014: *Community--acquired necrotizing fasciitis caused by Acinetobacter calcoaceticus: a case report and literature review*. J. Infect. Chemother. (Amsterdam) 20: 330-335. https://doi.org/10.1016/j.jiac.2013.12.011

Pan, Q., A. Liu, F. Zhang, Y. Ling, C. Ou, N. Hou & C. He, 2012: *Co-infection of broilers with Ornithobacterium rhinotracheale and H9N2 avian influenza virus*. BMC Vet. Res. (London) 8:104. https://doi.org/10.1186/1746-6148-8-104

Panackal, A. A., 2013: *Microbacterium resistens prosthetic joint infection: a case report due to a vancomycin-resistant coryneform and brief literature review of infections due to the genus*. Infect. Dis. Clin. Pract. (Philadelphia) 21: 349-354. https://doi.org/10.1097/IPC.0b013e31828d73db

Petkar, H., A. Li, N. Bunce, K. Duffy, H. Malnick & J. J. Shah, 2011: *Cellulosimicrobium funkei: first report of infection in a nonimmunocompromised patient and useful phenotypic tests for differentiation from Cellulosimicrobium cellulans and Cellulosimicrobium terreum*. J. Clin. Microbiol. (Washington) 49: 1175-1178. https://doi.org/10.1128/JCM.01103-10

Rezzonico, F., G. Vogel, B. Duffy & M. Tonolla, 2010: *Application of whole-cell matrix-assisted laser desorption ionization-time of flight mass spectrometry for rapid identification and clustering analysis of pantoea species*. Appl. Environ. Microbiol. (Washington) 76: 4497-4509. https://doi.org/10.1128/AEM.03112-09

Rivera, R., A. Cheema, J. Mai, R. L. Oehler, R. L. Sandin & J. N. Greene, 2012: *Curtobacterium brain abscess: case report*. Infect. Dis. Clin. Pract. (Philadelphia) 20: 17-19. https://doi.org/10.1097/IPC.0b013e318255d5bc

Shabbir, M. Z., T. Malys, Y. V. Ivanon, J. Park, M. A. Shabbir, M. Rabbani, T. Yagub & E. T. Harvill, 2015: *Microbial communities present in the lower respiratory tract of clinically healthy birds in Pakistan*. Poultry Sci. (Oxford) 94: 612-620. https://doi.org/10.3382/ps/pev010

Stenkat, J., M. E. Krautwald-Junghanns, A. Schitz-Ornes, A. Eilers & V. Schmidt, 2014: *Aerobic cloacal and pharyngeal bacterial flora in six species of free-living birds*. J. Appl. Microbiol. (Oxford) 117: 1564-1571. https://doi.org/10.1111/jam.12636

Tena, D., N. M. Martinez, J. Casanova, J. L. Garcia, E. Roman, M. J. Medina & J. A. Saez-Nieto, 2014: *Possible Exiguobacterium sibiricum skin infection in human*. Emerg. Infect. Dis. (Atlanta) 20: 2178-2179. https://dx.doi.org/10.3201/eid2012.140493

Tibra, N. K., S. Jalali, A. K. Reddy, R. Narayanan & R. Agarwal, 2010: *Traumatic endophthalmitis caused by Staphylococcus gallinarum*. J. Med. Microbiol. (London) 59: 365-366. https://doi.org/10.1099/jmm.0.011551-0

Tsiodras, S., T. Kelesidis, I. Kelesidis, U. Bauchinger & M. E. Falagas, 2008: *Human infections associated with wild birds*. J. Infect. (London) 56: 83-98. https://doi.org/10.1016/j.jinf.2007.11.001

Vancanneyt, M., P. Vandamme, P. Segers, U. Torck, R. Coopman, K. Kersters & K. H. Hinz, 1999: *Riemerella columbina sp. nov., a bacterium associated with respiratory disease in pigeons*. Int. J. Syst. Bacteriol. (Reading) 49: 289-295. https://doi.org/10.1099/00207713-49-1-289

Vuong, C. & M. Otto, 2002: *Staphylococcus epidermidis infections*. Microbes Infect. (Paris) 4:481-489. https://doi.org/10.1016/S1286-4579(02)01563-0

Waite, D. W. & M. W. Taylor, 2014: *Characterizing the avian gut microbiota: membership, driving influences, and potential function*. Front. Microbiol. (Lausanne) 5: 223. https://doi.org/10.3389/fmicb.2014.00223

Waldenstrom, J., S. L. W. On, R. Ottvall, D. Hasselquist, C. S. Harrington & B. Olsen, 2003: *Avian reservoirs and zoonotic potential of the emerging human pathogen Helicobacter canadensis.* Appl. Environ. Microbiol. (Washington) 69: 7523-7526. https://doi.org/10.1128/AEM.69.12.7523-7526.2003

Xu, X., S. A. Miller, F. Baysal-Gurel, K. H. Gartemann, R. Eichenlaub & G. Rajashekara, 2010: *Bioluminescence imaging of Clavibacter michiganensis subsp. michiganensis infection of tomato seeds and plants*. Appl. Environ. Microbiol. (Washington) 76: 3978-3988. https://doi.org/10.1128/AEM.00493-10

Yamazaki, A., J. Li, Q. Zeng, D. Khokhani, W. C. Hutchins, A. C. Yost, E. Biddle, E. J. Toone, X. Chen & C. H. Yang, 2012: *Derivatives of plant phenolic compound affect the type III secretion system of Pseudomonas aeruginosa via a GacS-GacA two-component signal transduction system*. Antimicrob. Agents. Chemoth. (Washington) 56: 36-43. https://doi.org/10.1128/AAC.00732-11

SILVER FIR (*ABIES ALBA* MILL.) ECTOMYCORRHIZA ACROSS ITS AREAL – A REVIEW APPROACH

EKTOMIKORIZNI SIMBIONTI BELE JELKE (*ABIES ALBA* MILL.) NA NARAVNEM OBMOČJU RAZŠIRJENOSTI - PREGLED

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ABSTRACT

Silver fir (*Abies alba* Mill.) ectomycorrhiza across its areal – a review approach

Silver fir is a long-living ecologically valuable and indigenous conifer species. In temperate forests it is considered as a ″stabilization tree species″. Currently, knowledge of silver fir ectomycorrhiza community is manly based on morphological-anatomical description of ectomycorrhizal fungi and their fruiting bodies. Only recently few studies were published in which authors identified ectomycorrhizal symbionts of silver fir with an aid of molecular (DNA-based) markers. We analysed the silver fir ectomycorrhiza diversity and species richness from different geographic areas and stand types. From all together nine original studies we calculated average species richness as well as a Bray-Curtis similarity index. The highest species diversity was observed in studies where a combination of morphological-anatomical and molecular approaches were used for identification. Bray-Curtis similarity index indicated highest dissimilarity of the southern sites comparing to other areas. We correlated the observed outcome to differences in soil conditions, climate, and only basic identification approach.

Keywords: Silver fir, ectomycorrhiza, literature review, community composition, site conditions, species diversity, species richness

IZVLEČEK

Ektomikorizni simbionti bele jelke (*Abies alba* Mill.) na naravnem območju razširjenosti – pregled

Bela jelka je vednozelena drevesna vrsta, ki ima v naravnih gozdovih ekološko pomembno vlogo, saj velja za stabilizacijsko drevesno vrsto. Podatki o ektomikoriznih simbiontih bele jelke pretežno temeljijo na morfološko-anatomskih opisih ektomikoriznih gliv in njihovih trosnjakov. Šele v zadnjih letih je bilo objavljenih nekaj študij, v katerih so avtorji združbo ektomikoriznih gliv bele jelke analizirali z molekularnimi pristopi. V preglednem članku smo analizirali rezultate pestrosti ektomikorize bele jelke z devet lokacij in preračunali povprečne vrednostmi vrstne pestrosti ter Bray-Curtisov indeks podobnosti združb. Največjo vrstno pestrost smo ugotovili za vzhodni del areala bele jelke. Poleg ugodnih rastiščnih razmer k temu predvidoma doprinesejo tudi kombinacija uporabljenih metod za identifikacijo. Bray-Curtisov indeks podobnosti združb kaže, da med zastopanimi regijami znotraj areala (centralna, vzhodna in južna) po vrstni sestavi najbolj odstopajo rastišča v južnem arealu bele jelke. Odstopanja vrstne sestave lahko povežemo z razlikami v pH tal, s tipom tal in s toplejšo, za belo jelko manj primerno klimo.

Ključne besede: bela jelka, ekomikoriza, pregledni članek, združba ektomikorize na jelki, rastišči pogoji, bogastvo vrst, vrstna pestrost

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1 INTRODUCTION

Although in recent years few studies, focusing on ectomycorrhizae of silver fir (*Abies alba* Mill.) have been published, little is known about ectomycorrhiza species richness of silver fir along its geographic areal. Silver fir is a long-living conifer and the largest tree (up to 60 m) in the genus *Abies* in Europe. The distribution area is limited mainly to the mountainous regions of eastern, western, southern and central Europe (Figure 1) (Westergren et al. 2010). Silver fir is also an ecologically valuable and indigenous tree species (Eberhardt et al. 2000). It is considered as a ″stabilization tree species" as well as a key tree species, without which maintenance of selection structure in forest communities would be difficult (Klopčič et al. 2009).

As most European forest tree species, silver fir forms an ectomycorrhiza, a symbiosis with fungi from Ascomycota and Basidiomycota (Schirkonyer et al. 2013). Beside the exchange of nutrients and metabolites between symbiotic ectomycorrhizal fungi and plant host, formation of ectomycorrhizae on tree roots alters root growth (Smith & Read 2008) and protects them against root diseases, which increases the survival rate of silver fir seedlings (Schirkonyer et al. 2013).

Currently ectomycorrhizal communities on silver fir remain poorly identified. Most silver fir ectomycorrhiza descriptions were based on morphological and anatomical characteristics (Comandini et al. 2004, Pacioni et al. 2001, Cremer 2009) and characterized without the exact identification of fungal symbiont (Rudawska et al. 2016). In addition, some potential ectomycorrhiza fungi were connected to silver fir based on proximity of sporocarps occurrence (Lagana et al. 2000, 2002). Until now only few studies have been published in which authors had identified ectomycorrhiza on silver fir applying molecular (DNA-based) markers (Eberhardt et al. 2000, Cremer 2009, Wazny 2014, Schirkonyer et al. 2013, Rudawska et al. 2016, Wazny & Kowalski 2017).

Ectomycorrhiza diversity and community structure, tree age, rooting depth, soil characteristics, and other characteristics can be used as a prediction data for potentially altered tree responses in given environments. To evaluate the significance of the ectomycorrhiza community shifts, a base knowledge on the ectomycorrhiza diversity and community structure is required. For this reason, we reviewed all published studies that focused ectomycorrhiza on silver fir to assess and analyse the species richness and its variation on geographic gradient, and under generalized site conditions from the currently analysed locations.

2 MATERIALS AND METHODS

2.1 Collection of mycorrhizal occurrence data

The review is based on published studies of ectomycorrhiza on silver fir (Table 1) where at least the list of identified types of ectomycorrhiza and basic site characteristics such as soil pH, soil type, stand type and location of the study were given.

Authors from reviewed studies have analysed ectomycorrhizal taxa either in pure adult natural silver fir stands, mixed stands with variable share of silver fir as well as from planted silver fir stands. Reviewed stands differ soil conditions, climatic condition, altitude and in tree species composition. Although most studies provided the stand characteristics, not all were readily available thus missing values for soil pH were gained either from online soil databases (soilgrids.org) or from other studies performed at the same study sites.

Ectomycorrhiza studies on silver fir covered three general parts of the silver fir distribution areal in Europe. The areal was also the rationale for grouping them into representative areas, namely southern, eastern and central Europe. No studies were available for western part of its areal. The position of studied location in areal as well as silver fir distribution in Europe is given in Figure 1.

2.2 Data analyses

From published papers the following variables have been extracted: number of ectomycorrhizal species of silver fir per study/site, basic soil characteristics (if given) such as soil pH and soil type, as well as type of stand in which ectomycorrhizal fungal of silver fir were analysed.

To compare species richness between geographic areas, average species richness per geographic area was calculated (Atlas & Bartha 1981). To show similarity of communities among geographic areas we calculated a Bray-Curtis similarity index for species richness (Bray & Curtis 1957).

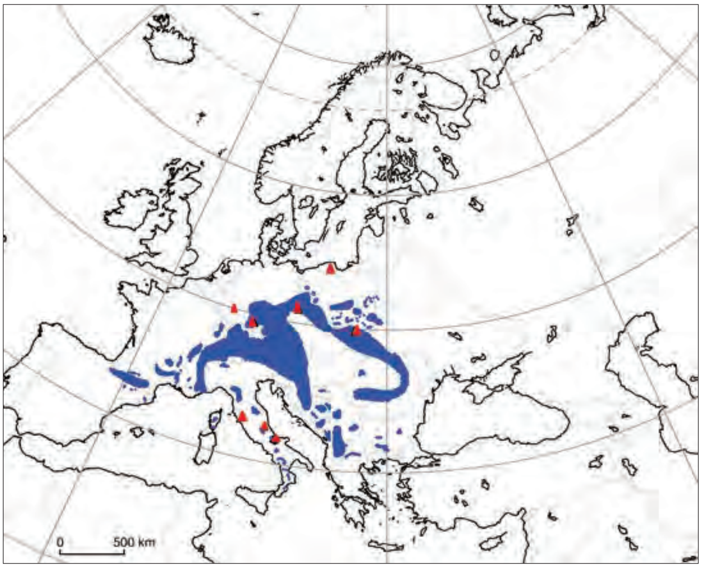

Figure 1: The location of reviewed stands and silver fir (Abies alba Mill.) distribution (source: EUFORGEN database).
Slika 1: Lokacije analiziranih sestojev bele jelke (Abies alba Mill.) in območje razširjenosti bele jelke (vir: podatkovna baza EUFORGEN).

3 RESULTS

3.1 Ectomycorrhizal fungal symbionts overview

The review of published works on ectomycorrhiza on silver fir revealed nine studies where sufficient data and metadata were available, to be included in the review. Studies covered only central, eastern and southern part of the silver fir areal (Table 1, Figure 1).

Table 1: Studies included in review.
Tabela 1: Študije vključene v pregled.

Geographic area	Data
Southern Europe	Comandini et al. 2001
	Lagana et al. 2002
	Pacioni et al. 2006
Central Europe	Schirkonyer et al. 2013
	Cremer, 2009
Eastern Europe	Wazny 2014
	Rudawska et al. 2016
	Wazny and Kowalski 2017
	Kowalski 2008

The average number of different types of ectomycorrhiza on silver fir was high, overall 85 different ectomycorrhizal types have been identified (Table 2). In eastern Europe 62 different ectomycorrhiza fungal taxa have been identified, however 5 ectomycorrhiza fungal taxa remained identified only at genus level. For southern Europe 12 out of 18 different ectomycorrhiza taxa of silver fir were identified to a species level and the rest to a genus level. However, there were still 13 ectomycorrhiza fungal taxa that remained as unidentified ectomycorrhiza. In central Europe, authors managed to identify 17 different ectomycorrhiza fungal taxa at a species level and 3 at a genus level.

Table 2: Number of different identified ectomycorrhiza fungal taxa on silver fir and number of different identified ectomycorrhiza taxa recorded per geographic area.
Tabela 2: Število različnih določenih ektomikoriznih glivnih taksonov bele jelke in število različnih določenih ekotmikoriznih glivnih taksonov zabeleženih po geografskih območjih.

Overall number	Southern Europe	Eastern Europe	Central Europe	Unidentified species
85	18	62	20	13

By comparing emerging ectomycorrhiza fungal taxa among areas only few species were present at all areas, namely *Byssocorticium atrovirens, Cenococcum geophilum* and *Laccaria amethystina*. Southern Europe differed most in terms of ectomycorrhiza taxa diversity while eastern and central Europe have much more species in common compared to southern Europe (Table 3).

Table 3: Identified ectomycorrhiza fungal taxa in symbiosis with silver fir based on area their occurrence. + indicates present of the species in particular area.
Tabela 3: Določeni ektomikorizni glivni taksoni v simbiozi z belo jelko na podlagi njihovega območja pojavljanja. + označuje prisotnost vrste na posameznem območju.

Fungal species	Present at eastern Europe	Present at southern Europe	Present at central Europe
Amanita rubescens	+		
Amanita spissa	+		
Amphinema byssoides	+		+
Boletus edulis	+		+
Boletus badius	+		
Boletus pruinatus	+		+
Byssocorticium atrovirens	+	+	+
Cantharellus sp.	+		
Cenococcum geophilum	+	+	+
Clavulina cristata	+		+
Clavulina rugosa	+		
Cortinarius anomalus			+
Cortinarius casimiri			+
Cortinarius fulvescens	+		
Cortinarius malachius	+		
Cortinarius semisanguineus	+		
Cortinarius sp.		+	
Craterellus lutescens	+		
Elaphomyces muricatus	+		
Entoloma sp.	+		
Genea sp.	+	+	
Geopora cervina	+		
Hydnotrya bailii	+		
Hydnotrya tulasnei	+		
Hydnum repandum	+		
Hydnum rufescens	+		
Hygrophorus pudorinues		+	
Hysterangium sp.		+	
Imleria badia	+		
Inocybe geophylla	+		
Inocybe terrigena	+		
Inocybe sp.		+	
Laccaria amethystina	+	+	+
Laccaria laccata	+		
Laccaria maritima	+		
Lactarius aurantiacus	+		
Lactarius camphoratus	+		
Lactarius ichoratus		+	
Lactarius intermedius		+	
Lactarius lignyotus	+		
Lactarius necator	+		
Lactarius rufus	+		
Lactarius salmonicolor	+	+	
Lactarius scrobiculatus		+	
Lactarius subericatus		+	
Lactarius subdulcis			+
Lactarius sp.			+
Melanogaster variegatus			+
Meliniomyces variabilis			+
Mycena galopus			+
Paxillus involutus	+		+
Phellodon niger		+	
Piloderma byssinum	+		
Piloderma fallax	+		
Piloderma sp.			+
Pseudotomentella tristis	+		
Russula amethystina	+		
Russula cyanoxantha	+		
Russula fellea	+		
Russula integra	+		
Russula nigricans	+		
Russula ochroleuca	+		+
Russula olivacea	+		
Russula puellaris	+		
Russula vesca	+		
Russula xerampelina	+		
Russula sp.		+	
Scleroderma citrinum			+
Sebacina sp.	+		
Thelephora terrestris	+		+
Tomentella albomarginata	+		
Tomentella botryoides	+		
Tomentella ellisii	+		
Tomentella stuposa	+		
Tomentella sublilacina	+		
Tomentella terrestris	+		
Tomentella sp.			+
Tomentellopsis sp.	+		
Tuber puberulum	+		
Tuber sp.		+	
Tricholoma bufonium		+	
Tricholoma saponaceum		+	
Tylopilus felleus	+		
Tylospora asterophora	+		
Tylospora fibrillosa	+		

3.2 Stands characteristic and ectomycorrhizal fungal species richness

All reviewed studies have analysed pure silver fir stands as well as mixed or planted stands. The southern Europe stands deviate from other areas mainly by the average pH values which are significantly higher, compared to eastern and central Europe (Table 3). As well as pH also soil type differed between reviewed areas, although for southern Europe we could not gain information from original papers about soil characteristics.

The highest average species richness was calculated for eastern Europe sites and the lowest for central European sites (Figure 2). High standard deviation within areas indicates high variability among sites and individual soil samples.

Table 4: Generalised characteristics of reviewed stands.
Tabela 4: Splošne značilnosti analiziranih sestojev.

Geographic generalized area	Reviewed stand type	Soil characteristics	pH
Eastern Europe	pure silver fir and mixed stands	acid brown	4.46 ± 0.4
Southern Europe	natural and planted silver fir stands	not specified	6.1 ± 1.13
Central Europe	pure silver fir and mixed stands	middle-red sandstone	4.28 ± 0.17

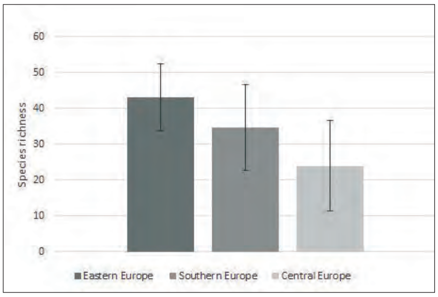

Figure 2: Average ectomycorrhiza fungal taxa richness analysed for eastern, southern and central Europe.
Slika 2: Povprečna pestrost ektomikoriznih glivnih taksonov analiziranih za območje vzhodne, južne in osrednje Evrope.

As average species richness, specifically a standard deviation calculated for individual areas showed high differences inside the same area, we compared species richness by a stand type (Table 4). Except in central Europe, pure (monospecific) silver fir stands showed higher species richness than mixed stands and plantation stands. In central Europe species richness in mixed stands with silver fir was higher compared to natural silver fir stands, where have been detected half less species compared to mixed stands.

Table 5: Average species richness for stand type and geographic area.
Tabela 5: Povprečna vrstna pestrost po tipih sestojev in geografskih območjih.

Stand type Av. spec.richn.	Monospecific silver fir stands	Mixed stands with silver fir	Plantation silver fir stands
Eastern Europe	33.5	26.7	20
Southern Europe	27	/	21
Central Europe	15	33	/

To show similarity of communities among reviewed geographic areas, Bray-Curtis similarity index was calculated. The highest species richness similarity was calculated among eastern and central Europe, while southern Europe differed more from eastern and from central Europe (Table 5). The result coincides with pattern of ectomycorrhizal fungal species occurrence.

Table 6: Bray-Curtis similarity index for species richness.
Tabela 6: Bray-Curtisov indeks podobnosti za vrstno pestrost.

Geographic areas	Bray-Curtis similarity index
Eastern & southern Europe	0.13
Eastern & central Europe	0.24
Southern & central Europe	0.16

4 DISCUSSION

4.1 Silver fir ectomycorrhiza has high diversity potential that remains underexploited

Silver fir ectomycorrhiza is not among better studied topics, what is reflecting in results of the review. From nine studies a relative high number of ectomycorrhizal taxa per site was retrieved, indicating a high potential for ectomycorrhiza diversity in silver fir stands. A high potential for hidden ectomycorrhiza taxa diversity on silver fir is also indicated with high number of types of ectomycorrhiza that remained unknown or identified only at genus level either due to lack of recognizable features or due to an insufficient identification method. Both indicate a need to study additional silver fir sites along the species distribution gradient in particular areas, where Silver fir ectomycorrhiza was not studied yet.

4.2 The silver fir ectomycorrhiza community differs among areas

In this review, published studies have been grouped into three general parts, which were further compared based on species occurrence, species richness, environmental propertied as well as based on ectomycorrhizal species similarity.

Bray-Curtis similarity index for species richness showed higher similarity between eastern and central

Europe, compared to southern Europe, which stands out. This could be a consequence of different climatic and environmental condition, as southern Europe is more characterized by Mediterranean conditions while silver fir prefers relatively high elevated areas (above 500 m a.s.l.) and requires high moisture conditions throughout the year (Tinner et al. 2013). This all can put silver fir in permanent stress conditions and a selection toward more resistant / pioneer types of ectomycorrhiza among which we identified at least genera *Cenococcum, Genea, Hysterangium* and *Tuber*.

Silver fir tolerates a wide variety of soil types with different nutrient content and alkalinity conditions (Ruosch et al. 2015) associated ectomycorrhiza community reacts to differences among site soils as only three ectomycorrhizal species were present at all areas, namely *B. atrovirens, C. geophilum* and *L. amethystina*. Several other types of ectomycorrhiza were present at two areas – eastern Europe and central Europe, namely *Genea* sp., *Clavulina cristata*, *Russula ochroleuca*, *Thelephora terrestris* etc. which favour conditions as well as on stand types in common for eastern and central sites. These species can also be regarded as generalist as they occur at two different geographic areas.

Species richness analysis showed the highest ectomycorrhizal species richness in eastern Europe and on lowest species richness in central Europe. This result could be a consequence of either lower sampling intensity in central Europe or either of insufficient ectomycorrhizas identification. As the sampling intensity of studies was in general between four till six-week period, we can assume that beside the differences in environmental properties, the identification method was the mainly reason for a large ectomycorrhizas species richness differences between geographic areas. Analysis success of ectomycorrhiza fungal diversity based on morphological descriptions is often low and only rarely allows sufficient identification of mycorrhizas at the fungal species level (Rudawska et al. 2016).

Only for eastern Europe sites DNA-based identification approaches were used for ectomycorrhiza identification thus we assume, that higher number of ectomycorrhiza fungal species is a result of combination of methods used for identification (Suz et al. 2008).

The ectomycorrhiza species richness differ also between stand types. The species richness was higher at natural pure fir stands compared to mixed stands and plantation fir stands. Although it is generally accepted that co-occurrence of different host tree species within a stand promotes ectomycorrhiza diversity at the local scale (Rudawska et al. 2016), the ectomycorrhiza communities can be highly diverse even in a mono-specific stands (Cremer 2009). Many studies have shown that relevant factors determining the composition of the ectomycorrhizal fungi are age of the associated host trees and stand history (PACIOni et al. 2001, Lagana et al. 2002). Cremer (2009) indicated that adult silver fir trees on average, host higher number of different ectomycorrhiza than juvenile trees suggesting an increase of the ectomycorrhiza species richness over time. In case of other conifers, a rapid increase was shown in species richness and sporocarp productivity during first 30-40 years of the stand and a more gradual decrease to a constant level afterwards (Comandini et al. 2004). This explains observations where the individual tree increased its ectomycorrhiza community richness in time by allowing multi-mycorrhization of its expending root systems (Cremer 2009). Lack of some silver fir ectomycorrhizal fungi in analysed stands could be also a result of unfavourable site characteristics such as pH, litter and soil quality, climate, etc. (Rudawska et al. 2016). This explains the higher ectomycorrhiza species richness at natural fir stands compared to planted sites supporting the idea to focus diversity studies on either more natural or combination of natural and planted sites (Lagana et al. 2002).

4.3 Specialists versus generalist ectomycorrhiza species on silver fir

At all investigated silver fir stands, *Cenococcum geophilum* was present in most soil samples. The species is known to be one of the most widely distributed ectomycorrhizal fungal species in various ectomycorrhiza forests (Hrenko et al. 2009). Predominance of *C. geophilum* can indicate thick organic layer or high fluctuations of soil temperature and moisture content as it is regarded as stress tolerant species and can persist as ectomycorrhiza up to 10 times longer compared to other ectomycorrhiza species (Lobuglio 1999). In such conditions, *C. geophilum* is a highly competitive ectomycorrhizal fungus. Similar *Tomentella stuposa* can be regarded as common ectomycorrhiza symbiont of silver fir with long list of ectomycorrhiza plant partners (Cremer 2009, Wazny 2014).

Among silver fir specialist ectomycorrhizal fungi is *Lactarius salmonicolor* (Pillukat 1996). This ectomycorrhiza was found at silver fir stands in southern and eastern Europe, but was not recorded in central Europe. Other species that exhibit some level of silver fir preference are also *L. albocarneus, L. intermedius* and *Russula* spp. (Rudawska et al. 2016). From mentioned *Lactarius* species, only *L. intermedius* has been identified in southern Europe. Absence of other silver fir-specialist ectomycorrhizal fungi in southern Europe can be a result of distinct climate and soil conditions or of an insufficient (e.g. only ectomycorrhiza morphology-based) identification.

The occurrence of several other species and be related to the area or forest type characteristics. *Laccaria amethystina* was also found in ectomycorrhiza with silver fir occurring regardless to the age of the stand, although it was previously regarded as an early stage ectomycorrhizal species (Cremer 2009). Occurrence of *Clavulina cristata* at stands in eastern and central Europe may indicate at high concentrations of Ca- and Mg-cations in the soil, as high cation concentrations positively affected the development of *C. cristata* in spruce and beech stands (Wazny 2014).

CONCLUSSIONS

All together nine studies were conducted focusing the ectomycorrhiza of silver fir. Observed differences in silver fir stands between analysed areas (eastern, southern and central Europe) reflect some of the general site characteristics while the strong bias cannot be excluded and likely related to insufficient sampling effort and use of identification approaches and sampling strategies with poor discriminative power.

POVZETEK

Bela jelka je vednozelena drevesna vrsta iz rodu *Abies*, katere območje razširjenosti je omejeno na vzhodno, zahodno, južno ter centralno Evropo. Tako kot večina evropskih drevesnih vrst, tvori tudi bela jelka ektomikorizno simbiozo z več vrstami gliv. Mikorizna simbioza je stalen simbiotski odnos med koreninoo rastline in glivo, pri katerem prihaja do dvosmernega pretoka hranil. Do sedaj je bilo objavljenih le nekaj študij v kateri so avtorji analizirali pestrost ektomikoriznih simbiontov bele jelke. Trenutno, znanje o ektomikorizah bele jelke povečini temelji na morfološko-anatomskih opisih ektomikoriznih gliv in njihovih trosnjakov. V zadnjih letih je bilo objavljenih tudi nekaj študij, v katerih so avtorji za identifikacijo ektomikoriznih glivnih vrst uporabili tudi analize molekularnih markerjev.

V članku smo povzeli rezultate objavljenih študij in z analizami vrstne pestrosti in podobnosti združb, med seboj primerjali posamezna geografska območja ter tipe sestojev.

Največja vrstna pestrost ektomikoriznih simbiontov bele jelke je bila ugotovljena za območje vzhodne Evrope, medtem ko je južna Evropa najmanj vrstno pestra glede na število vrst ektomikoriz bele jelke. Ugotovljena razlika je najverjetneje posledica izbire identifikacijskih metod, saj so samo na območju vzhodne Evrope, avtorji študij za identifikacijo ektomikoriznih gliv bele jelke uporabili tudi molekularne metode identifikacije – analize molekularnih markerjev.

Vrstna pestrost se razlikuje tudi med posameznimi analiziranimi tipi sestojev. V naravnih sestojih bele jelke je vrstna pestrost ektomikoriznih gliv večja v primerjavi z umetnimi oz. mešanimi sestoji. Zraven starosti sestojev so najverjetnejši vzroki za ugotovljeno razliko neugodni okoljski dejavniki.

Pri primerjavi prisotnosti ektomikoriznih glivnih simbiontov na posameznem geografskem območju smo ugotovili, da se v vseh analiziranih sestojih pojavljajo nekateri generalisti, kot npr. *B. atrovirens, C. geophilum* in *L. amethystine*. Kljub prisotnosti nekaterih generalistov, se v analiziranih sestojih bele jelke pojavljajo tudi vrste, ki preferirajo sestoje bele jelke, *Lactarius salmonicolor, Lactarius intermedius* ipd. Na podlagi prisotnosti nekaterih ektomikroiznih glivnih vrst lahko ocenimo tudi starost sestojev ter lastnosti tal.

Skupaj smo analizirali devet objavljenih študij, v katerih so se avtorji osredotočili na analize pestrosti ektomikoriznih gliv bele jelke. Ugotovljene razlike so zraven vpliva različnih lastnosti sestojev, najverjetneje rezultat uporabe identifikacijskih metod, kot tudi različnih metod ter časovne dinamike vzorčenja, katerih so se v svojih študijah poslužili avtorji.

7 REFERENCES - LITERATURA

Atlas, R. & R. Bartha, 1981: *Introduction to microbiology.* Boston.

Bray, J. R. & J. T. Curtis, 1957: *An ordination of upland forest communities of southern Wisconsin.* Ecological Monographs (Washington) 27(4): 325-349. http://dx.doi.org/10.2307/1942268

Comandini, O., I. Haug, A. C. Rinaldi & T. W. Kuyper, 2004: *Uniting Tricholoma sulphureum and T. bufonium.* Mycological Research (London) 108(10): 1162-1171. https://doi.org/10.1017/S095375620400084X

Cremer, E., K. Donges, S. Liepelt, K. H. Rexer, G. G. Vendramin, I. Leyer, G. Kost & B. Ziegenhagen, 2009: *Ontogenetic and genotypic effects of silver fir (Abies alba Mill.) on associated ectomycorrhizal communities.* In: Cremer, E. (ed): *Population genetics of silver fir (Abies alba) in the Northern Black Forest-preconditions for the recolonization of wind throw areas and associated ectomycorrhizal communities.* Phillipps-Universität Marburg, Biologie (Marburg, pp. 62-83).

Eberhardt, U., F. Oberwinkler, A. Verbeken, A. C. Rinaldi, G. Pacioni & O. Comandin, 2000: *Lactarius ectomycorrhizae on Abies alba: morphological description, molecular characterization, and taxonomic remarks.* Mycologia (Oxfordshire) 92(5): 860-873. https://doi.org/10.2307/3761582

Euforgen database, 2017. EUFORGEN Secretariat. Rim.
http://www.euforgen.org/forest-genetic-resources/poplars-clones-database/

Hrenko, M., B. Štupar, T. Grebenc & H. Kraigher, 2009: *Mycobioindication method simplified : Sclerotia of Cenococcum geophilum Fr. as indicators of stress in forest soils.* V: Himmelbauer, M. (Ed.): *Short paper abstracts : 7th ISRR Symposium root research and applications.* Institute of Hydraulics and Rural Water Management (Vienna, p. 116).

Klopčič, M., K. Jerina & A. Bončina, 2009: *Long-term changes of structure and tree species composition in Dinaric uneven-aged forests: are red deer an important factor?* European Journal of Forest Research (Berlin) 129(3): 277-288. https://doi.org/10.1007/s10342-009-0325-z

Kowalski, S., 2008: *Mycorrhizaef of the European silver fir (Abies alba Mill.) seedlings from natural and artificial regeneration in forests of the Karkonosze National Park.* In: Barzdajn, W. & A. Raj (eds): *Silver fir in the Karkonosze National Park.* Karkonoski National Park (Jelenia Góra, 175–212 pp.).

Lagana, A., E. Salerini, C. Barluzzi, C. Perini & V. De Dominicis, 2000: *Mycocoenology in Abies alba Miller woods of central-southern Tuscany (Italy).* Acta societatis Botanicorum Poloniae (Varšava) 69(4): 293-298. https://doi.org/10.5586/asbp.2000.039

Lagana, A., C. Angioli, S. Loppi, E. Salerini, C. Perini, C. Barluzzi & V. De Dominicis, 2002: *Periodicity, fluctuations and successions of macrofungi in fir forests (Abies alba Miller) in Tuscany, Italy.* Forest Ecology and Management (Amsterdam) 169(3): 187-202. https://doi.org/10.1016/S0378-1127(01)00672-7

Lobuglio, K. F., 1999: *Cenococcum.* In: Cairney J. W. G & S. M. Chambers (eds.): *Ectomycorrhizal fungi: key genera in profile.* Springer-Verlag Berlin. (Berlin, 287–309 pp.). https://doi.org/10.1007/978-3-662-06827-4

Pacioni, G., O. Comandini & A. C. Rinaldi, 2001: *An assessment of below-ground ectomycorrhizal diversity of Abies alba miller in central Italy.* Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology (Firenze) 135(3): 337-350. https://doi.org/10.1080/11263500112331350960

Pillukat, A., 1996: *Lactarius salmonicolor R. Heim &Leclair + Abies alba Mill.* Descr Ectomyc (Schwäbisch Gmünd) 2: 59–64. https://doi.org/10.2307/3761582

Rudawska, M., M. Pietras, I. Smutek, P. Strzelisnki & T. Leski, 2016: *Ectomycorrhizal fungal assemblages of Abies alba Mill. outside its native range in Poland.* Mycorrhiza (Berlin) 26(1): 57-65. https://doi.org/10.1007/s00572-015-0646-3

Ruosch, M., R. Spahni , F. Joos, P. D. Henne, W.O. Van der Knaap & W. Tinner, 2015: *Past and future evolution* of *Abies alba forests in Europe – comparison of a dynamic vegetation model with paleo data and observations.* Global Change Biology (Switzerland) 22: 727-740. https://doi.org/10.1111/gcb.13075

Schirkonyer, U., C. Bauer & G. M. Rothe, 2013: *Ectomycorrhizal diversity at five different tree species in forests of the Taunus Mountains in Central Germany.* Open Journal of Ecology (Berlin) 3(1): 66-81. https://doi.org/10.4236/oje.2013.31009

Smith, S. E. & D. J. Read, 2008: *Mycorrhizal Symbiosis.* London.

Suz, L. M., A. M. Azul, M. H. Morris, C. S. Bledsoe & M. P. Martin, 2008: *Morphotyping and Molecular Methods to Characterize Ectomycorrhizal Roots and Hyphae in Soil.* In: Nautiyal C. S. & P. Dion (Eds.): *Molecular Mechanisms of Plant and Microbe Coexistence.* Heidelberg: Springer Berlin Heidelberg. (Berlin, 437-474 pp.). https://doi.org/10.1007/978-3-540-75575-3

Tinner, W., D. Colombaroli, O. Heiri, P. D. Henne, M. Seitnacher, J. Untenecker, E. Vescovi, J. R. M. Allern, G. Carro, M. Conedera, F. Joos, A. F. Lotter, J. Luterbacher, S. Sanartin & V. Valsecchi, 2013: *The past ecology of Abies alba provides new perspectives on future responsesn of silver fir forests to global warming.* Ecological Monographs (Washington) 83(4): 419-439. https://doi.org/10.1890/12-2231.1

Wazny, R., 2014: *Ectomycorrhizal communities associated with silver fir seedlings (Abies alba Mill.) differ largely in mature silver fir stands and in Scots pine forecrops.* Annals of Forest Science (Paris) 71(7): 801-810. https://doi.org/10.1007/s13595-014-0378-0

Wazny, R. & S. Kowalski, 2017: *Ectomycorrhizal fungal communities of silver-fir seedlings regenerating in fir stands and larch forecrops.* Trees (Berlin): 1-11. https://doi.org/10.1007/s00468-016-1518-y

Westergren, M., A. Poljanec & H. Kraigher, 2010: *Tehnične smernice za ohranjanje in rabo genskih virov : bela jelka : Abies alba : Sloveenija.* Gozdarski vestnik (Ljubljana) 68 (10): 491-494.

NAVODILA AVTORJEM

Folia biologica et geologica so znanstvena revija IV. razreda SAZU za naravoslovne vede. Objavljajo naravoslovne znanstvene razprave in pregledne članke, ki se nanašajo predvsem na raziskave v našem etničnem območju Slovenije, pa tudi raziskave na območju Evrope in širše, ki so pomembne, potrebne ali primerljive za naša preučevanja.

1. ZNANSTVENA RAZPRAVA

Znanstvena razprava zajema celovit opis izvirne raziskave, ki vključuje teoretični pregled tematike, podrobno predstavlja rezultate z razpravo in zaključki ali sklepi in pregled citiranih avtorjev. V izjemnih primerih so namesto literaturnega pregleda dovoljeni viri, če to zahteva vsebina razprave.

Razprava naj ima klasično razčlenitev (uvod, material in metode, rezultati, diskusija z zaključki, zahvale, literatura idr.).

Dolžina razprave, vključno s tabelami, grafikoni, tablami, slikami ipd., praviloma ne sme presegati 2 avtorskih pol oziroma 30 strani tipkopisa. Zaželene so razprave v obsegu ene avtorske pole oziroma do dvajset strani tipkopisa.

Razpravo ocenjujeta recenzenta, od katerih je eden praviloma član SAZU, drugi pa ustrezni tuji strokovnjak. Recenzente na predlog uredniškega odbora revije *Folia biologica et geologica* potrdi IV. razred SAZU.

Razprava gre v tisk, ko jo na predlog uredniškega odbora na seji sprejmeta IV. razred in predsedstvo SAZU.

2. PREGLEDNI ČLANEK

Pregledni članek objavljamo po posvetu uredniškega odbora z avtorjem. Na predlog uredniškega odbora ga sprejmeta IV. razred in predsedstvo SAZU. Članek naj praviloma obsega največ 3 avtorske pole (tj. do 50 tipkanih strani).

3. NOVOSTI

Revija objavlja krajše znanstveno zanimive in aktualne prispevke do 7000 znakov.

4. IZVIRNOST PRISPEVKA

Razprava oziroma članek, objavljen v reviji *Folia biologica et geologica*, ne sme biti predhodno objavljen v drugih revijah ali knjigah.

5. JEZIK

Razprava ali članek sta lahko pisana v slovenščini ali katerem od svetovnih jezikov. V slovenščini zlasti tedaj, če je tematika lokalnega značaja.

Prevod iz svetovnih jezikov in jezikovno lektoriranje oskrbi avtor prispevka, če ni v uredniškem odboru dogovorjeno drugače.

6. POVZETEK

Za razprave ali članke, pisane v slovenščini, mora biti povzetek v angleščini, za razprave ali članke v tujem jeziku ustrezen slovenski povzetek. Povzetek mora biti dovolj obširen, da je tematika jasno prikazana in razumljiva domačemu in tujemu bralcu. Dati mora informacijo o namenu, metodi, rezultatu in zaključkih. Okvirno naj povzetek zajema 10 do 20 % obsega razprave oziroma članka.

7. IZVLEČEK

Izvleček mora podati jedrnato informacijo o namenu in zaključkih razprave ali članka. Napisan mora biti v slovenskem in angleškem jeziku.

8. KLJUČNE BESEDE

Število ključnih besed naj ne presega 10 besed. Predstaviti morajo področje raziskave, podane v razpravi ali članku. Napisane morajo biti v slovenskem in angleškem jeziku.

9. NASLOV RAZPRAVE ALI ČLANKA

Naslov razprave ali članka naj bo kratek in razumljiv. Za naslovom sledi ime/imena avtorja/avtorjev (ime in priimek).

10. NASLOV AVTORJA/AVTORJEV

Pod ključnimi besedami spodaj je naslov avtorja/avtorjev, in sicer akademski naslov, ime, priimek, ustanova, mesto z oznako države in poštno številko, država, ali elektronski poštni naslov.

11. UVOD

Uvod se mora nanašati le na vsebino razprave ali članka.

12. ZAKLJUČKI ALI SKLEPI

Zaključki ali sklepi morajo vsebovati sintezo glavnih ugotovitev glede na zastavljena vprašanja in razrešujejo ali nakazujejo problem raziskave.

13. TABELE, TABLE, GRAFIKONI, SLIKE IPD.

Tabele, table, grafikoni, slike ipd. v razpravi ali članku naj bodo jasne, njihovo mesto mora biti nedvoumno označeno, njihovo število naj racionalno ustreza vsebini. Tabele, table, slike, ilustracije, grafikoni ipd. skupaj z naslovi naj bodo priloženi na posebnih listih. Če so slike v digitalni obliki, morajo biti pripravljene u zapisu **.tiff** v barvni skali **CMYK** in resoluciji vsaj **300 DPI/inch.** Risane slike pa v zapisu **.eps.**

Pri fitocenoloških tabelah se tam, kjer ni zastopana rastlinska vrsta, natisne pika.

14. LITERATURA IN VIRI

Uporabljeno literaturo citiramo med besedilom. Citirane avtorje pišemo v kapitelkah. Enega avtorja pišemo » (Priimek leto)« ali »(Priimek leto: strani)« ali »Priimek leto« [npr. (Bukry 1974) ali (Oberdorfer 1979: 218) ali ... Poldini (1991) ...]. Če citiramo več del istega avtorja, objavljenih v istem letu, posamezno delo označimo po abecednem redu »Priimek leto mala črka« [npr. ...Horvatić (1963 a)... ali (Horvatić 1963 b)]. Avtorjem z enakim priimkom dodamo pred priimkom prvo črko imena (npr. R. Tuxen ali J. Tuxen). Več avtorjev istega dela citiramo po naslednjih načelih: delo do treh avtorjev »Priimek, Priimek & Priimek leto: strani« [npr. (Shearer, Papike & Simon 1984) ali Pearce & Cann (1973: 290-300)...]. Če so več kot trije avtorji, citiramo »Priimek prvega avtorja et al. leto: strani« ali »Priimek prvega avtorja s sodelavci leto« [npr. Noll et al. 1996: 590 ali ...Meusel s sodelavci (1965)].

Literaturo uredimo po abecednem redu. Imena avtorjev pišemo v kapitelkah:

– **Razprava ali članek:**

Dakskobler, L, 1997: *Geografske variante asociacije Seslerio autumnalis-Fagetum (Ht.) M. Wraber ex Borhidi 1963.* Razprave IV razreda SAZU (Ljubljana) 38 (8): 165–255.

Kajfež, L. & A. Hočevar, 1984: *Klima. Tlatvorni činitelji.* V D. Stepančič: *Komentar k listu Murska Sobota.* Osnovna pedološka karta SFRJ. Pedološka karta Slovenije 1:50.000 (Ljubljana): 7–9.

Le Loeuff, J., E. Buffeaut, M. Martin & H. Tong, 1993: *Decouverte d'Hadrosauridae (Dinosauria, Ornithischia) dans le Maastrichtien des Corbieres (Aude, France).* C. R. Acad. Sci. Paris, t. 316, Ser. II: 1023–1029.

– **Knjiga:**

GORTANI, L. & M. GORTANI, 1905: *Flora Friuliana.* Udine.

Če sta različna kraja založbe in tiskarne, se navaja kraj založbe.

– **Elaborat ali poročilo:**

PRUS, T., 1999: *Tla severne Istre.* Biotehniška fakulteta. Univerza v Ljubljani. Center za pedologijo in varstvo okolja. Oddelek za agronomijo. Ljubljana. (Elaborat, 10 str.).

– **Atlasi, karte, načrti ipd.:**

KLIMATOGRAFIJA Slovenije 1988: Prvi zvezek: *Temperatura zraka 1951–1980.* Hidrometeorološki zavod SR Slovenije. Ljubljana.

LETNO poročilo meteorološke službe za leto 1957. Hidrometeorološki zavod SR Slovenije. Ljubljana.

Za vire veljajo enaka pravila kot za literaturo.

15. LATINSKA IMENA TAKSONOV

Latinska imena rodov, vrst in infraspecifičnih taksonov se pišejo kurzivno. V fitocenoloških razpravah ali člankih se vsi sintaksoni pišejo kurzivno.

16. FORMAT IN OBLIKA RAZPRAVE ALI ČLANKA

Članek naj bo pisan v formatu RTF z medvrstičnim razmikom 1,5 na A4 (DIN) formatu. Uredniku je treba oddati izvirnik in kopijo ter zapis na disketi 3,5 ali na CD-ROM-u. Tabele in slike so posebej priložene tekstu. Slike so lahko priložene kot datoteke na CD-ROM-u, za podrobnosti se vpraša uredništvo.

INSTRUCTIONS FOR AUTHORS

Folia biologica et geologica is a scientific periodical of the Classis IV: Natural history that publishes natural scientific proceedings and review articles referring mainly to researches in ethnic region of ours, and also in Europe and elsewhere being of importance, necessity and comparison to our researches.

1. SCIENTIFIC TREATISE

It is the entire description of novel research including the theoretical review of the subjects, presenting in detail the results, conclusions, and the survey of literature of the authors cited. In exceptional cases the survey of literature may be replaced by sources, if the purport requires it.

It should be composed in classic manner: introduction, material and methods, results, discussion with conclusions, acknowledgments, literature, etc.

The treatise should not be longer than 30 pages, including tables, graphs, figures and others. Much desired are treatises of 20 pages.

The treatises are reviewed by two reviewers, one of them being member of SASA as a rule, the other one a foreign expert.

The reviewers are confirmed by the Classis IV SASA upon the proposal of the editorial board of *Folia biologica et geologica*.

The treatise shall be printed when adopted upon the proposal of the editorial board by Classis IV and the Presidency SASA.

2. REVIEW ARTICLE

On consultation with the editorial board and the author, the review article shall be published. Classis IV and the Presidency SASA upon the proposal of the editorial board adopt it. It should not be longer than 50 pages.

3. NEWS

The periodical publishes short, scientificaly relevant and topical articles up to 7000 characters in lenght.

4. NOVELTY OF THE CONTRIBUTION

The treatise or article ought not to be published previously in other periodicals or books.

5. LANGUAGE

The treatise or article may be written in one of world language and in Slovenian language especially when the subjects are of local character.

The author of the treatise or article provides the translation into slovenian language and corresponding editing, unless otherwise agreed by the editorial board.

6. SUMMARY

When the treatise or article is written in Slovenian, the summary should be in English. When they are in foreign language, the summary should be in Slovenian. It should be so extensive that the subjects are clear and understandable to domestic and foreign reader. It should give the information about the intention, method, result, and conclusions of the treatise or article. It should not be longer than 10 to 20% of the treatise or article itself.

7. ABSTRACT

It should give concise information about the intention and conclusions of the treatise or article. It must be written in English and Slovenian.

8. KEY WORDS

The number of key words should not exceed 10 words. They must present the topic of the research in the treatise or article and written in English and Slovenian.

9. TITLE OF TREATISE OR ARTICLE

It should be short and understandable. It is followed by the name/names of the author/authors (name and surname).

10. ADDRESS OF AUTHOR/AUTHORS

The address of author/authors should be at the bottom of the page: academic title, name, surname, institution, town and state mark, post number, state, or e-mail of the author/authors.

11. INTRODUCTION

Its contents should refer to the purports of the treatise or article only.

12. CONCLUSIONS

Conclusions ought to include the synthesis of the main statements resolving or indicating the problems of the research.

13. TABLES, GRAPHS, FIGURES, ETC.

They should be clear, their place should be marked unambiguously, and the number of them must rationally respond to the purport itself. Tables, figures, illustrations, graphs, etc. should be added within separated sheets. In case that pictures in digital form, **TIFF** format and **CMYK** colour scale with **300 DPI/inch** resolution should be used. For drawn pictures, **EPS** format should be used.

In cases, when certan plant species are not represented, a dot should be always printed in phytocenologic tables.

14. LITERATURE AND SOURCES

The literature used is to be cited within the text. The citation of the authors is to be marked in capitals. One writes the single author as follows: "(Surname year)" or "(Surname year: pages)" or "Surname year" [(Bukry 1974) or (Oberdorfer 1979: 218) or ... Poldini (1991)...]. The works of the same author are to be cited in alphabetical order: "Surname year small letter" [**...**Horvatić (1963 a)... or (Horvatić (1963 b)]. The first letter of the author's name is to be added when the surname of several authors is the same (R. Tuxen or J. Tuxen). When there are two or three authors, the citation is to be as follows: "Surname, Surname & Surname year: pages" [(Shearer, Papike & Simon 1984) or Pearce & Cann (1973: 290-300)...]. When there are more than three authors, the citation is to be as follows: "Surname of the first one et al. year: pages" or "Surname of the first one with collaborators year" [Noll et al. 1996: 590 or Meusel with collaborators (1965)].

The literature is to be cited in alphabetical order. The author's name is written in capitals as follows:

– **Treatise or article:**

Dakskobler, L, 1997: *Geografske variante asociacije Seslerio autumnalis-Fagetum (Ht.) M. Wraber ex Borhidi 1963.* Razprave IV. Razreda SAZU (Ljubljana) 38 (8): 165-255.

Kajfež, L. & A. Hočevar, 1984: *Klima. Tlatvorni činitelji.* V D. Stepančič: *Komentar k listu Murska Sobota.* Osnovna pedološka karta SFRJ. Pedološka karta Slovenije 1:50.000 (Ljubljana): 7–9.

Le Loeuff, J., E. Buffeaut, M. Martin & H. Tong, 1993: *Déecouverte d'Hadrosauridae (Dinosauria, Ornithischia) dans le Maastrichtien des Corbieres (Aude, France).* C. R. Acad. Sci. Paris, t. 316, Ser. II: 1023-1029.

– **Book:**

GORTANI, L. & M. GORTANI, 1905: *Flora Friuliana.* Udine.

In case that the location of publishing and printing are different, the location of publishing is quoted.

– **Elaborate or report:**

PRUS, T., 1999: *Tla severne Istre.* Biotehniška fakulteta. Univerza v Ljubljani. Center za pedologijo in varstvo okolja. Oddelek za agronomijo. Ljubljana. (Elaborat, 10 str.).

– **Atlases, maps, plans, etc.:**

KLIMATOGRAFIJA Slovenije 1988: Prvi zvezek: *Temperatura zraka 1951-1980.* Hidrometeorološki zavod SR Slovenije. Ljubljana.

LETN0 poročilo meteorološke službe za leto 1957. Hidrometeorološki zavod SR Slovenije. Ljubljana.

The same rules hold for sources.

15. LATIN NAMES OF TAXA

Latin names for order, series, and infraspecific taxa are to be written in italics. All syntaxa written in phytocoenological treatises or articles are to be in italics.

16. SIZE AND FORM OF THE TREATISE OR ARTICLE

The contribution should be written in RTF format, spacing lines 1.5 on A4 (DIN) size. The original and copy ought to be sent to the editor on diskette 3.5 or on CD-Rom. Tables and figures are to be added separately. Figures may be added as files on CD-Rom. The editorial board is to your disposal giving you detailed information.

17. THE TERM OF DELIVERY

The latest term to deliver your contribution is May 31.

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