INTRODUCTION

The lichen diversity in the Carpathians has been studied for over 150 years (for detailed references see, i.a., Bielczyk et al., 2004; Ciurchea, 2007; Vondrák et al., 2010). Some regions have local, detailed studies, while others are still poorly explored. In recent years, the best preserved old-growth forests and oakwood pastures in the eastern part of this mountain range have become the spectacular object of lichenological interest, resulting in a significant enrichment of the Carpathian and regional species lists (i.a., Vondrák et al., 2009, 2015; Ardelean et al., 2013; Dymytrova et al., 2013; Czarnota et al., 2018; Maliček et al., 2014, 2018a), including lichenized fungi new to science (Maliček et al., 2018b, 2020). Also recent taxonomic revisions supported by molecular data reveal a greater species richness of lichens in the Carpathians than previously thought (i.a., Frolov et al., 2016; Guzow-Krzemińska et al., 2016; Maliček et al., 2017). In the Polish Carpathians, the most intensive field research, covering almost all ranges of these mountains, took place in the last century (see Bielczyk, 2003; Kiszka & Kościelniak, 2003). Currently, in the era of new challenges in science, reports of new discoveries or noteworthy lichen species appear less and less often (Flakus, 2014). Therefore, the records of the species previously unknown in this part of the Carpathians seem to be particularly valuable. The presentation of several of these species, with their distinctive features, as well as their current distribution in Europe is the purpose of this work. No less important motivation is the compilation of the list of all known lichen-forming species in the Carpathians prepared as Polish part of an international project led by Dr. A. Bérešová (SAV Bratislava).

MATERIAL AND METHODS

Lichens were collected by the authors from the beginning of this century during several field explorations in Polish Western Carpathians focused on: 1) lichen-bryophyte communities inhabiting sandstone outcrops (PC), 2) diversity and ecology of wood-inhabited fungal species (PC & MT), 3) lichen diversity within the zones established to protect Western Carpathian Lobaria pulmonaria (L.) Hoffm. population (PC), and 4) forest ecology studies on permanent monitoring plots (PC). Most noteworthy species including new to Poland, the Carpathians or the Polish part of this mountain range have already been published (i.a., Czarnota, 2011, 2015, 2016; Czarnota & Hernik, 2013; Czarnota et al., 2018; Kukwa et al., 2017); five more are mentioned here.

Specimens were identified under stereomicroscope Zeiss Stemi DV4 and light-microscope Zeiss Axiostar Plus using routine lichenological methods, including morphological and anatomical characters, spot test reactions with KOH, Na-
ClO, C\textsubscript{6}H\textsubscript{4}(NH\textsubscript{2})\textsubscript{2} [ethanolic p-phenylenediamine solution], TLC analyses (Orange et al., 2001) and the reaction with UV light. Collections have been deposited in the herbarium of Gorce National Park (GPN). The nomenclature follows Faltynowicz and Kossowska (2018), with the support of Baloch et al. (2013) for Gyalecta russula, and Nordin (2004) for Tetramelas choloroleucus. Distribution maps (Figs 1D, 2D, 3C, 4E, 5D) are based on literature and on-line data and are updated with the authors’ data listed in this article.

THE SPECIES

Absconditella celata Döbbeler & Poelt

Specimens examined: Poland, Carpathians: Tatra Mts, Tatra National Park, forest section 261h, Tomanowa Dolina valley, Zadni Smeřecký Grzbiet area, alt. ca. 1420 m, 49°13'13.3"N, 19°53'04.3"E, Atpol Gd59, on decaying wood of decorticated Picea abies trunk, leg. P. Czarnota 7016 (GPN); Western Beskidy Mts, Gorce Mts, Gorce National Park, forest section no. 97, alt. 1146 m, 49°33'07.07"N, 20°11'16.91"E, Atpol Ge21, on decaying wood of spruce log, 10.07.2018, leg. M. Tanona, F. Karpowicz & P. Czarnota 8409 (GPN); ibid., valley of Forendówki stream, forest section no. 168b, alt. 1150 m, 49°32'21"N, 20°09'36"E, Atpol Ge21, on lignum of decaying spruce log in an upper mountain spruce forest Plagiothecio-Piceetum, 2019, leg. M. Tanona & P. Czarnota 8453 & 8454 (GPN).

Although A. celata is a very inconspicuous lichen-forming fungus with a thallus resembling free-living wood-inhabited algae, its minute perithecia-like apothecia of orange colour and 3-septate fusiform ascospores (Fig. 1A–C) are very distinct diagnostic features that distinguish it from several other microlichens. The most similar species in appearance of ascocarps are representatives of Psorolaena genus, i.e. P. abscondita (Coppins & Vézda) Hafellner & Türk and P. dictyospora (Orange) H. Harada. These species form pale orange perithecia, however, without an open ostiolar and hamathecium composed of only periphyses (there are no interascal filaments) in contrast to hamathecium of simple, slightly widening paraphyses in A. celata. Ascospores of P. abscondita can also be 3-septate (1–3-septate), but more elongate than fusiform, and its thallus is minutely leprose. P. dictyospora forms even more leprous thallus and muriiform ascospores. The three species can inhabit similar substrata, growing on a dead wood, decaying lichens and bryophytes in natural as well as post-mining habitats (Czarnota, unpubl. data). Porina leptalea (Durieu & Mont.) A.L. Sm. can also resemble A. celata due to its orange, hemispherical ascocarps, thin, smooth, olive-green, crustaceous thallus, and 3-septate, fusiform ascospores. The fruit bodies of P. leptalea are in fact perithecia surrounded by Porina-yellow pigmented involucreum with physiologically hamathecium; its photobiont belongs to Trentepohlia, while in A. celata the photobiont is chlorococcoid. Both species prefer also different habitats since P. leptalea is a corticolous lichen.

Absconditella celata was not reported to date from Polish Western Carpathians being known from single localities in Slovak Carpathians (Palice, 1999) and Polish Eastern Carpathians (Bielczyk & Kiszka, 2002). Its distribution includes, moreover, mainly temperate to cold regions of Scandinavia (Holien et al., 2016; Döbbeler & Poelt, 1977; Palice, 1999), Estonian Saaremaa Island on Baltic Sea (貂troot et al., 2005), Tver Region in European Russia (Notov et al., 2011), the Czech Republic (Palice, 1999; Malíček & Palice, 2013; Malíček et al., 2019; Vondrák, unpubl. data available in http://botanika.bf.jcu.cz, accessed on 3.10.2019) and British Isles (Coppins, 2009; https://species.nbnatlas.org/species/NHMSYS0001472736, accessed on 3.10.2019) (Fig. 1D). Single reports from British Columbia in North America (Spri et al., 2009), and Tasmania (Kantvilas & Jarman, 2012) and South Siberia in Russia are also known (Urbanavichene & Palice, 2016).

In the two Polish localities this microlichen was found to be growing on dead wood in subalpine belt covered with Norwegian spruce stands more or less destroyed by bark-beetle outbreaks. It was accompanied there by Micarea nowakii Czarnota & Coppins s.l. (the sister taxon to Micarea herbarum M. Brand, Coppins, Sérus. & van den Boom; see Guzow-Krzesińska et al., 2019), M. misella (Nyl.) Hedl., Placynthiella dasaea (Stirt.) Tønsberg and Thelocarpon epibolum Nyl.

Epigloe a bactrospora Zukal

Specimen examined: Poland, Carpathians, Western Beskidy Mts, Gorce Mts, Gorce National Park, forest section no. 128, on decaying wood of spruce log within Carpathian beech forest, 49°33'26.90"N, 20°13'55.83"E, alt. 1050 m, Atpol Ge21, 3.08.2018, leg. M. Tanona & P. Czarnota 8442 (GPN).
This minute species represents algicolous fungi associated with Coccomyxa. The relationship of both lichen components is probably not only symbiotic as mycobiont is sometimes parasitic depending on environmental conditions and the stage of its development (Jagg & Thomas, 1934). *Epigloea bactrospora* mostly resembles *E. pleiospora* Döbbeler in its narrowly elongate 1-septate ascospores and multisporied asci, but the ascospores of *E. bactrospora* are slightly narrower (6.0–11.0 × 1.5–2 μm while in *E. pleiospora* reach 5.5–11.5 × 2–3 μm) and asci produce more than 32 spores contrary to the less then 32-spored asci in *E. pleiospora* (see Fig. 2A–C). For excellent descriptions of both species see Döbbeler (1984) and Ceynowa-Giełdon (2002).

*Epigloea bactrospora* is rarely reported from only dispersed localities throughout Europe (Fig. 2D): Norway (GBIF Norway; https://artskart.artsdatabanken.no, accessed on 3.10.2019), Denmark and Schleswig-Holstein (Jacobsen, 1990), the Netherlands (Aptroot et al., 1999), northern Poland (Ceynowa-Giełdon, 2002, 2005), montainous regions of Austria, Germany, Italy (Grummann, 1968; Döbbeler, 1984; Nimis...
et al., 2018), and Switzerland (Jaag & Thomas, 1934); recently it has been also found in the Czech Republic (Vondrák, unpubl. data available in http://botanika.bf.jcu.cz, accessed on 12.12.2019). Here *E. bactrospora* is recorded for the first time in the Carpathians.

**Fellhanera gyrophorica** Sérus., Coppins, Diedrich & Scheid.

**Specimens examined:** Poland, Carpathians, Western Beskidy Mts, Gorce Range, Gorce National Park, valley of Kamienica river, 49°33′34.09″N, 20°12′17.15″E, alt. 930 m, Atpol Ge21, on bark of *Fagus sylvatica* in the Carpathian beech forest, 11.08.2015, leg. P. Czarnota 8023, L. Widak, K. Wasik (GPN); ibid., N slope of Kudłoń Mt below Stawieniec glade, forest section no. 101a, close to the Kamienica river, 49°33′35.72″N, 20°11′48.69″E, alt. 890 m, Atpol Ge21, on bark of *Fagus sylvatica* in old-growth Carpathian beech forest, 23.11.2018, leg. P. Czarnota 8434 (GPN).

A description of the species based on only pycnidial stage had been made by Serusiaux et al. (2001) with an excellent comparison to other crustose corticolous species producing similar

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**Fig. 2.** *Epigloea bactrospora* Zukal: A – habit, B – hamathecium and asci filled in ascospores, C – ascomatal cross section (A–C: leg. M. Tanona & P. Czarnota 8442; GPN), D – distribution in Europe; circles – localities known to date, ring – new locality in the Carpathians.
± stipitate, barrel-like and widely gapping pycnidia, namely *Micarea pycnidiophora* Coppins & P. James, *Micarea doliformis* (Coppins & P. James) Coppins & Sérus., and *Fellhanera ochracea* Sparrius & Aptroot. Systematic position of *F. gyrophorica* was proposed to be provisional that time due to pyriform conidia likely in other species of the genus. The doubt was soon clarified by Sparrius (2002) who recorded its fertile specimens. Other excellent taxonomical and ecological notes was made by Kubiak (2011) based on many collections of *F. gyrophorica* from Polish lowland. His and author’s (PC) investigations of Polish herbaria materials showed that the species was formerly collected many times with apothecia (especially in the Bialowieża Primeval Forest) but misidentified mostly as *Bacidina sulphurella* (Samp.) M. Hauck & V. Wirth (see Cieśliński & Tobolewski, 1988 as *Bacidia arnoldiana* (Körb.) V. Wirth & Vězda).

*Fellhanera gyrophorica* has most frequently been found in central-eastern European lowland including NE Poland, Belarus, Lithuania, Estonia and W Russia growing in well-preserved, humid, broad-leaved forests and old manor parks (Czyżewska et al., 2001; Sérusiaux et al., 2001; Motiejūnaitė & Prigodina-Lukošienė, 2002; Sparrius, 2002; Golubkov & Kukwa, 2006; Łubek, 2009; Kubiak, 2011; Yatsyna, 2014; Stepanchikova et al., 2018; Yatsyna et al., 2018). There it is regarded as an indicator of lowland old-growth forests (Motiejūnaitė et al., 2004). In southern, mountainous part of Poland this crustaceous epiphyte has never been found to date, but it has been rarely recorded here and there in other mountainous regions of Central Europe including Switzerland, Austria, Luxembourg (Sérusiaux et al., 2001), Germany (Wirth et al., 2013), the Czech Republic (Maliček & Palice, 2013), and in Slovak and Ukrainian Eastern Carpathians (Sérusiaux et al., 2001; Pisút et al., 2007; Maliček et al., 2018a; Fig. 3C); recently this lichen has been also found in Caucasus (Vondrák et al., 2019). Everywhere in mountains it is mostly confined to old-growth, mainly beech forests, and therefore, also in montane environment, *F. gyrophorica* could be an indicator of most natural or primeval forest ecosystems. Here it is reported for the first time from Polish Carpathians.

**Gyalecta russula** (Körb. ex Nyl.) Baloch, Lumbsch & Wedin, = *Belonia russula* Körb. ex Nyl., = *Belonia fennica* Vain., = *Beloniella cinerea* Norman

Gagarina (2015) included also *Gyalecta lyngei* Baloch & Lücking, formerly *Belonia arctica* Lynge [invalid name, see Baloch et al. (2013)] as a synonym for this name, but without revision of the type specimen which is stored in O.

**Specimen examined:** Poland, Carpathians, Gorce Mts, Gorce National Park, N slope of Kudłoń Mt, forest section no. 12c, 49°34’36.2”N, 20°10’16.2”E, alt. 1120 m, Atpol Ge11, on calcareous sandstone wall of

![Fig. 3. Fellhanera gyrophorica Sérus., Coppins, Diederich & Scheid: A – habit of pycnidial stage, B – pycnospores (A–B: leg. P. Czarnota 8434; GPN), C – distribution in Europe; circles – localities known to date, ring – new locality in the Carpathians.](image-url)
Kudłoński Baca outcrop, 20.06.2014, leg. P. Czarnota 8437 (GPN).

This epilithic lichen inhabiting more or less basic rocks was described few times by different lichenologists as to belong to different genera, but recent phylogenetic studies by Baloch et al. (2010) nested it again within *Gyalecta*.

The thallus of this lichen contains *Trentepohlia* algae, which is usually reflected in a reddish tinge of its thallus (see e.g. Purvis & Orange, 2009). In the case of the Polish finding, its inconspicuous perithecia-like fruiting bodies are immersed in pale yellowish green thallus warts (Fig. 4C & D) without any reddish tinge, its less than 20-septate worm-like ascospores reached 60–80(–85) μm in length (Fig. 4B), and some part of asci seem to be 4-spored (Fig. 4A). These characteristics could refer to *Gyalecta calcicola* (Walt. Watson) Baloch & Lücking (see Purvis & Orange, 2009; Gagarina, 2015). Taxonomic position of this species, known only from Great Britain is, however, controversial; Purvis and Orange (2009) suggested that it could be conspecific with *G. russula*. We decided to keep our finding as *G. russula*, since its thallus is distinctly su-

![Fig. 4. Gyalecta russula (Körb. ex Nyl.) Baloch, Lumbsch & Wedin: A – hamathecium and ascus filled in ascospores, B – ascospore, C – habit, D – ascomatal cross section (A–D: leg. P. Czarnota 8437; GPN), E – distribution in Europe; circles – localities known to date, ring – new locality in the Carpathians.](image-url)
perifical, minutely areolate and inhabits slightly calcareous substrata contrary to semi-immersed thallus of *G. calcicola* which was found to date on limestones. The pale coloured thallus warts are probably due to usually dead additional algal cells reaching up to 25 μm in diam. and surrounded by gelatinous, thick walls of 3 μm in width. Moreover, Nimis and Martellos (2017) noted also, that *G. russula* found in Italian Alps can form pale yellowish grey verrucales, what seems to refer to our Polish finding.

*Gyalecta russula* is regarded as an alpine-arctic, probably circum-polar species (Nimis et al., 2018) since it is known in the whole Scandinavia, especially mountainous regions of Norway and Sweden, European NW Russia, Ural, Siberia and alpine as well as subalpine belts in mountains of Central Europe (Eitner, 1910; Vezda, 1959; Urbanavichus & Andreev, 2010; Wirth et al., 2013; Gagarina, 2015, and literature cited therein; https://artskart.artsdatabanken.no/app, accessed on 7.08.2019; Nimis et al., 2018), also in Scotland (Purvis & Orange, 2009), Alaska (Thomson & Sowl, 1989; Amchitka Island), Iceland (Kristinsson, 1999) and Greenland (Alstrup et al., 2009). This species has recently been also reported from Polish part of Sudetes being rediscovered after c. 150 years in the *locus classicus* of Giant Mountains (Kossowska, 2011). Several Carpathian records of *G. russula* are known in the Slovak part of Tatra Mts (see Lisická, 2005) and in the Ukrainian part of Eastern Carpathians, namely Czornohora Mts (Black Mountain) (Vondrák et al., 2010, and literature cited therein). In Polish Carpathians this saxicolous species has never been recorded before thus here it is the only locality in this part of the Carpathians.

**Tetramelas chloroleucus** (Körb.) A. Nordin, = *Buellia chloroleuca* Körb.; = *B. poeltii* T. Schauer; = *Tetramelas poeltii* (T. Schauer) Kalb

**Specimen examined:** Poland, Western Carpathians, High Tatra Mts, Tatra National Park, forest sec. no 47c, NW slope of Zabia Grań Mt near the border of Slovakia, 49°12'40"N, 20°05'24"E, alt. 1500 m, on bark of *Sorbus aucuparia* at the base of trunk close to the timber-line in upper mountain spruce forest, Atpol Ge60, 09.07.2002, leg. P. Czarnota 7561 (GPN); det. M. Giralt.

This species, under the name *Buellia chloroleuca*, was described by Körber (1865) based on the material collected in the currently Polish part of Sudetes. Only recently Giralt et al. (2000) clearly re-defined *B. chloroleuca* showing characters of this species referring to *Tetramelas* Norman. The genus name was resurrected by Marbach (2000) for the group of *Buellia* s.l., which is generally characterized by the presence of xanthones (at least 6-O-methylarthonothelin; see Elix, 2019), and two-layered spore wall with cracked, dark coloured perispore (Nordin, 2004). Based on the re-examined type materials, Giralt et al. (2000) synonymized also *Buellia poeltii* with *B. chloroleuca*. Finally, Nordin (2004) transferred this taxon to the genus *Tetramelas* including *T. poeltii*, the name earlier combined by Kalb (2004). The taxonomic distinction of *Tetramelas* from the other groups of polyphyletic *Buellia* s.l. was supported soon by the ITS phylogeny analysis (Nordin & Tibell 2005).

Diagnostic features of the Polish specimen (Fig. 5A–C) correspond well with the description of *T. chloroleucus* by Giralt et al. (2000), including thallus UV+ orange, K+ and C+ yellowish, KC+ orange reactions (due to the presence of xanthone), brown thick-walled ascospores with perispore, bacilliform, straight, 4.5–5.5(-6) × 1 μm conidia and its ecological requirements. Faltynowicz (2003) included this species within the list of lichens in Poland using the former Körber’s record and additional report by Kiszka and Kościeliak (1998). These authors excluded it, however, from their own Polish Eastern Carpathian list of lichens published in the same year (Kiszka & Kościeliak, 2003) as probably doubtful. Considering this, *T. chloroleucus* is reported here from Polish Carpathians for the first time, and rediscovered in Poland after 150 years. This boreal-montane, epiphytic or wood inhabiting species is known to be widely distributed in high mountains of Europe, especially in Pyrenees, Alps (Giralt et al., 2000; Nimis et al., 2018) and Scandinavian mountains (Nordin, 2000). It has only recently been found in Carpathians, i.e. in Ukrainian (Dymytrowa et al., 2013) and Slovak (Vondrak et al., 2015) parts of Eastern Carpathians (Fig. 5D). Additional European records of *T. chloroleucus* are known in arctic regions of Russia (Zhdanov & Dudoreva, 2008), Norway and Island; in boreal forests in Finland (Nordin, 2000; Bjerke et al., 2011) and Leningrad Region of Russia (Himelbrant et al., 2017). It is also reported from a distant area of Asian part of Russia (Urbanavichus & Andreev, 2010).
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