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CRITICAL REVIEW OF *RUSSULA* SPECIES (AGARICOMYCETES) KNOWN FROM TATRA NATIONAL PARK (POLAND AND SLOVAKIA)

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Abstract. All available published data on the occurrence of *Russula* species in Tatra National Park are summarized. Excluding the doubtful data, which are discussed herein, 66 species are recognized in Tatra National Park. Within each of the three main geomorphological units of the range, 42 species were recorded in the West Tatras, 18 in the High Tatras, and 16 in the Belanské Tatry Mts; additionally, 35 species were found in areas outside the Tatra Mts but within the National Park borders. Montane forests are the richest in *Russula* species (58); 13 species were found in the subalpine and 8 in the alpine belt. The number of reported species is highest in the Polish part of the West Tatra Mts; almost no data are available from the Slovak High Tatras. The smallest unit, the Belanské Tatry Mts, is the Tatra region best studied for alpine species. In comparison to other regions in Poland and Slovakia, Tatra National Park seems to be relatively well investigated, but in view of the richness of habitats in the Tatra Mts, we believe the actual diversity of *Russula* species in the region is higher than presently known.

Key words: *Russula*, fungi, biodiversity, Slovakia, Poland, mountains, altitudinal zones

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INTRODUCTION

The genus *Russula* is among most diverse genera of Agaricomycetes. It is represented by hundreds of species worldwide (Kirk *et al.* 2008). All species are thought to be obligatorily symbiotic and to form ectomycorrhizal symbiotic relationships of various degrees of host-specificity, with many species of mostly tree and shrub hosts (Beenken 2004). The members of this fungal genus occur in both the Northern and Southern Hemispheres, in a wide range of climatic regions including boreal, temperate, Mediterranean, subtropical and tropical areas (e.g., Romagnesi 1967; Singer *et al.* 1983; Buyck 1993, 1994, 1997, 2007; Beenken 2004). About 160 *Russula* species have been reported from Central Europe (Beenken 2004), where they are regarded as important components of the diversity and ecology of forest ecosystems. Several species are typical arctic-alpine fungi occurring exclusively in mountainous areas above the timberline or in high-latitude regions, where they are ecologically important as common mycorrhizal partners of arctic-alpine dwarf shrubs (Kühner 1975; Knudsen & Borgen 1982).

In assessing biodiversity and ecological resources on a regional scale, there are areas particularly important for the biodiversity of a region. For Central Europe the Tatra Mts are such an area of particular relevance for biodiversity studies. This range forms the highest part of the Carpathians, situated along the border between Poland and Slovakia. It is characterized by regionally unique ecological diversity due to the variety of bedrock types and the well developed range of altitudinal belts including extensive deciduous and coniferous forests, subalpine shrub communities, and treeless alpine and subnival vegetation (Pawłowski 1977). Moreover, relatively large parts of these ecosystems have suffered little from anthropogenic impacts and therefore represent primeval natural assemblages. The Tatra Mts are covered by the highest category of legal protection on both sides of the national border.

The Tatras are a study area of key importance for assessing the known data on the mycological diversity of the region, as the mountain forests and habitats above the timberline provide a wide range of habitats and are usually rich in rare fungi (e.g., Favre 1955, 1960; Brunner & Horak 1990; Ronikier 2009). Here we critically review the available data on the diversity of the genus *Russula* in the Tatra National Parks on both sides of the border. The first records of *Russula* species in Tatra National Park were published by Pilát (1926). Since then a number of reports have been published, but the information is scattered and usually not easily accessible. The three main aims of this study are (*i*) to summarize the literature data on the diversity of *Russula* species reported in Tatra National Park, (*ii*) to review these data with special attention to a critical taxonomical analysis of the species reported from the study area and the correct placement of their localities within geomorphological units of the Tatra Mts and (*iii*) to estimate the known diversity of *Russula* species across altitudinal belts and to assess the degree of mycological exploration of the Tatra Mts in light of the example of work on the genus *Russula*.

Material and methods

Study area

The two national parks protecting the Tatra Mts, Tatranský Národný Park (Slovakia) and the Tatrzański Park Narodowy (Poland), are independent administratively but they constitute a spatially coherent protected territory and will be referred to here as one entity, Tatra National Park. It covers the entire Tatra Mts and small parts of adjacent regions: the Podtatranská Kotlina basin (SE part of the Park, Slovakia) and the Rów Podtatrzański trough (NE part of the Park, Poland) (Fig. 1).

The Tatra Mts are divided into three geomorphological units: the West Tatras, High Tatras and the Belanské Tatry Mts. The West and High Tatras are on both sides of the Polish-Slovak border, whereas the Belanské Tatry Mts lie entirely within Slovakia (Fig. 1). Five vegetation belts are recognized in the mountains: lower montane (up to 1200 m a.s.l.), upper montane (up to 1500 m a.s.l.), subalpine (up to 1800 m a.s.l.), alpine (up to 2300 m a.s.l.) and subnival (up to the highest peak – 2655 m) (Pawłowski 1977; Šoltésová 1994). Spruce forests predominate in the lower montane belt, especially on nutrient-poor granitic moraines (sometimes with admixture of *Pinus sylvestris* in Slovakia; Łysek 1974), but on the northern (Polish) side of the mountains, usually on calcareous bedrock, beech forests cover relatively wide areas (Myczkowski & Lesiński 1974; Myczkowski 1975; Pawłowski 1977; Michalko *et al.* 1984). The upper montane belt is dominated by spruce forests. *Larix decidua* and *Pinus cembra* may also be found at the timberline. These trees are rare on the northern (Polish) side, but form bigger forest patches on the southern (Slovak) side of the Tatra Mts (Sokołowski 1928). The subalpine belt is dominated by dwarf mountain pine (*Pinus mugo*) communities (Šibík *et al.* 2005). The alpine belt is covered by alpine meadows, tundra-like vegetation of dwarf prostrate woody perennials (e.g., *Salix reticulata* and *Dryas octopetala* in calcareous areas) or snowbeds with *S. herbacea* (Šibík *et al*. 2004; Kliment & Valachovič 2007). At the highest elevations of the subnival belt the vegetation is very sparse, limited to rock crevices (Paclová 1977, 1979).

Although the Tatra Mts constitute a distinct massif, their borders with adjacent regions are not easily delimited, and have been variously defined. Similarly, the borders between the High Tatra and West Tatra geomorphological units on the Slovak side are variously treated. In this work the Tatra Mts boundaries and the geomorphological units follow Radwańska-Paryska and Paryski (1995) and Balon (1996) for Poland, and they follow Mazúr and Lukniš (1980) and Urbánek *et al.* (2008) for Slovakia (Fig. 1).

Data analysis

We analyzed all available literature data on the occurrence of *Russula* species in Tatra National Park (Polish and Slovak sides). The species reported are listed in Table 1 together with information (if available) on altitudinal belt and region of occurrence in the area. Species concepts, synonymy and delimitation of taxa follow Romagnesi (1967) and Sarnari (1998, 2005).

The map of localities (Fig. 1) shows all known sites of *Russula* species in the study area. For precise location of the sites within a given geomorphological unit we used maps of the Tatra Mts (1:50000, 1:25000 and 1:10000) as well as the GIS system. Some published reports did not give precise enough locations so those positions on the map are approximate (see legend to Fig. 1). Localities of certain species given too generally (e.g., 'common in the whole area' or 'High Tatra Mts') are not included in the map. Species reported from imprecisely defined localities were also not incorpo-

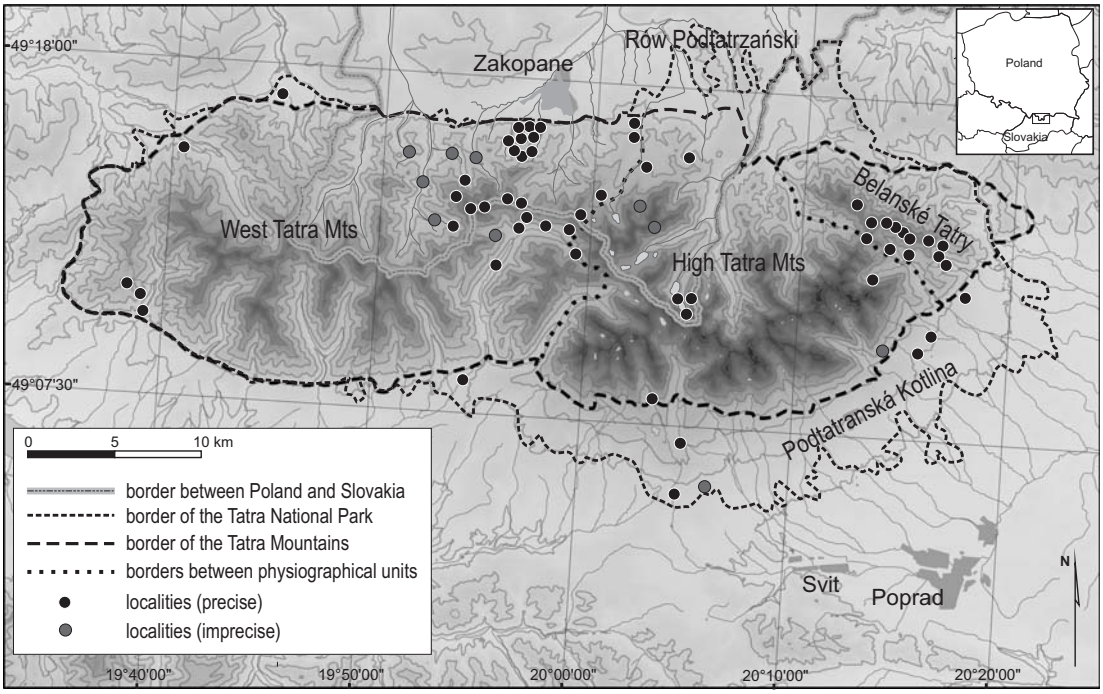

Fig. 1. Tatra National Park and localities of *Russula* species known from the area.

rated in the quantitative analysis of species diversity in geomorphological units. Species reported from border areas between two units were classified in both units. For instance, species reported from the Zadná Tichá Dolina valley (Škubla 1998b; Lizoň & Kautmanová 2004) on the border between the West Tatras and High Tatras were counted twice, in the High Tatras and West Tatras.

Results and discussion

The list of *Russula* species known from the study area is given in Table 1. Some records reported in the literature are doubtful because of possible misidentification of specimens. Such results are excluded from Table 1 and discussed separately below. Several site descriptions in the literature do not correspond to the borders of the geomorphological units accepted here. Such incongruence may be due to the use of imprecise maps, differences in classification, or evident errors. Some authors refer to the phytogeographical classification by Futák (1980). For instance, this system is followed by Adamčík *et al.* (2003) for analysis of the diversity of macrofungi in Slovakia. Futák's (1980) phytogeographical unit 'Vysoké Tatry' (High Tatras) covers a wider area than the High Tatras geomorphological unit accepted here, and includes part of the Podtatranská Kotlina basin as defined by Mazúr and Lukniš (1980). Some localities assigned by Kuthan and Singer (1987) and Kuthan (1989a, b) to the High Tatra Mts are in fact within the Podtatranská Kotlina basin, outside the Tatra Mts as defined by Mazúr and Lukniš (1980) and Urbánek *et al.* (2008), but probably within Vysoké Tatry (High Tatras) according to Futák's (1980) system. The site 'Hrbačka near Pribylina' assigned by Škubla (1998b) to the West Tatra Mts lies in the Podtatranská Kotlina basin outside Tatra National Park. Gubałówka Mt. classified by Rudnicka-Jezierska (1965) in Tatra National Park on the Polish side, is in fact a small ridge several kilometers north of the Tatra Mts, and not part of them. Several authors reported species from Tatra National Park without sufficient information on their localities (Dominik & Nespiak 1953; Dominik & Pachlewski 1956; Nespiak 1962a, b; Dermek 1977; Skirgiełło

1991; Lazebníček & Gáper 1994; Wojewoda 1996; Domański 1997; Knudsen & Ronikier 2003); those records cannot be assigned to specific parts of the massif.

Excluding doubtful data, 66 species have been reported from the Tatra National Park: 42 species are known from the West Tatra Mts, 18 from the High Tatra Mts, 16 from the Belanské Tatry Mts, and 35 from outside the Tatra Mts but within the Tatra National Park borders (Podtatranská Kotlina basin). Twelve species were reported exclusively from the area of the Park lying outside the Tatra Mts.

Most *Russula* species reported from the study area are known from single or a few localities. The general distribution of localities is scattered and reflects mostly incidental collecting events (Fig. 1). Although the Polish part of the massif constitutes only about a fourth of the area of the Tatra Mts (Radwańska-Paryska & Paryski 1995), the numbers of reported localities on the Slovak and the Polish sides are comparable (Fig. 1), and the numbers of species are also similar: 45 in the Polish and 50 in the Slovak Tatra Mts (Table 1). The higher diversity of *Russula* species in relation to surface area on the Polish (northern) side is probably due to the local presence of one of the most important mycorrhizal partners of *Russula* species, *Fagus sylvatica*. This tree is almost absent on the Slovak side (Myczkowski & Lesiński 1974; Myczkowski 1975). For this reason such species as *R. aurora*, *R. fellea*, *R. laurocerasi*, *R. mairei*, *R. risigalina*, *R. romellii* and *R. veternosa* are known only from the Polish side.

Of the three geomorphological units of the Tatra Mts, the smallest unit, the Belanské Tatry Mts, is relatively well sampled. Nevertheless, although this area has been visited a number of times (Nespiak 1960; Fellner & Landa 1993a, b; Škubla 1998c; Adamčík 1998, 2001; Adamčík & Knudsen 2004; Ronikier & Adamčík 2009) and relatively many localities have been studied (Fig. 1), only 16 species of *Russula* have been reported from this region. Interestingly, as many as 6 of them were collected in the alpine zone (Table 1), making the Belanské Tatry Mts the local area best-studied for alpine species.

There are almost no records of *Russula* species in the Slovak High Tatra Mts (Fig. 1). The data from this area can be found in five papers (Pilát 1926; Škubla 1998b, c; Lizoň & Kautmanová 2004; Ronikier & Adamčík 2009) reporting only 11 species in total, 7 of which were found in areas bordering neighboring units (West Tatras or Belanské Tatry Mts). The Polish part of the High Tatras has also been poorly investigated. Only 12 *Russula* species have been reported so far, in one article summarizing longer-term studies during the summer months of two years in the Morskie Oko valley (Frejlak 1973) and in a few papers reporting accidental observations (Nespiak 1953, 1960; Anonymous 1968; Ronikier & Adamčík 2009).

More data are available from the West Tatra Mts (Fig. 1). The first long-term systematic research in the West Tatras was conducted only recently in the Sarnia Skała massif (Ronikier 2005). The list of *Russula* species found during that work was published recently (Ronikier & Adamčík 2009). Together with previously published data (Nespiak 1960; Rudnicka-Jezierska 1965; Anonymous 1968), 37 *Russula* species were reported from many localities in the Polish West Tatra Mts (55% of the total number of species known from the entire Tatra National Park area). Fewer localities are known in the Slovak West Tatras, from where 21 species are listed (Fellner & Landa 1991; Škubla 1998b; Adamčík 2001, 2002; Lizoň & Kautmanová 2004; Ronikier & Adamčík 2009).

Two reports of mycological meetings (Kuthan 1989b; Lizoň & Kautmanová 2004), studies of peat bogs (Kuthan 1989a) and a 10-year study in a spruce forest close to Štrbské Pleso (Kuthan & Singer 1987) have made significant contributions to the fungal diversity of the Podtatranská Kotlina basin. Other authors have provided data on species collected incidentally or identified from herbarium material (Pilát 1926; Dermek 1977; Hagara 1992; Škubla 1998b; Adamčík 2001, 2004; Adamčík & Knudsen 2004; Ronikier & Adamčík 2009). The list of species found in the part of the Podtatranská Kotlina basin lying within Tatra National Park numbers 35 species in total. The montane forests of the Podtatranská Kotlina basin are very similar to those located at higher elevations

Table 1. List of *Russula* species known from the area of the Tatra National Park (Poland and Slovakia). Species names provided in source literature differing from currently accepted names are given in parentheses. WT – West Tatra Mts, HT – High Tatra Mts, BT – Belanské Tatry Mts, PK – Podtatranská Kotlina basin (area lying at the foot of the High Tatras and Belanské Tatry Mts, within Tatra National Park).

Species	Geomorphological unit				Country		Vegetation belt			Reference
	WT	HT	BT	PK	Slovakia	Poland	montane	subalpine	alpine	
R. acrifolia Romagn.	+				+		+			Ronikier & Adamčík 2009
R. adusta (Pers.) Fr.		+			+		+			Pilát 1926
R. aeruginea Lindblad				+	+		+			Pilát 1926, Kuthan 1989b
R. albonigra (Krombh.) Fr.	+					+	+			Ronikier & Adamčík 2009
R. amethystina Quél.						+	+			Skirgiełło 1991
R. anthracina Romagn.	+					+	+			Ronikier & Adamčík 2009
R. aquosa Leclair				+	+		+			Kuthan 1989b, Lizoň & Kautmanová 2004
R. atrorubens Quél.	+	+		+	+	+	+			Domański 1997, Lizoň & Kautmanová 2004, Ronikier & Adamčík 2009
R. aurea Pers. [*R. aurata* (With.) Fr.]	+	+				+	+	+		Dominik & Nespiak 1953, Dominik & Pachlewski 1956, Ronikier & Adamčík 2009
R. aurora (Krombh.) Bres.	+					+	+			Ronikier & Adamčík 2009
R. azurea Bres.		+	+	+	+		+			Pilát 1926, Kuthan & Singer 1987, Škubla 1998c
R. badia Quél.				+	+		+			Pilát 1926, Ronikier & Adamčík 2009
R. betularum Hora				+	+		+			Kuthan 1989b
R. cavipes Britzelm.	+					+	+			Ronikier & Adamčík 2009
R. cessans A. Pearson	+			+	+	+	+	+		Ronikier & Adamčík 2009, Kuthan 1989b
R. chloroides (Krombh.) Bres.	+			+	+	+	+	+		Ronikier & Adamčík 2009, Kuthan 1989b
R. claroflava Grove (*R. flava* Romell.)	+			+	+	+	+			Rudnicka-Jezierska 1965, Kuthan 1989a, b
R. clavipes Velen.				+	+		+			Adamčík 2001, 2004
R. consobrina (Fr.: Fr.) Fr.				+	+		+			Lazebníček & Gáper 1994, Kuthan 1989a
R. cyanoxantha (Schaeff.) Fr.	+			+	+	+	+			Pilát 1926, Dominik & Pachlewski 1956, Nespiak 1962a, Kuthan 1989b, Ronikier & Adamčík 2009
R. cupreola Sarnari			+		+				+	Fellner & Landa 1993b
R. decolorans (Fr.) Fr.	+	+	+	+	+	+	+	+		Dominik & Nespiak 1953, Nespiak 1960, Anonymous 1968, Frejlak 1973, Kuthan & Singer 1987, Kuthan 1989a, b, Lazebníček & Gáper 1994, Škubla 1998b, c, Ronikier & Adamčík 2009
R. delica Fr.	+				+	+	+			Pilát 1926, Dominik & Pachlewski 1956, Rudnicka-Jezierska 1965, Anonymous 1968
R. dryadicola Fellner & Landa			+		+				+	Fellner & Landa 1993a
R. emetica (Schaeff.: Fr.) Pers.	+	+	+	+	+	+	+	+		Dominik & Nespiak 1953, Nespiak 1960, 1962a, 1962b, Anonymous 1968, Kuthan 1989a, b, Škubla 1998b, c, Lizoň & Kautmanová 2004, Ronikier & Adamčík 2009

(cont.)

Table 1. *Continued.*

Species	Geomorphological unit				Country		Vegetation belt			Reference
	WT	HT	BT	PK	Slovakia	Poland	montane	subalpine	alpine	
R. farinipes Romell	+					+				Rudnicka-Jezierska 1965
R. favrei M. M. Moser	+				+	+	+			Adamčík 2001, 2002[1], Ronikier & Adamčík 2009
R. fellea (Fr.) Fr.	+					+	+			Ronikier & Adamčík 2009
R. firmula Jul. Schäff.	+					+	+			Anonymous 1968, Ronikier & Adamčík 2009
R. foetens Pers.: Fr.				+	+	+	+			Pilát 1926, Dominik & Pachlewski 1956, Kuthan 1989b
R. font-queri Singer				+	+		+			Škubla 1995
R. fragilis (Pers.: Fr.) Fr.		+		+	+	+	+	+		Dominik & Nespiak 1953, Kuthan 1989b, Skirgiełło 1991, Hagara 1992
R. griseascens (Bon & Gaugué) Marti	+					+	+			Ronikier & Adamčík 2009
R. integra (L.) Fr.	+	+	+	+	+	+	+			Anonymous 1968, Dermek 1977, Škubla 1998c, Lizoň & Kautmanová 2004, Ronikier & Adamčík 2009
R. laccata Huijsman (*R. norvegica* D. A. Reid)			+		+				+	Fellner & Landa 1993b, Knudsen & Ronikier 2003
R. laurocerasi Melzer	+					+	+			Ronikier & Adamčík 2009
R. mairei Singer	+					+	+			Ronikier & Adamčík 2009
R. mustelina Fr.	+	+	+	+	+	+	+	+		Pilát 1926, Frejlak 1973, Skirgiełło 1991, Wojewoda 1996, Kuthan & Singer 1987, Kuthan 1989a, b, Škubla 1998b, c, Lizoň & Kautmanová 2004, Ronikier & Adamčík 2009
R. nana Killerm. (*R. emetica* var. *alpestris* Sing., '*R. emetica* var. *alpina*')	+		+		+	+		+	+	Nespiak 1960, 1962a, Fellner & Landa 1991[2], 1993b, Adamčík 1998, Škubla 1998c
R. nauseosa (Pers.) Fr.	+		+		+	+	+	+		Pilát 1926, Škubla 1998c, Ronikier & Adamčík 2009
R. nigricans Fr.	+			+	+	+	+			Pilát 1926, Dominik & Pachlewski 1956, Kuthan 1989b, Lizoň & Kautmanová 2004, Ronikier & Adamčík 2009
R. nitida (Pers.) Fr.				+	+		+			Pilát 1926, Kuthan 1989a, b
R. ochroleuca Pers.	+	+		+	+	+	+			Dominik & Pachlewski 1956, Anonymous 1968, Kuthan 1989b, Škubla 1998b, Lizoň & Kautmanová 2004, Ronikier & Adamčík 2009
R. olivacea (Schaeff.) Pers.			+	+	+		+			Kuthan & Singer 1987, Škubla 1998c
R. paludosa Britzelm.	+	+	+	+	+	+	+	+		Nespiak 1960, 1962a, Frejlak 1973, Dermek 1977, Kuthan & Singer 1987, Kuthan 1989a, b, Lazebníček & Gáper 1994, Wojewoda 1996, Škubla 1998c, Ronikier & Adamčík 2009
R. pascua (F. H. Møll. & Jul. Schäff.) Kühner (*R. felleaecolor* Bon & Jamoni, *R. oreina* Singer)	+		+		+	+			+	Fellner & Landa 1993b, Adamčík 2001, Knudsen & Ronikier 2003, Adamčík & Knudsen 2004, Škubla 1998c

Table 1. *Continued.*

Species	Geomorphological unit				Country		Vegetation belt			Reference
	WT	HT	BT	PK	Slovakia	Poland	montane	subalpine	alpine	
R. postiana Romell	+				+	+	+			Ronikier & Adamčík 2009
R. puellaris Fr.		+		+	+	+	+		+	Nespiak 1953, Kuthan & Singer 1987, Kuthan 1989b
R. queletii Fr.	+	+	+	+	+	+	+	+		Pilát 1926, Nespiak 1960, 1962b, Škubla 1998b, c, Lizoň & Kautmanová 2004, Ronikier & Adamčík 2009
R. rhodopoda Zvára				+	+		+			Kuthan 1989a, b
R. risigallina (Batsch) Sacc. (*R. chamaeleontina* Fr.)	+					+	+			Dominik & Pachlewski 1956, Ronikier & Adamčík 2009
R. romellii Maire	+					+	+			Ronikier & Adamčík 2009
R. roseipes Bres.	+				+		+			Ronikier & Adamčík 2009
R. saliceticola (Singer) Kühner *ex* Knudsen & T. Borgen			+		+				+	Fellner & Landa 1993b, Knudsen & Ronikier 2003
R. sanguinea (Bull.) Fr.	+					+				Rudnicka-Jezierska 1965
R. sapinea Sarnari	+				+	+	+			Ronikier & Adamčík 2009
R. silvestris (Singer) Reumaux (*R. emetica* var. *silvestris* Singer)	+	+		+	+	+	+	+		Kuthan 1989b, Škubla 1998b, Lizoň & Kautmanová 2004, Ronikier & Adamčík 2009
R. subfoetens Wm. G. Sm.				+	+		+			Kuthan 1989b
R. subrubens (J. E. Lange) Bon	+			+	+	+	+		+	Adamčík 2001, Adamčík & Knudsen 2004[3]
R. turci Bres.		+		+	+	+	+			Frejlak 1973, Ronikier & Adamčík 2009
R. vesca Fr.	+	+		+	+	+	+	+		Dominik & Pachlewski 1956, Frejlak 1973, Kuthan & Singer 1987, Lizoň & Kautmanová 2004, Ronikier & Adamčík 2009
R. veternosa Fr.	+					+	+			Ronikier & Adamčík 2009
R. vinosa Lindblad	+	+	+	+	+	+	+			Kuthan 1989b, Škubla 1998b, c, Lizoň & Kautmanová 2004, Ronikier & Adamčík 2009
R. virescens (Schaeff.) Fr.					+		+			Pilát 1926
R. viscida Kudřna				+	+		+			Kuthan 1989b
R. xerampelina (Schaeff.) Fr. (*R. erythropoda* Pelt.)	+	+		+	+	+	+			Frejlak 1973, Kuthan & Singer 1987, Kuthan 1989b, Škubla 1998b, Lizoň & Kautmanová 2004
Total	42	18	16	35	50	45	58	13	8	

[1] The altitude given in these papers for the localities in the Jalovecká dolina valley (730 m a.s.l.) and the Bobrovecká dolina valley (750 m a.s.l.) are incorrect. The correct altitude for both localities should be *ca* 850 m a.s.l.

[2] The authors report the species as collected in the 'High Tatra (Red Hills)'; however, if they collected it within the 'Red Hills' area which is certainly the Czerwone Wierchy massif, they collected it within the West Tatras, not the High Tatra region (see Radwańska-Paryska & Paryski 1995).

[3] The altitudes given in this paper for the Štrba locality (550 and 600 m a.s.l.) are incorrect. The correct altitude for both localities should be *ca* 950 m a.s.l.

within the High Tatras geomorphological unit, so the species diversity of *Russulae* in those two areas should be similar. The difference in species numbers from the High Tatras and Podtatranská Kotlina basin can be explained by insufficient investigation of higher areas (Fig. 1).

Almost all *Russula* species known from the study area were reported from the montane forests (58), while only 13 have been found in the subalpine belt and 8 in the alpine belt. No species have been collected in the subnival belt of the mountains, although *Salix herbacea*, a potential mycorrhizal partner for *Russula*, grows even on the highest peaks in rock crevices (Paclová 1979). Some alpine *Russulae* may occur at the highest localities together with *S. herbacea* without producing basidiomes due to the extremely harsh climatic and edaphic conditions. It would be interesting to verify this suggestion by direct examination of ectomycorrhizae.

Ronikier and Adamčík (2009) demonstrated that many *Russulae* reported from the Tatra Mts are considered mountain species. Most of them are rare in Poland (Wojewoda 2003) and more frequently encountered in Slovakia (Kuthan *et al.* 1999). Poland is mostly a lowland country, and the Carpathian chain, to which the Tatra Mts belong, covers only 6% of its territory. The mountainous areas of the Carpathians and Sudetes are in the south of the country, and they occupy less than 10% of its surface (Kondracki 2001). These two mountain chains harbor most localities of mountain species in Poland. Most of Slovakia, in contrast, lies within the Carpathians. Nevertheless, as the highest massif of these two countries the Tatra Mts are undoubtedly the most important area of occurrence of mountain fungi.

In comparison to other well investigated region in Slovakia, the Vihorlatské vrchy Mts, where 53 *Russula* species have been found (Adamčík *et al*. 2006; Ripková *et al*. 2007), or the Bieszczady/Bukovské vrchy Mts (Polish and Slovak sides, respectively) from where 82 species have been reported (Kuthan *et al*. 1999; Gierczyk *et al*. 2009), Tatra National Park, with 66 species of *Russula* presently known, seems to be relatively well investigated. Considering the richness of habitats in the Tatra Mts, however, we believe that the true diversity of *Russula* species in the region is higher. Further investigation of rarely visited areas in the Tatra Mts (mainly in the Slovak High and West Tatras) should produce interesting new data.

Dubious taxa or doubtful records

Some records of *Russula* species reported in the literature are doubtful because of possible misidentification of specimens or misinterpretation of species concepts. There is an urgent need for revision of herbarium material in order to clarify the identity of specimens. Unfortunately, most papers do not mention herbaria where the collected material has been deposited. In some cases, voucher specimens of some published records may not be deposited in any herbarium. Below is an annotated list of records we regard as dubious or doubtful, which are excluded from our synthesis.

1. ***Russula alutacea*** (Pers.) Fr.

References: Pilát (1926), Dominik & Pachlewski (1956), Nespiak (1962a), Škubla (1998a, b).

Note. The species has been reported from several localities by several authors, suggesting that it is rather common in the area. However, the current interpretation is narrow and refers to *R. alutacea* ss. Melzer & Zvára, a very rare species associated with *Fagus* or *Quercus*, more rarely *Picea*, and occurring on rich soil (Kränzlin 2005; Knudsen *et al.* 2008), while the fungus has been reported from the study area either from the High Tatra Mts (poor soils, absence of *Fagus*) or without a detailed locality.

2. ***Russula amoena*** Quél.

References: Frejlak (1973).

Note. The species is associated with *Castanea*, *Quercus* and *Fagus* (Kränzlin 2005; Sarnari 2005), but it was reported from spruce forest in the vicinity of Morskie Oko lake, where none of its symbiotic trees occurs (Myczkowski 1975; Radwańska-Paryska 1975).

3. ***Russula cicatricata*** Romang. *ex* Bon

REFERENCES: Kuthan (1989b).

NOTE. Recent study of *R. clavipes* and related taxa, including the type collection of *R. cicatricata*, revealed that the species is known only from the type locality and two collections from Greenland (Adamčík 2004; Adamčík & Knudsen 2004). That work also showed that most herbarium specimens collected in Central Europe and determined as *R. cicatricata* represent *R. clavipes* (Adamčík 2004).

4. ***Russula curtipes*** F. H. Møller & Jul. Schäf.

REFERENCES: Škubla (1998b, c).

NOTE. *Russula curtipes* is mycorrhizal with *Fagus* (or *Quercus*), more rarely with other broad-leaved trees (Romagnesi 1967; Kränzlin 2005; Sarnari 2005; Knudsen *et al.* 2008), but it was reported from Podbanské where neither *Fagus* nor *Quercus* occur and only spruce-dominated forest is present (Michalko *et al*. 1984).

5. '***Russula depallens*** Ricken'

REFERENCES: Pilát (1926).

NOTE. There is probably an error in the author's phrase: the record may represent *R. depallens* ss. Ricken = *R. vesca* Fr. (Sarnari 1998, 2005).

6. ***Russula emeticella*** (Singer) Romagn.

REFERENCES: Kuthan & Singer (1987).

NOTE. The name *R. emeticella* has been used for various taxa and is not accepted in recent taxonomic treatments (Sarnari 1998). The report from the Tatra National Park probably refers to a species with affinity to *R. silvestris* Singer.

7. ***Russula emeticolor*** (Jul. Schäff.) Singer

REFERENCES: Nespiak (1960, 1962a).

NOTE. The species was reported from the Tatra Mts exclusively from the alpine belt, but it is reported to be associated with *Fagus* and to occur at lower elevations (Kränzlin 2005; Sarnari 2005; Knudsen *et al.* 2008).

8. ***Russula firmula*** Jul. Schäf.

REFERENCES: Skirgiełło (1991).

NOTE. The specimen reported by Skirgiełło (1991) represents a species with a very low spore ornamentation. Currently, *R. firmula* is recognized as characterized by spores covered with high spines (Sarnari 1998; Kränzlin 2005; Knudsen *et al.* 2008).

9. ***Russula krombholzii*** Schaffer

REFERENCES: Škubla (1998b).

NOTE. *Russula krombholzii* is a synonym of *R. undulata* Velen., a species associated primarily with *Quercus*, a tree absent from the Tatry Mts (Myczkowski & Lesiński 1974; Radwańska-Paryska 1975). Although it may occur more rarely under conifers (Sarnari 1998; Knudsen *et al.* 2008) it prefers warm locations (Kränzlin 2005).

10. ***Russula laricina*** Velen.

REFERENCES: Lizoň & Kautmanová (2004).

NOTE. *Russula laricina* is reported to be likely conspecific with *R. nauseosa* (Knudsen *et al.* 2008), a fungus frequently occurring in the Tatra Mts.

11. ***Russula linnaei*** Fr.

REFERENCES: Pilát (1926).

NOTE. The name *R. linnaei* ss. Bres. refers to *R. paludosa* (Sarnari 2005). Although Pilát (1926) did not specify the species concept that he followed, he probably used Bresadola's concept, as in his other publication (Pilát 1951) he mentions '*R. linnaei* Bres.' under synonyms of *R. paludosa* Britzelm. However, as *R. linnaei* ss. auct. non Bres. refers to other species (e.g., *R. lepida* Fr.) we prefer to treat the record of *R. linnaei* from the Tatra Mts as uncertain.

12. '***Russula livida*** Gramb.'

REFERENCES: Dominik & Pachlewski (1956).

NOTE. The name '*R. livida* Gramb.' is not interpretable. There is probably an error in the

author's phrase; the record may represent *R. livida* (Pers.) Schroet. = *R. heterophylla* (Fr.) Fr. (e.g., Kränzlin 2005).

13. ***Russula pascua*** (F. H. Møller & Jul. Schäff.) Kühner

REFERENCES: Kuthan (1989a).

NOTE. The specimen collected by Kuthan (1989a) has been revised; it represents *R. subrubens* (Adamčík & Knudsen 2004).

14. ***Russula pruinosa*** Velen.

REFERENCES: Škubla (1998c).

NOTE. *R. pruinosa* is a dubious name. According to Romagnesi (1967) it is a synonym of *R. xerampelina* var. *marthae* Singer, while according to Sarnari (2005) it is a possible synonym of *R. graveolens* Romell.

15. ***Russula violacea*** Quél.

REFERENCES: Škubla (1998b).

NOTE. The name is interpreted variously in the literature. *R. violacea* ss. Romagn. is a species associated with *Populus*, rare on the Slovak side of the Tatras (Radwańska-Paryska 1975). According to Kränzlin (2005) *R. violacea* Quél. ss. Schäff. et auct. non ss. Quél. is a synonym of *R. cavipes* Britzelm.

16. ***Russula viscida*** Kudřna

REFERENCES: Škubla (1998c).

NOTE. The species typically grows in montane mixed forest with *Abies*, *Fagus* and *Picea* (Sarnari 2005). Its presence at the higher elevation of the subalpine belt (a site with *Pinus mugo*) seems doubtful.

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