CHECKLIST AND ECOLOGY OF THE AGARICALES, RUSSULALES AND BOLETALES IN THE ALPINE ZONE OF THE ROCKY MOUNTAINS (COLORADO, MONTANA, WYOMING) AT 3000-4000 M A.S.L.

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Cripps, C.L. & Horak, E. 2008. Checklist and Ecology of the Agaricales, Russulales and Boletales in the alpine zone of the Rocky Mountains (Colorado, Montana, Wyoming) at 3000–4000 m a.s.l. – Sommerfeltia 31: 101-123. ISBN 82-7420-045-4. ISSN 0800-6865.

Previously, the Rocky Mountain alpine zone was a mycological blank spot. There have only been a few scattered records of macrofungi from this region and limited number of publications. This alpine survey covers the Beartooth Plateau in Montana/Wyoming for the North-central Floristic Region (lat 45^{0}N) and the Front Range, San Juan Mountains, Sawatch Range for the Southern Floristic Region in Colorado (lat 36^0–38^{0}N), and reports over 165 species in 46 genera and 11 families (ca 1 500 collections). It is estimated that over 75% are known arctic-alpine macromycetes and the remainder are Rocky Mountain species. Of these, we estimate that 2–5% are new to science, 75% are new records for this Rocky Mountain alpine zone, and that over half will be new to Colorado or Montana/Wyoming. Approximately 56% are mycorrhizal species associated with *Salix reticulata, S. arctica, S. planifolia, S. glauca, Betula nana = B. glandulosa*, *Dryas octopetala* and *Polygonum viviparum*. Mycorrhizal species that occur with *Betula* are rare in the Rockies due to a paucity of this host. The most diverse mycorrhizal family is the Cortinariaceae with over 74 species, primarily of *Inocybe* and *Cortinarius*. Saprobic genera associate with a diversity of bryophytes or are terrestrial primarily in grassland; macrofungi on woody debris are rare. A greater diversity occurs in southern mountain ranges which are more diverse in geology and habitat. The southern extent of the Rockies at latitudes of 36–38^{0}N likely includes the southernmost extent of certain Arctic-alpine fungi such as *Arrhenia auriscalpium* for the Northern hemisphere. Macrofungal fruitings are sparse compared to those in maritime arctic-alpine habitats due to a well-defined continental climate with drying winds, low relative humidity, periodic droughts, fire, strong diurnal temperature fluctuations and high elevations of 3 000–4 000 m. This report helps complete distributions of arctic-alpine fungi, and discusses the ecology of individual taxonomic groups in relation to other Arctic-alpine areas.

Keywords: Alpine, Agaricales, Boletales, Ecology, Macrofungi, Rocky Mountains, Russulales.

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INTRODUCTION

The arctic-alpine macrofungi are relatively well known in the Alps, Scandinavia, Greenland, Iceland, Scotland and to a lesser extent in Russia, Alaska, Canada and Antarctica. Prior to our research only a limited number of fungi have been recorded for the Rocky Mountain alpine zone south of the Canadian border (Overholtz 1919, Kauffman 1921, Seaver & Shope 1930, Solheim 1949, Miller & Evenson 2001). Most reports are from brief sojourns into the high elevation habitats and cite only a few alpine species. A few additional studies have contributed knowledge of alpine plant-fungal associations in the Rockies (Lesica & Antibus 1986a, 1986b, Gardes & Dahlberg 1996, Schadt et al. 2003, Cripps & Eddington 2005). Meinhard Moser's brief visits revealed 31 species of alpine *Cortinarius*, 13 of them new, and these are included in this report (Moser & McKnight 1987, Moser 1993, Moser et al. 1994, 1995).

The present report results from the first extensive survey and documentation of arctic-alpine macrofungi for the Rocky Mountain alpine zone in North America south of the Canadian border. This study focused on two primary floristic zones above timberline along the spine of the Rockies between latitudes 36^0–45^0N. This area includes the extensive alpine areas of the Beartooth Plateau just north of Yellowstone National Park in Montana/Wyoming which is part of the Middle-Northern Rocky Mountain Floristic Zone with tree-lines at ca 3 000 m at latitude 45^0N. Further south into Colorado, the high mountain passes and cirques of the Front Range, Sawatch Range, and the San Juan Mountains provide ample alpine areas with treelines at ca 3 700 m; these lie within the Southern Floristic Zone of the Rockies at latitude 36–38^0N. Southern alpine areas are thousands of miles from the Arctic and could well represent the southernmost extent of arctic-alpine species within North America. A list of identified taxa collected within these alpine areas is provided and the diversity, distribution, ecology within families is discussed.

STUDY AREA

The Rocky Mountains extend along the spine of North America, continuing 5 000 km from the Canadian border to New Mexico (and further into Canada; however, these areas are not covered here). The main cordillera is composed of numerous mountain ranges each with unique geological and ecological features. The bedrock is a complex of igneous, metamorphic and sedimentary rock with younger ranges uplifting in the Cretaceous 65–140 million years ago and Precambrian 400–600 million years ago. Glaciation occurred periodically from the Pleistocene to the Holocene. Less than 15 000 years ago, 90% of Yellowstone National Park was covered with ice from the recent Pinedale Glaciation period. The "little ice age" with glacial advance lasted from 1550 to 1860 (Grove 1990). The Rocky Mountain alpine tundra, although fragmented on mountain tops, constitutes a phytogeographically significant region, comprised of the Northern, Middle, and Southern floristic provinces across a range of latitudes (Arno & Hammerly 1984). This study comprised sites above treeline at 3 000 m in the north at latitude 45^0N (Montana and Wyoming) and at 3 700 m in southern Colorado between latitudes 37–39^0N. Certain alpine areas both in the north and in the south escaped glaciation.

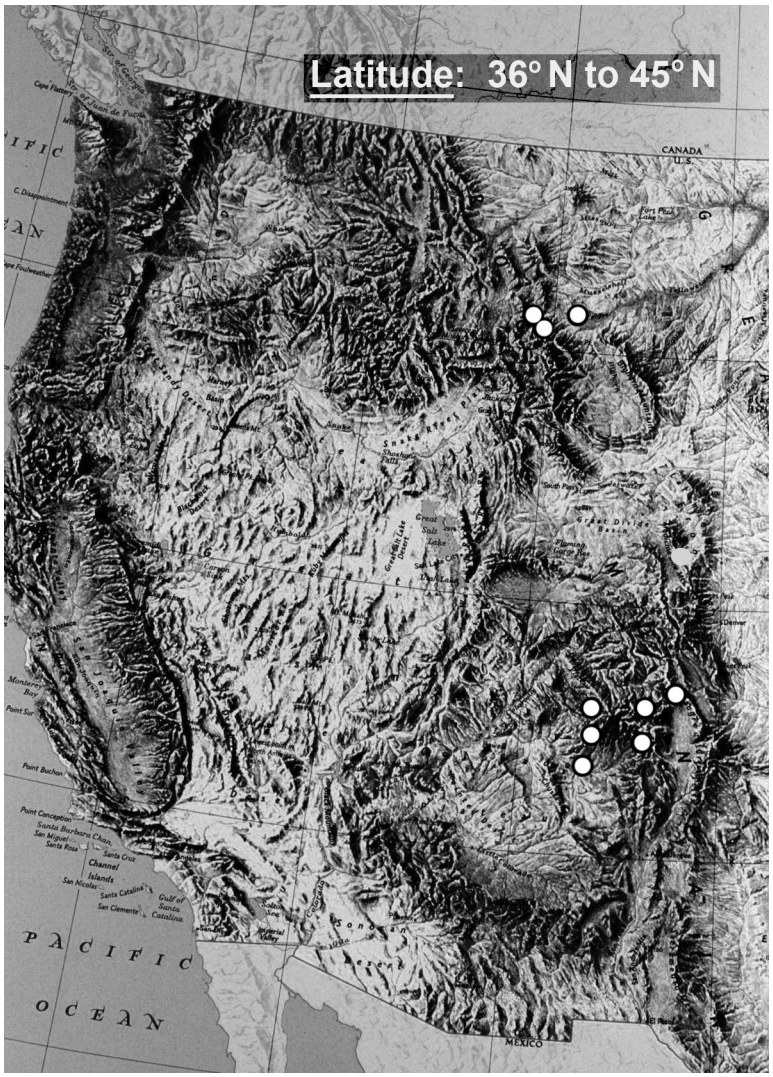

Fig. 1. Western USA. Rocky Mountain alpine collecting sites for macrofungi: Middle-Northern Floristic Zone = Beartooth Plateau (MT/WY), Southern Floristic Zone = Medicine Bow Mts (WY), Colorado Front Range, Sawatch Range and San Juan Mts (CO). (Used with permission of the National Geographic Society.)

Middle-northern floristic zone

The Beartooth Plateau is the primary study area for this floristic zone, and extends from Montana (MT) into northern Wyoming (WY). It is one of 11 plateaus along the MT-WY border, which together comprise the most extensive alpine tundra in the lower 48 states. The area is floristically diverse with over 432 species of alpine plants which is attributed to its east-west orientation with many moist N-facing slopes and high elevation areas in the south which escaped glaciation (Anderson 1994, Cooper

et al. 1997). About 900 000 hectares have been designated wilderness, and a substantial portion of this is above the 3,000 m treeline. The Beartooth Plateau itself is about 20 km long by 10 km wide, at lat. 45^{0}N and long. 109^0 W. The vast sweeping gentle slopes are covered by an intricate patchwork of meadows, shrubby wetlands, grasslands and fell-fields. The plateau was formed from an uplift of Precambrian granitic rock cut by basaltic and acid-porphyry dikes (Johnson & Billings 1962). There is no weather data for this site, but precipitation could be considered closest to that of Niwot Ridge, CO, except for a peak of rain/snow in May-June in the Beartooths (Cooper et al. 1997). This puts the annual precipitation (mostly snow) near 1000 mm/yr and the average annual temperature at around –3.8^{0}C. The geology and soils (Nimlos & McMcConnell 1962), vegetation (Johnson and Billings 1962, Bamberg & Major 1968, Anderson 1994, Scott 1995, Cooper et al. 1997), and lichens (Eversman 1995) have been studied. For details of the willows see Dorn (1970) and Heinze (1994). Treeline in the northern areas is bordered by *Pinus albicaulis, Picea engelmanii*, and *Abies lasiocarpa*. The collecting season is typically from the middle of July until the end of August or longer if temperatures remain high and moisture persists. Serious drought has affected the area periodically over years making collection of fungi a challenge.

Southern floristic zone

The southern Rocky Mountains are isolated from the northern mountain ranges by the Wyoming Plateau. Southern ranges run mostly north-south and are primarily granitic flanked by sedimentary rock, but this varies for particular ranges. The individual study sites lie in a chain along the Continental Divide at elevations from 3 600 to 4 000 m and lat. 36–38^{0}N. The sites include high mountain passes, unique cirques, and basins with a wealth of habitats including open windswept slopes, shrubby wetlands, extensive dwarf *Salix* and *Dryas* patches, meadows, turf, and fell-fields. The alpine vegetation is well-studied in Colorado and consists of approximately 440 vascular plant species (Willard 1979, Webber 1987). Limestone areas often support distinct vegetation (Arno & Hammerly 1984). The overlap between the Arctic plant flora and these alpine areas decreases towards the south to only 25% in common (Blair 1996). Trees that border the alpine are *Picea engelmanii* and *Abies lasiocarpa*. Weather data from Niwot Ridge can be used for these sites, and for the San Juan Mountains Engineer Pass at 3 350 m precipitation of 1100 mm/yr has been recorded of which most coming as snow (Blair 1996). Most sites in the San Juan Mountains require lengthy hikes or a four-wheel drive jeep for access, but high passes in the Sawatch and Front Ranges are more accessible. The fruiting season is from mid-July through August or into September after which snow can close the high areas.

Ectomycorrhizal vascular plants

The primary ectomycorrhizal plants of these areas include dwarf willow species *S. reticulata* L., *S. arctica* Pall. and rarely *S. rotundifolia* Trautv. and *S. cascadensis* Cockll. (Dorn 1970, Heize 1994, Scott 1995, Cripps & Eddington 2004). Extensive dwarf willow mats occupy low, wet areas and more upland sites. Shrub willows consist primarily of *S. glauca* L. which is more common in the southern areas and *S. planifolia* Pursh. with mahogany red stems that is more prevalent in the north. Shrub willows can cover extensive areas and while to the European eye these larger willows might not be considered part of the true alpine, in the Rockies they are an integral part of the alpine habitat, extending past treeline to 4 000 m. *Betula glandulosa* Michx. (= *B. nana* L.) is rare in the Rocky Mountain alpine and thus macrofungi which typically associate with birch are constrained to areas where it exists. This, along with the dry climate, renders the Rocky Mountain mycoflora more de-

pauperate than maritime Arctic-alpine areas. The bistort *Polygonum viviparum* L. is also ectomycorrhizal, at least on the Beartooth Plateau (Cripps & Eddington 2005). *Dryas octopetala* L. mats can be extensive, and often occur early in plant succession in the north. These mats can be exceedingly dry, and in times of drought, few fungi fruit from *Dryas*. In certain areas of the Beartooth Plateau, 90% of the roots are covered with *Cenococcum geophilum*, a fungus that does not produce above-ground fruiting bodies. *Dryas* in the southern sites can be on more lush sites mixed with willows as well as on harsh open slopes. In the Montana alpine, *Dryas* is reported on a mix of limestone, granite, gneiss soils with limestone predominating, and pH ranges of 6.2–7.8. *Salix glauca* appears more on calcareous sandstone in Montana and *S. planifolia* on more granitic type soils with an average pH of 6.3. Dwarf willows are likewise on a mix of soils with pH averages of 6.5–7.3 (Cooper *et al.* 1997). In the Rocky Mountains delineation between calcareous and granitic soils is not as clear as in Europe, and calcareous dust blown in from western deserts can complicate the edaphic and ecological conditions of the habitats.

Alpine vegetational community types

Alpine vegetation community types for Montana are described in Cooper et al. (1997) although the Beartooth Plateau is not addressed directly. The bibliography does include alpine literature on vegetation and soils for the Beartooth Plateau and vegetation and soil surveys for several mountain ranges in Colorado (Eddleman & Ward 1984). Vegetation consists of a patchwork of open turf and *Geum* meadows, wetlands of willows and moss, and extensive fell-fields with limited vegetation. Bryophytes have not been studied for the Beartooth Plateau, but limited work has been done in the Colorado alpine.

MATERIAL AND METHODS

Basidiomes were collected from 1999 to 2003 from areas listed in Table 1; locations for the general collecting areas are shown in Fig. 1 with the Beartooth Plateau in the North, and the Front Range, Sawatch Range and San Juan Mountains marked in the south. Species were described, photographed, drawn, and identified on subsequent completion of microscopic examination in 3% KOH. Fresh material was dried and packaged and voucher specimens are kept at MONT (Montana State University, Bozeman, MT) and at ZT (Geobotanical Institute, ETH, Zurich, Switzerland).

The species list for the study area is based upon more than 1 500 collections, and also includes species noted by Moser in previous publications (Moser & McKnight 1987, Moser 1993, Moser *et al.* 1994, 1995).

Additional note: While many of the reported species are new reports for the Rocky Mountain alpine zone south of the Canadian border, some have been previously reported from arctic areas of Alaska and western Canada. It is beyond the scope of the present study to include more than a few of these references for comparison at this point.

Tab. 1. Western USA. Rocky Mountain alpine collecting sites for macrofungi: Middle-Northern Floristic Zone = Beartooth Plateau (MT/WY), Southern Floristic Zone = Medicine Bow Mts (WY), Colorado Front Range, Sawatch Range and San Juan Mts (CO).

Field site	County, state	Range/pass	Elevation
Birch site: 1	Carbon, MT	Beartooths	3 000
Highline Trail: 2	Park, MT	Beartooths	3 100
Frozen Lakes: 3	Park, WY	Beartooths	3 150
Gardiner Headwall: 4	Park, WY	Beartooths	3 400
Solifluction Terrace: 5	Park, WY	Beartooths	3 400
Sugarloaf Saddle	Carbon, WY	Medicine Bow	3 500
Loveland Pass	Clear/Summit, CO	Front Range	3 655
Summit Lake	Summit, CO	Front Range	3 700
Niwot Ridge	Boulder, CO	Front Range	3 600
Independence Pass	Pitkin/Chaffee, C	Sawatch Range	3 660
Blue Lake Dam (birch)	Summit, CO	10-mile Range	3 500
Quartz Creek (birch)	Gunnison, CO	Sawatch Range	subalpine
Haggerman's Pass	Lake, CO	Sawatch Range	3 600
Cottonwood Pass	Gunnison, CO	Sawatch Range	3 700
Cumberland Pass	Gunnison, CO	Sawatch Range	3 600
Linkin Lake Valley	Pitkin, CO	Sawatch Range	3 780
Cinnamon Pass	San Juan, CO	San Juan Mts	3 840
Horse Shoe Lake	San Juan, CO	San Juan Mts	3 810
U.S. Basin	San Juan, CO	San Juan Mts	3 660
Stony Pass	San Juan, CO	San Juan Mts	3 840
Black Bear Pass	San Juan, CO	San Juan Mts	3 900
Molas Pass	San Juan, CO	San Juan Mts	3 500
Engineer Pass	Hinsdale, CO	San Juan Mts	4 000

RESULTS AND DISCUSSION

Over 165 species in 46 genera and 11 families are reported from the Rocky Mountain alpine zone (Appendix 1), but the list is still not complete as species are still being identified. Approximately 58% are mycorrhizal species, primarily associated with *Salix reticulata, S. arctica, S. planifolia, S. glauca, Betula nana*, *Dryas octopetala* and *Polygonum viviparum*. Important mycorrhizal genera are *Inocybe* (22+ species), *Cortinarius* (35+), *Hebeloma* (7), *Entoloma* (2 mycorrhizal species), *Laccaria* (5) and Russulales (12).

Mycorrhizal species that occur with birch have been extremely rarely recorded in the Rockies due to rarity of this host. We have recorded only *Leccinum rotundifoliae* (Sing.) A.H. Sm., Thiers & Watling, *Lactarius pubescens* (Fr.) Fr. and *Lactarius glyciosmus* (Fr.) Fr. as strictly associated with *Betula*. Only one small shrub of *Betula* was found on the Beartooths and both the *Leccinum* and *L. glyciosmus* were collected nearby; this being the only known occurrence of these species on the plateau. These three macromycetes were prolific with *Betula* in the only area studied in Colorado where birch

occurs in an alpine area considered to be a relict vegetation type (Webber, pers. comm.). The saprobic genera *Arrhenia, Gerronema, Rickenella, Mycena, Omphalina, Galerina, Hypholoma* and *Psilocybe* species were associated with a diversity of bryophytes. We report *Arrhenia auriscalpium*, a true arctic-alpine fungus from the southern Rockies, but not from the northern sites. Macrofungi on wood were rare and so far limited to *Crucibulum* and *Flammulina*. Terrestrial saprophytes included species of *Agaricus, Agrocybe, Calocybe, Clitocybe, Collybia, Cystoderma, Hygrocybe, Lepista, Melanoleuca* and *Stropharia.* Rarer yet were *Alnicola, Dermoloma, Fayodia, Hemimycena, Lepiota, Marasmiellus* and *Rhodocybe*. To date, four new species have been identified (*Agrocybe praemagna, Amanita absarokensis, Entoloma sp.* and *Laccaria pseudomontana*). A majority of species (74+) belonged in the family Cortinariaceae which has a high diversity in western North America, both in subalpine and alpine habitats, and this is particularly true for the genus *Cortinarius*, subgenus *Telemonia* in the alpine. The 13 new *Cortinarius* species described by Moser for the Rocky Mountain alpine are included as well (Moser 1993, Moser & McKnight 1987, Moser et al. 1994, 1995). Species richness was, in general, higher in the south, likely due to a higher diversity of geology, different habitat types and precipitation. Webber (pers. comm.) has suggested that northern areas have been stressed by drought due to their exposed location. The ecology and distributions of individual basidiomycete families are discussed relative to other arctic-alpine regions in the systematic treatment.

COMMENTED LIST OF SPECIES

The following treatment addresses families, genera and species as enumerated in Appendix 1.

Basidiomycota: Agaricales, Boletales, Russulales

Agaricus* cf *aristocratus Gulden

(Fig. 2)

Description. Pileus up to 70–90 mm in diam, fleshy, convex, white, distinctly scaly and floccose-scaly at margin, cuticle extending beyond the gills; lamellae free, pink-gray becoming brown in age; annulus floccose, flaring up or down; stipe 30–60 × 15–25 mm, substantial, white, equal but pointed at base, smooth above annulus, minutely floccose below; odor faint; context firm, generally no color change except some yellow at base.

Observations. The two collections made at 3 100 m (Montana) and 3 600 m (Colorado).

Taxonomic note. This appears as a substantial and scaly form of *A. campestris*. The two collections fit the description for *Agaricus aristocratus* Gulden due to a robust stature, scaly cap, overhanging pileus margin, and substantial annulus (Gulden *et al.* 1988: 41, Gulden and Torkelsen 1996).

Note on distribution. If confirmed, this will be the first report of this species for alpine areas of Colorado and Montana.

Agaricus campestris L.

Observations. Beartooth Plateau and the southern Rockies, in open meadows, not common.

Fig. 2. *Agaricus* cf. *aristocratus* Gulden from the Beartooth Plateau, exhibiting a scaly pileus, overhanging cuticle, and more substantial annulus than the typical *A. campestris.*

Agrocybe praecox (Pers.) Fayod

Observations. One of earliest species to fruit in the alpine zone, occurs in open grasslands or in grass near willows in the lower alpine zone.

Taxonomic note. Basidiomes typical for this well known species as are the microscopic characteristics.

Agrocybe praemagna E. Horak & M.M. Moser

Taxonomic note. The new species *A. praemagna* E. Horak & M.M. Moser (2006) is characterized by large, ringless basidiomes.

Note on distribution. From alpine and subalpine areas of Montana and Wyoming, and under aspen at lower elevations (Horak and Moser 2006).

Amanita absarokensis (sp. n., ad int.)

(Fig 3)

Description. Pileus 50–70 mm in diam, broadly convex, pale salmon, mottled with pale metallic brown color in age, with one to few patches of cream-colored universal veil; lamellae free, crowded, white to dingy cream or pale salmon; annulus lacking; stipe 30–70 × 12–10 mm, enlarged at base, buff with pink tint, surface pruinosity breaking up into adder-pattern; volva saccate, flaring out, cream color or pale pink buff staining ocher; odor unpleasant.

Observations. Basidiomes can be prolific on the Beartooth Plateau, associated with both dwarf and shrubby willow and possibly *Dryas* (Table 2). Found throughout the short season from July to September in wet and mesic habitats.

Taxonomic note. The new species in sect. Vaginatae is named for the Absaroka Mountains.

Fig. 3. *Amanita absarokensis* (sp.n., ad int). from the Beartooth Plateau in MT/WY, Rocky Mountains, USA. It is close to *A. groenlandica* but differs by a more salmon-colored pileus, velar tissue which does not gray on drying, a less viscid pileipellus and taller stature.

It appears close to *A. groenlandica* Bas ex Knudsen & T. Borgen (1987) from which it differs by a pale orange pileus and velar material that does not gray on drying. In aspect, it is also taller and less squat than *A. groenlandica*. Microscopic characteristics are similar to *A. groenlandica* with globose spores 9.5–11(12) × 10–12(13) µm and filamentous velar tissue with some sphaerocysts present. It is significantly more robust than the arctic-alpine fungus *A. nivalis*.

Note on distribution. To date only known from alpine areas of the Beartooth Plateau where it fruits prolifically; it is not recorded for Colorado or elsewhere (Table 2).

Amanita nivalis Grev. s.l.

Observations. Species is in alpine situations with dwarf willows *S. reticulata* and *S. arctica*, and occasionally with shrubby willow *S. glauca*.

Taxonomic note. Collections fit *Amanita nivalis* s.l. as described by Gulden *et al.* (1985: 25) with a grayish pileus and pinkish-salmon tinted lamellae. Similarly, basidiomes are rather small and delicate for this genus. Large collections of fruiting bodies allowed examination of variation in universal veil remnants on the pileus which can be absent, remain as a few patches, or can separate into scattered warts. The latter condition can be a result of dry conditions even though the velar structure of filamentous tissue remains constant (Knudsen & Borgen 1987). The microscopic structures, in particular the globose spores measuring 9–11 µm, fit this typical arctic-alpine species. Other related arctic species such as *A. arctica* Bas, Knudsen & Borgen and *A. mortenii* Knudsen & T. Borgen have not been found in the Rocky Mountains.

Note on distribution. All collections are from the southern Rocky Mountains and from over half of the individual passes and cirques visited there (Table 3). No representatives are reported for

Tab. 2. Distribution of *Amanita absarokensis* (sp. nov., ad int.). All sites are on the Beartooth Plateau in southern Montana and northern Wyoming.

Collecting site	Host	Elevation
Beartooths: site 1	*Salix reticulata* (D)	3 000 m
Beartooths: site 2	*Salix reticulata* (D), *S. glauca* (S), *S. planifolia* (S)	3 100 m
Beartooths: site 4	*Salix reticulata* (D)	3 400 m
Beartooths: site 5	Salix reticulata & S. arctica (D)	3 400 m

Tab. 3. Collections and distribution of *Amanita nivalis* in the Colorado alpine. FR = Front Range, SW = Sawatch Range, SJ = San Juan Mountains. S = shrub, D = dwarf.

Collecting site	Host	Elevation
FR: Loveland Pass	*Dryas octopetala* & dwarf *Salix*	3 650 m
SJ: Cinnamon Pass	Mixed dwarf willows	3 850 m
SW: Cottonwood Pass	*Salix glauca* (S)	3 700 m
SW: Cumberland Pass	*Salix glauca* (S)	3 800 m
SJ: Mineral Basin	*Salix reticulata* (D)	3 650 m
SJ: Stony Pass	*Salix reticulata* (D) & *S. arctica* (D)	3 700 m
SJ: Black Bear Pass	*Salix reticulata* (D)	3 900 m
SW: Independence Pass	not noted	3 650 m
SW: Independence Pass	*Salix reticulata* (D)	3 650 m

northern sites. This is the first published account of this species from alpine areas of Colorado, likely near its southernmost distribution in North America.

Amanita vaginata (Bull.) Lam.

Observations. A specimen typical of *A. vaginata* is reported from the Beartooth Plateau with shrubby willows *S. planifolia* and *S. glauca*.

Note on distribution. Occurs in subalpine areas with conifers and aspen (Cripps 1997) and this is the first report for the adjacent alpine zone. All three species of *Amanita* reported for the Rocky mountain alpine zone are in sect. Vaginatae.

Arrhenia lobata (Pers.) Kühner & Lamoure ex Redhead

Observations. Common some years in the San Juan Mountains and absent in others. It occurs primarily on moss along streams, we suspect high run-off events of periodically scouring the moss substrates from stream banks. On the Beartooth Plateau, where it is less common, two collections are on woody debris instead of moss as for most specimens.

Note on distribution. This *Arrhenia* species is recorded for northern and southern alpine sites and is also known from subalpine mossy habitats in Montana.

Arrhenia auriscalpium (Fr.) Fr.

Observations. A rare taxon now reported from both Independence and Loveland Pass at elevations of 3 300–3 700 m on open soil near the lichen *Thamnolia subuliformis* (Cripps & Horak 2006).

Note of distribution. Extends the distribution of this true arctic-alpine fungus to 37^{0}N, which is likely near the southern extent of its range which northwards reaches to the Arctic.

Clitocybe dryadicola (J. Favre) Harmaja

Observations. Discovered once among *Dryas octopetala*, and known to associate with *Dryas* in actic-alpine habitats.

Notes on distribution. This is the first report for the Rocky Mountain alpine region.

Collybia cookei (Bres.) J.D. Arnold

Observations. This taxon occurs in shrubby *Salix* litter and is reported once each on northern and southern sites.

Cortinarius absarokensis M.M. Moser & McKnight

Observations. Moser and McKnight (1987) first described this species from the Beartooths, and we confirm that it is common on the plateau with shrubby willows and also occurs in southern alpine areas studied. Extremely large specimens up to 10 cm in diam were noted in some areas of Colorado.

Taxonomic note. It is typically delineated by its larger basidiomes and association with shrubby willows in contrast to *C. favrei* which is smaller and favors dwarf willows.

Note on distribution. Sister species *C. favrei* is common both in Europe and North America however, *C. absarokensis* is rare in the Alps according to Moser. Here we extend its distribution to the southern Rocky Mountains.

Cortinarius favrei D.M. Hend.

Observations. Widely distributed and often encountered in the Rocky Mountains with dwarf willows, and recorded for most of our sites. It was first confirmed on the Beartooth Plateau by Moser and McKnight (1987), and the pale form he described is also present. It fruits from willow mats even in dry weather. Some basidiomes are of intermediate size making confirmation of identification (*A. absarokensis* or *A. favrei*) difficult in situations of mixed willows. A few medium-sized specimens fruiting below mixed willows on Independence Pass had brilliant lavender gills in contrast to others in the same collection with pale lamellae, and this did not appear to result from age.

Note on distribution. This well known species of many arctic-alpine habitats is now extended from Moser's original report on the Beartooths to the southern Rocky Mountains.

Entoloma alpicola (J. Favre) Bon & Jamoni

Observations: One of the most frequently observed macrofungi in mats of dwarf willows *S. reticulata* and *S. arctica*, and more rarely with *Dryas octopetala* in the alpine zone. It appears particularly abundant on the Beartooth Plateau where it fruits even in dry seasons and during years of low rainfall.

Taxonomic notes. A robust species for this genus in the alpine zone recognized by a greasy gray brown pileus, stout white stipe and pink angular spores.

Notes on distribution. Known from other arctic-alpine habitats, this was first reported by Moser and McKnight (1987) as *Entoloma clypeatum* (L.) P. Kumm. var. *alpicola* J. Favre on the Beartooth Plateau and now it is confirmed in both the northern and southern Rocky Mountains.

Hebeloma mesophaeum (Pers.) Fr. s.l.

Observations. A form of *Hebeloma mesophaeum* common with shrubby willows in the alpine zone, and the species is also known with conifers and aspen in subalpine areas of the western USA. Three alpine *Hebeloma* species have been reported from Colorado (Miller & Evenson 2001), and this includes Loveland Pass. In dry years, Hebelomas are nearly absent from the Rocky Mountain alpine.

Hygrocybe conica (Scop.) P. Kumm. s.l.

Observations. Occasionally found in alpine grasslands; the genus is not nearly as common as known for arctic-alpine grasslands in Europe. Also, a greater diversity of arctic-alpine *Hygrophorus* species has previously been reported from Alaska (Laursen et al. 1987).

Note on distribution. Species occurs in southern and northern Rocky Mountains, but is rarely observed.

Hygrocybe marchii (Bres.) Singer (= *Hygrocybe constrictospora* Arnolds)

Observations. One collection is reported from the high elevation of 3 700 in Colorado on rotten debris of grasses.

Hygrocybe psittacina (Schaeff.) P. Kumm.

Observations. One collection is reported from the high elevation of 4 100 m in Colorado in moss.

Inocybe calamistrata (Fr.) Gillet

Observations. Appears occasionally on both southern and northern alpine sites with willows, and is known from subalpine habitats in the area likely with conifers.

Taxonomic note. Easily recognized by its scaly brown pileus, a stipe that stains turquoise and a fishy odor; basidiomes are quite miniature in the alpine compared to subalpine habitats. A few collections with wide spores are separated out *as I. subhirsuta* Kühner.

Note on distribution. It was first reported on the Beartooths in 1987 by Moser and McKnight and is now confirmed in the southern Rocky Mountain alpine for the first time.

Inocybe dulcamara (Alb. & Schwein.) P. Kumm.

Observations. Common in Colorado, but does not occur with any frequency in MT/WY in the alpine zone.

Taxonomic note. Many forms of this species exist, and most specimens fit Favre's description of *I. dulcamara f. typique* (1955: 74). The form *f. peronata* is also reported and delineated by a peronate veil. Additional forms are present but sufficient material is lacking for complete description.

Note on distribution. Various forms are also known from arctic habitats in Canada and Siberia (Ohenoya *et al.* 1998) and the Alaskan tundra (Miller 1987). This is the first report for the Rocky Mountain alpine to our knowledge, however the typical form is known from aspen forests in Montana and other western habitats (Cripps 1997).

Inocybe giacomi J. Favre

Observations. Occurs on the Beartooth Plateau and at high elevations (3 600 m) on Independence Pass of Colorado's Sawatch Range. Common on the Pass along with several other *Inocybe* species with sub-nodulose spores.

Inocybe lacera (Fr.) P. Kumm.

Observations. One of few *Inocybe* species reported for the Beartooths, and also occurs in the Colorado alpine. Collections are often from open gravelly soil near willows.

Taxonomic note. Apparently at least two forms of this species exist in the alpine zone of the Rockies, a more typical form and one with red-staining flesh and a spermatic odor that is currently delineated as [*Inocybe lacera*] *f. americana* (in ed.).

Note on distribution. The typical species is known from other arctic-alpine habitats and from subalpine areas of the Rocky Mountains (Cripps 1997).

Inocybe cf ***leiocephala*** D.E. Stuntz

Observations. This species is common on northern, but not southern sites and found under willows.

Taxonomic note. Specimens are considered to best fit *I. leiocephala* s.l. described from western subalpine habitats. It is recognized as the only taxon with smooth spores and a completely pruinose stipe reported for these Rocky Mountain alpine sites to date. However, additional study is necessary to determine if it is truly the subalpine species described with conifers and/or that reported from the Alps.

Inocybe rufofusca (J. Favre) Bon

(= *Inocybe pratervisa* var. *rufofusca* J. Favre)

Taxonomic note. One of the few nodulose-spored species from sites, the pileus exhibits a more red brown than the typical golden form. However, microscopic features are the same (Horak 1987).

Note on distribution. First described for the alpine zone of the Swiss National Park (Favre 1955) and now recorded for the Rocky Mountain alpine zone.

Laccaria laccata var. ***pallidifolia*** Peck (Peck)

(= *L. tetraspora* Singer)

Observations. To date this species is reported only with *Betula* and *Dryas* and not willows in alpine habitats (Osmundson et al. 2005).

Note on distribution. Occurrences are from one area of the Colorado Front Range where *Betula* and *Dryas* occur in wet habitats, and the species is not reported from Northern sites where it is known to occur in the subalpine.

Laccaria montana Singer

Observations. One of only two *Laccaria* species reported from alpine habitats of the Beartooth Plateau primarily with shrubby willow.

Taxonomic note. It is recognized by its four-spored basidia which contrasts with the only other Beartooth species, *L. pumila,* which has two spores per basidium.

Note on distribution. Common on the Beartooth Plateau, it is apparently rare in the Colorado alpine, according to our records.

Laccaria nobilis A.H. Sm.

Observations. This taxon is reported for the first time in association with shubby willows.

Taxonomic note. This is a small alpine form of *L. nobilis* A.H. Sm. originally thought to be *L.*

bicolor until it was sequenced with the type of *L. nobilis* (Osmundson et al. 2005). *Laccaria nobilis* is a western North American species which produces a violet mycelium similar to *L. bicolor*, but has been previously separated by mating and molecular studies. *Laccaria nobilis* is usually considered to be a larger form of *L. bicolor* by western mycologists, but the alpine form is small and often lacks the violet coloration at the stipe base. However, the mycelium is violet in culture at first, and sporocarps that proliferate in collecting boxes can confirm this (Osmundson et al. 2005). It can also be recognized by its rather rough-striate stipe compared to other alpine species.

Note on distribution. It is only recorded for the low alpine in Colorado however the type is from a mountainous area of Colorado with Pinaceae.

Laccaria pseudomontana Osmundson, C. Cripps and G.M. Mueller

Observations. Discovered in three alpine locations of Colorado, all with shubby willows present, and one also with birch.

Taxonomic notes. This newly described species has small dark reddish fruiting bodies that look similar to those of *L. montana*, but molecular data and different (lighter?) spore ornamentation support its taxonomic separation (Osmundson et al. 2005).

Note on distribution. It is reported for the type locality at Blue Lake Dam in Colorado, the San Juan Mountains and Independence Pass.

Laccaria pumila Fayod

Observations. Associated almost exclusively with shrubby willows, with a few rare reports for *S. arctica*.

Taxonomic note. This is the only two-spored species of *Laccaria* recorded for our alpine sites, but it is macroscopically similar to the four-spored species *L. montana.*

Note on distribution. It is reported from all sites on the Beartooth Plateau and most cirques of the San Juan Mountains, and only one low elevation site for the Colorado Front Range.

Lactarius glyciosmus (Fr.) Fr.

Observations. This species fruits annually near the only birch shrub on the Beartooths and was also observed at the Blue Lake Dam site (the other occurrence of *Betula*). It is also known from subalpine areas of Colorado where bog birch occurs.

Lactarius nanus J. Favre

Observations. The tiny *L. nanus* occurs with dwarf willows, at least with *S. arctica* on our alpine sites. It is easily over-looked because of its small size and drab color.

Note on distribution. This species was first reported from the Beartooth Plateau by Moser and McKnight (1987) and is recorded again, along with an extension of its range into the San Juan Mountains of Colorado.

Lactarius pubescens (Fr.) Fr.

Observations. Occurrence is limited to areas where *Betula* exists and is also known from the subalpine where birch extends to lower elevations.

Lactarius repraesentaneus Britzelm.

Observations. The large-bodied *L. repraesentaneus* Britzelm. is reported with *Salix glauca* in Colorado

and on more calcareous soils of Cottonwood and Independence Pass. It also occurs at a particular area of the Beartooth Plateau where *S. glauca* is present. All areas are in the lower alpine elevation zone. It is known to associate with conifers in the Rocky Mountains at lower elevations, and *Betula* in the Alaskan tundra (Laursen and Ammirati 1982). These are the first reports with *Salix* in Rocky Mountain alpine habitats.

Lactarius cf. ***salicis-reticulatae*** Kühner

Observations. A small pale yellow species with pale salmon gills and acrid taste that appears to fit *L. salicis-reticulatae* occurs at 3600–3800 m with dwarf willow and possibly *Betula.* Collections of this taxon need further examination. This species is reported from arctic Canada along with other arctic-alpine species of *Lactarius* (Ohenoya & Ohenoya 1993).

Leccinum rotundifoliae (Singer) A.H. Sm., Thiers & Watling

Observations. Only one species of bolete is reported from the true alpine above treeline for all sites visited. It occurs regularly with the only *Betula* shrub found to date on the Beartooth Plateau and is prolific at one collecting site in Colorado which is a low elevation relict area where *Betula* spans alpine and subalpine elevations. *Suillus sibiricus* (Singer) Singer occurs in the lower krummholz zone on the Beartooth Plateau, but always near the 5-needle *Pinus albicaulis*.

Note on distribution. This species is known with *Betula nana* in arctic-alpine habitats, and from below treeline with birch in the western USA. It is reported here for the first time on the Beartooth Plateau and for particular sites in Colorado.

Lepiota alba (Bres.) Sacc.

Observations. Pure white fruiting bodies are reported from a grassland at 3 700 m in the San Juan Mountains.

Note on distribution. This is the first report of this species for alpine areas of Colorado.

Lepiota magnispora Murrill (= *L. ventriosospora* D.A.Reid)

Observations. Two fruiting bodies are reported from an open meadow high in the Colorado Front Range.

Note on distribution. This is the first report of this species for alpine areas of Colorado.

Marasmius epidryas Kühner

Observations. Known to occur on *Dryas* species, *M. epidryas* is reported here with *Dryas octopetala.*

Note on distribution. These collections are from Loveland Pass in Colorado and so far not elsewhere on our Rocky Mountain sites. However, it is reported in the Canadian Rockies to the north, in Alaska, and Glacier National Park (Horak, pers. obs.; Redhead et al. 1982).

Omphalina rivulicola (J. Favre) Lamoure

Observations. By far the most common *Omphalina* species particularly in Colorado where it grows deep in mosses along small waterways.

Note on distribution. This is the first report for alpine areas of Montana, Wyoming and Colorado.

Psilocybe chionophila Lamoure

Observations. This species is common on dead or dying moss, particularly along stream channels. Its occurrence is commonly associated with the previous presence of grazing cattle and it has been observed fruiting in moss compromised by hoof prints.

Rickenella fibula (Bull.) Raithelh.

Observations. This bright orange species occurs in wet mosses along streams and lakes.

Note on distribution. This fungus is commonly reported from arctic-alpine habitats and it is now reported for both northern and southern Rocky Mountain alpine sites.

Rickenella swartzii (Fr.) Kuyper

(= *R. setipes* (Fr.) Raithelh.)

Observations. This taxon with a lilac stipe apex is reported in moss from Colorado.

Russula cf. ***delica*** Fr.

Observations. This taxon fits *Russula delica* as described for other arctic-alpine habitats with minor differences that are yet to be evaluated. Rocky Mountain specimens are reported in the vicinity of *Dryas* and dwarf willows with shrubby willows nearby. Basidiomes are typically buried in the litter and can go unnoticed.

Taxonomic note. The species is recognized by a white concave pileus and pale greenish cast to the gills, reminiscent of a small *R. brevipes* Peck.

Notes on distribution. This species is known from a variety of arctic-alpine habitats and this is the first formal report for the Rocky Mountain alpine.

Russula nana Killerm.

Observations. *Russula nana* has been reported on the Beartooths without its typically hot taste (Moser & McKnight 1987). It is noteworthy, however, that our specimens run the gamut from acrid, radish hot, to mild. This well known arctic-alpine agaric with a cherry red pileus fading to white is ubiquitous in the Rocky Mountain alpine, primarily with dwarf willows. It spans all alpine elevations of our sites.

Note on distribution. *Russula nana* is now reported for Niwot Ridge, the Beartooth Plateau, the Front Range, Sawatch Range and from most cirques in the San Juan Mountains. This helps complete its global distribution which apparently stretches to northern arctic-alpine habitats around the North Pole.

Russula laccata Huijsman

(= *R. norvegica* D.A. Reid)

Observations. Specimens of *R. laccata* were consistently acrid to the taste. Similarly, *R. laccata* was found on most of the same sites as *R. nana* with dwarf willows, and is likewise a common species. It is delineated by a deep blackish red pileus.

Note on distribution. This is the first formal report of this species in the Rocky Mountain alpine zone, but is a well known arctic-alpine fungus.

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

Observations. One of the more robust species of *Russula* recorded, this species was primarily with *Salix glauca* in southern areas.

Taxonomic note. Species is recognized by its fishy odor and mottled brown-yellow cap.

Note on distribution. This is the first formal report of this species in the Rocky Mountain alpine zone.

ACKNOWLEDGMENTS

We would like to thank the National Science Foundation Biotic Surveys and Inventories Program for funding this research, and in particular for funding graduate student Todd Osmundson and eight undergraduate students who aided in field work, database entry and voucher accession in the MONT Herbarium. We also thank our field assistants Almut Horak and Don Bachman for their volunteer work and constancy.

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Appendix 1. Preliminary list of species of alpine Agaricales, Russulales & Boletales in the Rocky Mountains of Colorado, Montana, and Wyoming, USA at elevations of ca. 3000 to 4000 m. F = frequent, O = occasional and R = rare (typically 1 collection).

AGARICALES
AGARICACEAE (& LEPIOTACEAE)
Agaricus cf *aristocratus* Gulden (R)
Agaricus campestris L. (F)
Agaricus spp. (R)
Lepiota alba (Bres.) Sacc. (R)
Lepiota magnispora Murrill (=*L. ventriosospora* D.A. Reid) (R)

AMANITACEAE
Amanita absarokensis (sp.n., ad int.) (F)
Amanita nivalis Grev. (O)
Amanita vaginata (Bull.) Lam. (R)

BOLBITIACEAE
Agrocybe praecox (Pers.) Fayod (O)
Agrocybe cf. *praemagna* E. Horak & M.M. Moser
Conocybe spp. (R)

COPRINACEAE
Coprinus sp. (R)
Anellaria semiovata (Sowerby) Pearson & Dennis

CORTINARIACEAE
Alnicola sp. (R)
Cortinarius absarokensis M.M. Moser & McKnight (F)
Cortinarius adelbertii J. Favre (R)
Cortinarius albonigrellus J. Favre (R)
Cortinarius anomalous (Fr.) Fr. (R)
Cortinarius atroalbus M.M. Moser (R)
Cortinarius caninus Fr. (R)
Cortinarius chrysomallus Lamoure (R)
Cortinarius expallens M.M. Moser (R)
Cortinarius favrei D.M. Hend. (F)
Cortinarius ferrugineifolius M.M. Moser (R)
Cortinarius fuscoflexipes M.M. Moser & McKnight (R)
Cortinarius galerinoides Lamoure (R)
Cortinarius hinnuleus Fr.
Cortinarius hybospermus M.M. Moser (R)
Cortinarius inops J. Favre (R)
Cortinarius laetus M.M. Moser (R)
Cortinarius minutalis Lamoure (= *C. hinnuleus* (Fr.) var. *minutalis* J. Favre) (R)
Cortinarius mucronatus M.M. Moser & McKnight (inval., non *C. mucronatus* Rob. Henry)
Cortinarius paraphaeochrous M.M. Moser (R)
Cortinarius pauperculus J. Favre (O)

Cortinarius phaeochrous J. Favre (R)
Cortinarius phaeopygmaeus J. Favre (R)
Cortinarius pusillus M.M. Moser, McKnight & Sigl (inval., non F.H. Møller, non Murrill) (R)
Cortinarius rufoanulifer M.M. Moser & McKnight (R)
Cortinarius stenospermus Lamoure (R)
Cortinarius subrigidipes M.M. Moser (R)
Cortinarius subtorvus Lamoure (R)
Cortinarius tenebricus J. Favre (R)
Cortinarius vibratilis (Fr.) Fr. (R)
Cortinarius vulpicolor M.M. Moser & McKnight
Cortinarius sp. (violet-gilled *Sericeocybe*) (O)
Dermocybe cinnamomeolutea (P.D. Orton) M.M. Moser (F)
Dermocybe polaris (Høiland) N. Arnold (O)
Dermocybe spp.
Galerina annulata (J. Favre) Singer
Galerina arctica (Singer) Nezdojm.
Galerina atkinsoniana A.H. Sm. (O)
Galerina clavata (Velen.) Kühner (= *G. heterocystis* (G.F. Atk.) ss. auct. europ.
Galerina cf. *pseudomycenopsis* Pilát (O)
Galerina unicolor (Vahl) Singer (R)
Galerina spp.
Hebeloma alpinum (J. Favre) Bruchet (O)
Hebeloma bruchetii Bon (O)
Hebeloma crustuliniforme (Bull.) Quél. (R)
Hebeloma kuehneri Bruchet (O)
Hebeloma mesophaeum (Pers.) Fr. (F)
Hebeloma pusillum J. E. Lange (O)
Hebeloma spp.
Inocybe bulbosissima (Kühner) Bon (R)
Inocybe calamistrata (Fr.) Gillet (O)
Inocybe canescens J. Favre (R)
Inocybe dulcamara (Alb. & Schwein.) P. Kumm.
Inocybe dulcamara f. *peronata* J. Favre (O)
Inocybe fraudans (Britzelm.) Sacc. (R)
Inocybe fuscomarginata Kühner (R)
Inocybe geophylla (Pers.) P. Kumm. (R)
Inocybe giacomi J. Favre (O)
Inocybe lacera (Fr.) P. Kumm. (F)
Inocybe lacera f. *americana* (f.n., ad int.) O
Inocybe cf. *leiocephala* D.E. Stuntz (F in North)
Inocybe maculipes J. Favre (O)
Inocybe cf. *malençonii* R. Heim (O)
Inocybe mixtilis Britzelm. (O)
Inocybe perbrevis (Weinm.) Gillet (R)
Inocybe cf. *rhacodes* J. Favre (R)
Inocybe rimosa (Bull.) P. Kumm. (R)
Inocybe rufofusca (J. Favre) Bon (F)
Inocybe cf. *taxocystis* (J. Favre ex E. Horak) Senn-Irlet

Inocybe spp. (R)
Phaeogalera stagnina (Fr.) Pegler & T.W.K. Young (R)
Tubaria sp. (R)

ENTOLOMATACEAE
Entoloma alpicola (J. Favre) Bon & Jamoni (F)
Entoloma cetratum (Fr.) M.M. Moser
Entoloma juncinum (Kühner & Romagn.) Noordel.
Entoloma sericeum (Bull.) Quél.
Entoloma (sp. n., ad int.)
Entoloma (*Nolanea*) spp.
Entoloma (*Leptonia*) spp.
Entoloma (*Alboleptonia*) sp.
Entoloma spp.
Rhodocybe cf. *popinalis* (Fr.) Singer (R)

HYGROPHORACEAE
Hygrocybe conica (Scop.) P. Kumm. (O)
Hygrocybe marchii (Bres.) Singer (= *Hygrocybe constrictospora* Arnolds) (R)
Hygrocybe psitticina (Schaeff.) P. Kumm. (R)

STROPHARIACEAE
Hypholoma polytrichi (Fr.) Ricken (O)
Psilocybe chionophila Lamoure (F)
Psilocybe sp. (R)
Stropharia alpina M. Lange (O)
Stropharia sp. (R)

TRICHOLOMATACEAE
Arrhenia auriscalpium (Fr.) Fr. (R)
Arrhenia lobata (Pers.) Kühner & Lamoure ex Redhead (F)
Arrhenia (*Pleurotellus*) *acerosa* (Fr.) Kühner (R)
Arrhenia sp. (R)
Calocybe chrysenteron (Bull.) Singer (R)
Calocybe onychina (Fr.) Kühner (R)
Clitocybe dryadicola (J. Favre) Harmaja (R)
Clitocybe lateritia J. Favre (O)
Clitocybe spp. (O)
Collybia cookei (Bres.) J.D. Arnold (R)
Cystoderma granulosum (Batsch) Fayod (R)
Cystoderma sp. (R)
Dermoloma sp. (R)
Fayodia leucophylla (Gillet) M. Lange & Sievertsen (R)
Flagelloscypha sp. (R)
Flammulina velutipes (Curtis) Singer (R)
Gerronema marchantiae Singer & Clémençon (R)
Gymnopus (*Collybia*) spp. (O)
Hemimycena sp. (R)

Hydropus sp. (R)
Laccaria laccata var. *pallidifolia* (Peck) Peck (= *L. tetraspora* Singer) (O)
Laccaria montana Singer (O)
Laccaria nobilis A.H. Sm. (O)
Laccaria pseudomontana Osmundson, C. Cripps & G.M. Muell. (R)
Laccaria pumila Fayod (F)
Lepista spp. (O)
Lyophyllum deliberatum (Britzelm.) Kreisel [= *L. infumatum* (Bres.) Kühner] (R)
Marasmius epidryas Kühner (R)
Melanoleuca cognata (Fr.) Konrad & Maubl. (O)
Melanoleuca subalpina (Britzelm.) Bresinsky & Stangl (= *M. evenosa* ss. auct. europ.) (O)
Mycena citrinomarginata Gillet (O)
Mycena pura (Fr.) P. Kumm. (R)
Mycena spp. (R)
Mycenella sp. (R)
Omphalina rivulicola (J. Favre) Lamoure (F)
Omphalina velutipes P.D. Orton (O)
Omphalina spp. (R, O)
Rickenella fibula (Bull.) Raithelh. (O)
Rickella swartzii (Fr.) Kuyper [= *R. setipes* (Fr.) Raithelh.] (R)
Rhodocollybia butyracea (Bull.) Lennox (R)
Rugosomyces fallax Bon (R)

RUSSULALES
RUSSULACEAE
Lactarius glyciosmus (Fr.) Fr. (R)
Lactarius nanus J. Favre (O)
Lactarius cf. *pseudouvidus* Kühner (R)
Lactarius pubescens (Fr.) Fr. (R)
Lactarius repraesentaneus Britzelm.
Lactarius salicis-reticulatae Kühner (O)
Lactarius spp.
Russula cf *delica* Fr. (O)
Russula nana Killerm. (F)
Russula laccata Huijsman [= *R. .norvegica* D.A. Reid] (F)
Russula cf. *pascua* (F.H. Møller & Jul. Schäff.) Kühner (O)
Russula spp. (R)

BOLETALES
BOLETACEAE
Leccinum cf. *rotundifoliae* (Singer) A.H. Sm., Thiers & Watling (R)