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Current knowledge of Umbrian macrofungi (central Italy)

P. ANGELINI[1], A. ARCANGELI[1], G. BISTOCCHI[1], A. RUBINI[2], R. VENANZONI[1], & C. PERINI[3]

[1]*Department of Chemistry, Biology and Biotechnology, University of Perugia, Italy;* [2]*National Research Council, Institute of Biosciences and Bioresources, Italy and* [3]*Department of Life Sciences, BIOCONNET, BIOdiversity and CONservation NETwork, University of Siena, Italy*

Abstract

An annotated checklist of 1016 species of fungi (Ascomycota and Basidiomycota), which have been recorded in 95 different localities, from 1990 to 2015, is presented for Umbria (Italy). The checklist was compiled from records of Umbrian fungi in scientific publications, unpublished lists and personal observations. This work represents the first comprehensive checklist of macrofungi for Umbria. Even if not complete, an exhaustive overview of the current knowledge of the mycobiota of Umbria is presented. Although a large amount of the regional territory has still to be explored for mycological diversity, this study offers an important support in compiling red-lists of endangered macrofungi, as well as to identify indicator species of particular habitats to be considered for wildlife reserves, as is currently done in many European countries.

Keywords: *Ascomycota, Basidiomycota, biodiversity, conservation, distribution, taxonomy*

Introduction

Conventionally, fungal species that produce fruiting bodies visible to the naked eye (greater than 1 mm in size) are grouped together as macrofungi (Arnolds 1981). They play an important role in the Earth's ecosystems. Saprotrophic macrofungi contribute to carbon cycling by decomposing woody debris on the forest floor (Thormann 2006), while mycorrhizal macrofungi aid the survival of other forest species by mobilizing nitrogen and phosphorus (Read & Perez-Moreno 2003).

Furthermore, macrofungi can establish numerous interactions with other organisms (mutualistic and/or antagonist) and can be an important source of food and medicine for humans and animals (Pagiotti et al. 2011; Picco et al. 2011; Angelini et al. 2006, 2008, 2009, 2012b; Perotto et al. 2013).

Despite their central role in ecosystems, and their applications in biotechnology (Perotto et al. 2013), they have largely been neglected and overlooked in national and international nature conservation actions, due to the lack of information on their distribution, abundance and underexplored taxonomic diversity (Zotti et al. 2013; Pecoraro et al. 2014). However, thanks to the research of professional and amateur mycologists and field observations, over the last few decades our knowledge has significantly increased. It is thus now largely feasible to evaluate the present and future status for fungal species diversity and how it is affected by human activities, such as land management procedures (Senn-Irlet et al. 2007; Perini et al. 2008; Heilmann-Clausen et al. 2014).

Located in the heart of Italy, Umbria is one of the smallest Italian regions (area: 28,456 km^2, 50–2436 m a.s.l.) and the only one on the peninsula to be landlocked. The climate, as revealed by the phytoclimatic analysis of the Umbria region and according to bioclimatic indices, can be defined as temperate macroclimate, upper hilly thermotype, lower humid umbrotype, with dry summers and maximum precipitation in spring and autumn (Venanzoni et al. 1998). The lowest temperatures are recorded in January–February, frequently falling below 0°C. The highest temperatures occur in July and August, normally reaching a maximum of 30°C, and rarely going above 35°C (Venanzoni et al. 1998). The landscape of Umbria consists mostly of mountains and hills, with an altitude between 40 m in the south and 2478 m on Mt. Vettore, situated in the East. The territory of the region is crossed by the rivers Tiber, Nera and Velino, the latter forming the amazing waterfall "cascata delle Marmore", located to the east of Terni. Of great relevance for

Correspondence: P. Angelini, Department of Chemistry, Biology and Biotechnology, University of Perugia, Via del Giochetto 6, 06123 Perugia, Italy. Tel: +39 0755857346. Fax: +39 075 5857346. Email: maurizio.sajeva@unipa.it

the presence of various characteristic habitats is also Lake Trasimeno, the biggest lake of Apennines (128 km^2) but only 6 m deep. Some 30% of the territory is hilly and 70% is considered mountainous. From a geobotanic point of view, Umbria belongs to the middle European floristic region with "islands" of the Mediterranean flora in more internal sectors (the transition zone between temperate and Mediterranean bioclimates) producing a patchiness at regional scale with a great richness and diversity of habitats and vegetation (Venanzoni et al. 1998).

The woods are characterized by the presence of downy oak (*Quercus pubescens* Willd.), turkey oak (*Quercus cerris* L.) and ash (*Fraxinus ornus* L.) groves mixed with evergreen sclerophyllous species. Southern and south-western hill slopes with rocky outcroppings are characterized by mesophilic holm oak (*Quercus ilex* L.) groves, while northern, eastern and western hill slopes mostly hold turkey oak and semi-mesophilic ash groves together with sweet chestnut (*Castanea sativa* Mill.) woods on rain-gathering grounds (Granetti et al. 2005).

There is a long history of research carried out for understanding the ecology of hypogeous fungi (Granetti et al. 2005). This region is particularly famous for the cultivation of truffles for which three international congresses have been held in Spoleto (Umbria) in 1968, 1988 and 2008 (Donnini 2010). On the other hand, compared to other Italian regions, little was known concerning the presence of epigeous macrofungi (Onofri et al. 2005; Patusso & Zotti 2009).

The study of Umbrian macrofungi can be traced back to the end of the twentieth century, with the publication of Tafini (1995), which included data of 100 species from approximately 150 different locations, and with a publication of Regione Umbria (1997) which included a list of 80 species. It is worthy to mention that the great mycologist Mauro Sarnari, born in Narni (TR, Umbria) who was an expert of the genus *Russula*, of the Mediterranean species in particular, described several new species most of them typical of Umbria (i.e.: *Russula convivialis, Russula cupreoaffinis*, *Russula dryophila*, *Russula faustiana*, *Russula fuliginosa*, *Russula inamoena*, *Russula rhodomarginata* and *Russula rhodomelana*) (Sarnari 1998, 2005).

Recently, the data of these early works were significantly enriched thanks to the activities promoted by the mycological amateur groups of Umbria (AMI-Umbria, Umbrian Mycologist Associations). Therefore, the need begins to emerge for an organized archive of Umbrian macrofungi based on taxonomic and geographical criteria. This is indispensable for the subsequent steps, such as the creation of an accurate Umbrian distribution map and a regional red-list.

The main aims of this work were to provide a picture of the present knowledge of the Umbrian macrofungi and to give information about the ecology and distribution of the listed species. This study may represent a valuable aid in compiling a red-list of endangered macrofungi and may help to identify indicator species to monitor ecological integrity and to select nature reserves, as it happens in other European countries.

Materials and methods

The present checklist is based on unpublished macrofungal lists compiled during the scientific committees of AMi Umbria in the last four years (Supplemental Annex 1) and data from the revision (in particular for species from taxonomically difficult genera or groups of species of doubtful occurrence) of mycological collections present in the herbarium of Perugia University (PERU), private herbaria, as well as from observations and private annotations of mycologists working in Umbria.

The list also includes information gleaned from literature (Ubaldi 1985; Sarnari 1988, 1990, 1991; Ribaldi & Pagiotti 1993; Sarnari 1993; Courtecuisse & Duhem 1994; Paolocci et al. 1995; Tafini 1995; Regione Umbria 1997, 1999, 2011, 2013; Farnesi et al. 1998; Donnini et al. 2000; Bistocchi et al. 2001; Mazzeschi et al. 2003; Sarnari 1998, 2005; Granetti et al. 2005; Onofri et al. 2005; Benucci et al. 2011; Carletti 2011; Rubini et al. 2011; Venturella et al. 2011; Angelini et al. 2012a, 2015, 2016a, 2016b, 2016c; CEMM 2015).

Before publication, a database of all macrofungi including date and source of the record, the name as it was originally published and the current name updated on 20 February 2016 according to the CABI Index Fungorum (http://www.indexfungorum.org/Names/Names.asp) was compiled.

The fungal records were obtained from 95 different localities of Umbria (Figure 1), from 1990 to 2015 (Table I, Figure 1). Species that appeared in multiple records, for same locality and year, were limited to one entry only. The distribution of relative species frequency and frequency of occurrence was analysed using a rank–frequency curve.

Based on relative frequency (range 0–1), the macrofungi were classified into the following five categories: rare/or rarely reported (0.01–0.20% occurrence), occasional/or infrequently reported (0.21–0.40%), frequent (0.41–0.60%), common (0.61–0.80%) and dominant. The frequency of occurrence and relative frequency of different species were determined by the following formula:

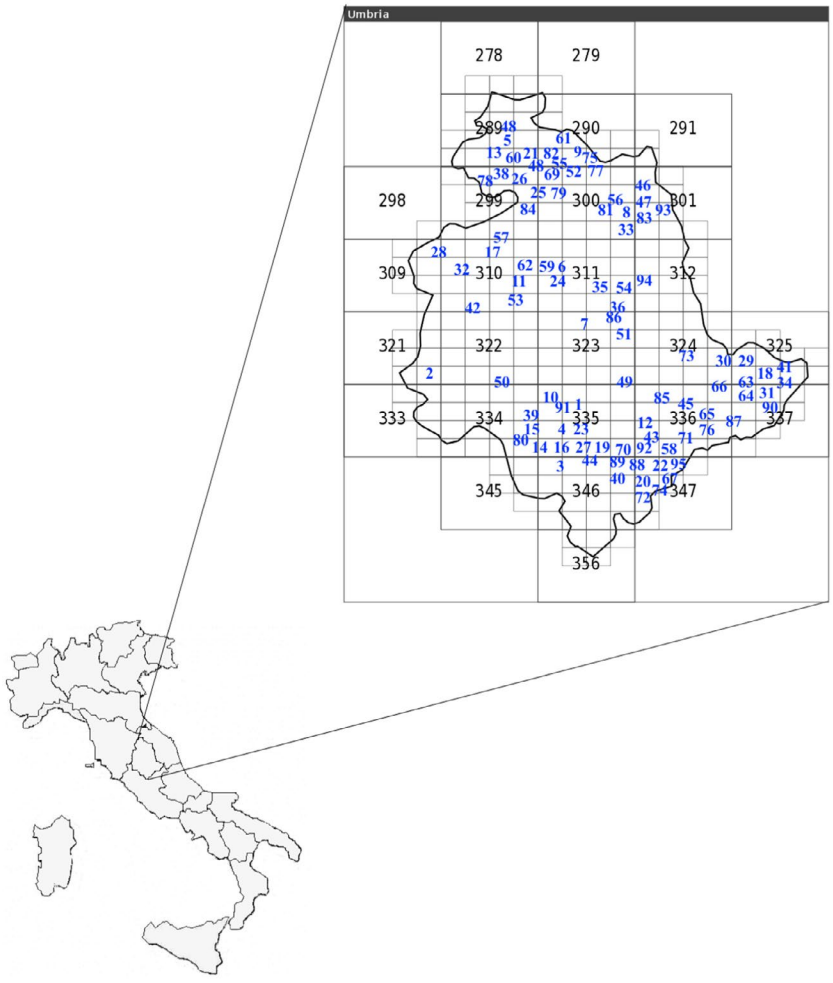

Figure 1. Map showing the 95 collection localities (Umbria, Italy) marked with a number (see Table I). The reported cartographic base of Umbria has been redrawn from CTR Technical Regional Map, scale 1:10,000, Umbria Region); the grid side corresponds to 1 km.

Frequency of occurrence (%): (number of sites in which the species is present/total number of sites) × 100

Relative frequency (%): (number of records for each species/total number of records) × 100

In order to calculate the frequency of occurrence, only records with precise sampling locations data were considered.

The compiled checklist includes entries for species within the phyla Ascomycota and Basidiomycota occurring in Umbria and supported by precise information about the locations of occurrence (Supplemental Annex 1). Entries belonging to the ascomycetes and basidiomycetes were reported separately and arranged in alphabetical order. Each specific and infra-specific name was reported followed by the author's name; for almost all entries the most significant and used synonyms were reported as well. For each entry, the following information was also given: the "distribution" reporting the collection localities according to the numeric code of Table I and Figure 1 and the bibliographic references and/or unpublished lists with the collection data of each record; the "habitat" reporting the description of the growth substrate and the code of Natura 2000 habitats (http://vnr.unipg.it/habitat/); the "conservation status" reporting the information about the Italian and European risk status; the code of specimen deposited at the "PERU Macrofungal Herbarium" of Perugia University when available. For some records (e.g. those retrieved from literature or from private mycological lists), only species description and/or photographic documentation were available. The photos of some representative species were provided in the Supplemental Annex 2. All these data will be available on the "anArchive" database (www.anarchive.it) at the Department of Chemistry, Biology and Biotechnology, University of Perugia (DCBB) (Venanzoni et al. 2012; Lucarini et al. 2015).

Table I. Number of fungal records and species per locality.

Localities		Species	Records
1	Acquasparta (TR)	3	3
2	Allerona (TR)	1	1
3	Amelia (TR)	12	14
4	Avigliano (TR)	205	212
5	Barzotti (Città di Castello, PG)	1	1
6	Basilica di San Pietro (PG)	2	2
7	Bettona (PG)	1	1
8	Branca (Gubbio, PG)	80	128
9	Caibelli (Gubbio, PG)	29	29
10	Camerata (Todi, PG)	28	38
11	Capocavallo (Corciano, PG)	2	2
12	Castagna Cupa (PG)	6	6
13	Castagneto (Città di Castello, PG)	12	12
14	Castagneto di S. Restituta (TR)	1	1
15	Castagneto di Toscolano (Avigliano Umbro, TR)	1	1
16	Castel dell'Aquila (Montecastrilli, TR)	30	33
17	Castel Rigone, Passignano sul Trasimeno (PG)	221	344
18	Castelluccio di Norcia (PG)	25	25
19	Cesi (TR)	1	1
20	Cimitelle (Stroncone, TR)	2	2
21	Città di Castello (PG)	1	1
22	Colle Bertone (Polino, TR)	27	33
23	Collelungo (Avigliano, TR)	1	1
24	Collestrada (PG)	359	944
25	Collevecchio (Città di Castello, PG)	10	10
26	Croce di Castiglione (Città di Castello, PG)	1	1
27	Farnetta (Montecastrilli, TR)	3	3
28	Ferretto (Castiglione del Lago, PG)	79	106
29	Forca di Ancarano (PG)	2	2
30	Forca di Gualdo (PG)	2	2
31	Forca Canapine (PG)	2	2
32	Isola Polvese (Castiglione del Lago (PG)	63	181
33	Le Terre del Verde (Gubbio, PG)	46	46
34	Macchia Cavaliera (Castelluccio di Norcia, PG)	37	37
35	Madonna dei tre Fossi (Assisi)	3	3
36	Madonna della Spella (Spello, PG)	10	10
37	Madonna della Valle (Bevagna, PG)	99	99
38	Marcignano (Monte S.M. Tiberina, PG)	8	8
39	Melezzole (Montecchio, TR)	241	248
40	Moggio (TR)	2	2
41	Monte Abuzzago (PG)	1	1
42	Monte Arale (Piegaro, PG)	1	1
43	Montebibico (Spoleto, PG)	36	40
44	Montecastrilli (TR)	1	1
45	Monte Coscerno (Sant'Anatolia di Narco, PG)	15	16
46	Monte Cucco (Costacciaro, PG)	68	69
47	Montefiore (Gubbio, PG)	56	85
48	Montemaggiore (Città di Castello, PG)	7	7
49	Montemartano (PG)	2	2
50	Monte Peglia (San Venanzo, TR)	112	112
51	Monte Santo Stefano (Foligno, PG)	1	1
52	Monti del Vento (Pietralunga, PG)	31	31
53	Mugnano (PG)	3	3
54	Mulino (Spello, PG)	25	25
55	Oasi di Candeleto (Pietralunga, PG),	50	50
56	Padule (Gubbio, PG)	46	46
57	Passignano sul Trasimeno (PG)	2	2
58	Penna Rossa (Collestatte, TR)	4	4
59	Perugia	358	648
60	Petricce (San Giustino, Pietralunga, PG)	1	1
61	Pianello di Cagli (PU in the proximity of Gubbio)	46	47
62	Pian di Massiano (PG)	1	1
63	Pian Grande (Parco Nazionale Monti Sibillini)	17	19
64	Piani di Castelluccio (Parco Nazionale Monti Sibillini)	1	1
65	Piani di Gavelli (Sant'Anatolia di Narco, PG)	17	17
66	Pian Perduto (Parco Nazionale Monti Sibillini)	5	5
67	Pie di Moggio (RI in the proximity of Marmore, TR)	1	1
68	Pietrolungo (Spello, PG)	2	2
69	Pieve dè Saddi (Pietralunga, PG)	22	22
70	Poggio Azzuano (Sangemini, TR)	2	2
71	Polino (TR)	52	52
72	Prati (Stroncone, TR)	17	21
73	Pupaggi (Sellano, PG)	1	1
74	Rascino (RI in the proximity of TR)	4	4
75	Salia (Gubbio, PG)	3	3
76	Salto del Cieco (Ferentillo, TR)	12	12

77	San Bartolomeo (Gubbio, PG)	29	29
78	San Leo Bastia (Città di Castello, PG)	1	1
79	San Lorenzo (Montone, PG)	29	29
80	Santa Restituta (Avigliano Umbro, TR)	2	2
81	San Vittorino (Gubbio, PG)	6	6
82	San Zino (Candeggio, Città di Castello, PG)	2	2
83	Spada (Gubbio, PG)	47	47
84	Spedalicchio (Umbertide, PG)	1	1
85	Spoleto (PG)	1	1
86	Stazzi (Spello, PG)	2	2
87	Tazzo (Cascia, PG)	3	3
88	Terni	4	4
89	Terni, via Martiri della Libertà	1	1
90	Val di Canatra (Norcia, PG)	65	67
91	Vallette (Todi, PG)	3	3
92	Valserra (TR)	2	2
93	Valsorda (Gualdo Tadino, PG)	118	158
94	Valtopina (PG)	246	308
95	Villalago (Piediluco, TR)	3	4

Results

The Umbrian checklist, based on 5232 records, includes 1016 species of macrofungi belonging to 296 genera and 93 families. The most represented were the Basidiomycota with 910 species, 239 genera and 70 families. At the class level, *Agaricomycetes* has the highest number of species (899), hosting almost the 99% of the entire set, followed by *Dacrymycetes* (5), *Tremellomycetes* (4) and *Puccinomycetes* (2) (Supplemental Annex 1).

The families that showed the highest number of species were the *Russulaceae* (146), *Tricholomataceae* (88), *Agaricaceae* (81), *Cortinariaceae* (64), *Boletaceae* (52), *Hygrophoraceae* (37) and *Amanitaceae* (35) which when combined, accounted for approximately 51% of the total. On the other hand, 17 families were represented by only one macrofungal species (Supplemental Annex 1).

The genera *Russula* was the most diverse with 106 species, followed by *Cortinarius* (52), *Tricholoma* and *Lactarius* (37), *Amanita* (32), *Mycena* (28) and *Agaricus* (25) (Supplemental Annex 1).

The Ascomycota are represented only by 106 (10.43%) species, distributed among 57 genera and 23 families (Figure 2, Supplemental Annex 1). The class *Pezizomycetes* has the largest number of species (72) followed by *Sordariomycetes* (15), *Leotiomycetes* (14), *Dothideomycetes* (2), *Orbilomycetes* (2) and *Eurotiomycetes* (1).

The families with the highest number of genera and species were the *Pyronemataceae* (23), *Tuberaceae* (15), *Helvellaceae* (12), *Pezizaceae* (10) and *Morchellaceae* (9), which combined accounted for approximately 6.79%. The most diverse genera, with 13 species, was *Tuber*, followed by *Peziza* (9) and *Helvella* (9) (Figure 2, Supplemental Annex 1).

The present study revealed that maximum frequency of occurrence was exhibited by *Russula heterophylla* (28.38), *Russula vesca* (28.38), *Amanita rubescens* (24.32), *Hygrophorus penarius* (22.97), *Amanita phalloides* (21.62) and *Russula maculata* (21.62) with distribution of records ranging from 17 (18.09%) to 22 (23.40%) of the 95 different localities studied (Figure 3; Supplemental Annex 1).

The distribution of relative frequency categories among the fungal species were: six common (*Russula delica*, *R. vesca*, *Hypholoma fasciculare*, *Lactarius chrysorrheus*, *Mycena rosea*, *Amanita rubescens*), 37 frequent, 103 occasional and 972 rare/or rarely reported. The fungal list of Umbria was dominated by rare/or rarely reported species (95.67%) with less than eight records (Figure 4; Supplemental Annex 1).

Among the Ascomycota, also *Scutellinia barlae*, *Scutellinia kerguelensis*, *Scutellinia olivascens* and *Scutellinia scutellata* are very rare. They were found in nine different localities on damp, rotten wood and bare soil (Supplemental Annexes 1–2).

Noteworthy in the macrofungal list (Supplemental Annex 1), is the presence of: (a) *Amanita eliae*, *Battarrea phalloides*, *Cortinarius orellanus*, *Hygrocybe spadicea*, *Leucopaxillus lepistoides*, *Lycoperdon mammiforme*, *Panaeolus cinctulus*, *Rhodotus palmatus*, *Russula seperina*, taxa included in the preliminary list of 23 species considered rare and/or threatened in Italy, as reported by the mycology work group for the Italian Botanical Society (Venturella et al. 1997); (b) *Boletopsis grisea*, *Cantharellus melanoxeros*, *Cortinarius ionochlorus Entoloma bloxamii*, *Myriostoma coliforme*, *Rubroboletus dupainii*, *Sarcosphaera coronaria*, taxa included in the list of 33 fungal species threatened at European level proposed for amendment to Annex 1 of the Bern Convention (Dahlberg & Croneborg 2006); (c) *Alessioporus ichnusanus*, *Entoloma bloxamii*, *Poronia punctata*, *Rubroboletus dupainii* (Supplemental Annexes 1–2), taxa recently included in the red-list of the Italian Flora (Rossi et al. 2013) (with 12 other "non policy species"), assessed against the IUCN Criteria and Categories. Moreover, in the nearby Tuscany, the only Italian region that has a fungal red-list, 12 species of the Umbrian checklist (*Alessioporus ichnusanus*, *Amanita lactea*, *Amanita porphyria*, *Battarrea phalloides*, *Boletus aemilii*,

Boletus fragrans, *Polyporus umbellatus*, *Hygrocybe punicea*, *Hygrocybe spadicea*, *Leucopaxillus lepistoides*, *Pulchroboletus roseoalbidus*, *Rickenella mellea*), are considered as critically endangered, endangered or vulnerable (Antonini & Antonini 2006).

Discussion

In this work, a checklist of macrofungi observed in Umbria over the last 25 years (1990–2015) in different deciduous forest ecosystems was compiled. The number of fungal species occurring in Umbria and documented on the basis of published information, unpublished lists and personal observations amount to 1016 of which 910 belonging to the Basidiomycota and 106 to the Ascomycota. The data considering regional population of macrofungal species is heterogeneous. We started our work by collecting relevant information from 29 publications (see References), some of them containing only limited information about regional distribution (Tafini 1995; Regione Umbria 1997, 1999, 2011, 2013; Angelini et al. 2016b). Most of the data have been recently collected in the field during the last five years thanks to the work of the "Unipg mycological group" (Angelini et al. 2012a, 2015, 2016a, 2016c), based at the Department of Chemistry, Biology and Biotechnology of University of Perugia, and thanks to unpublished data collected by the AMi Umbria (Umbrian Mycologist Associations). Thus, this checklist represents the first comprehensive listing of macrofungi that is known from Umbria.

By analysing the list, it appears that the macrofungi were represented by only a few families, with the seven richest families accounting for 58.3% of total diversity (Supplemental Annex 1).

By comparing the present checklist with data reported in Venturella et al. (2011), it appears that the number of macrofungi reported in Umbria is often similar to that found in other regions. At the family level, the composition of the macrofungi in Umbria is comparable, to that of Tuscany with *Cortinariaceae*, *Russulaceae* and *Tricholomataceae* being the most species-rich families in both regions (Antonini & Antonini 2004).

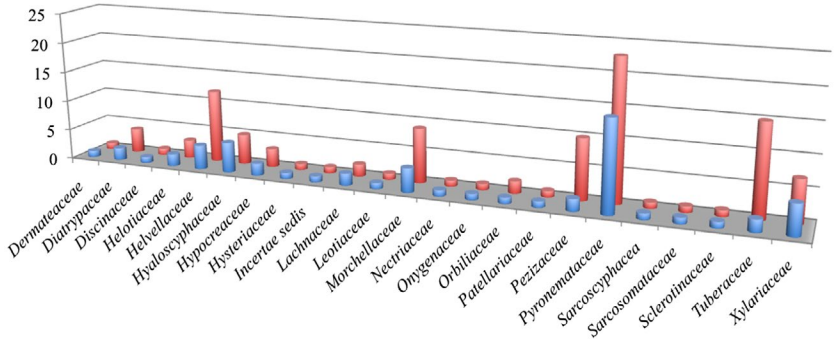

Figure 2. Distribution of macrofungal species and genera per family of Ascomycota: (i) the blue columns indicate the number of genera; (ii) the red columns indicate the number of species.

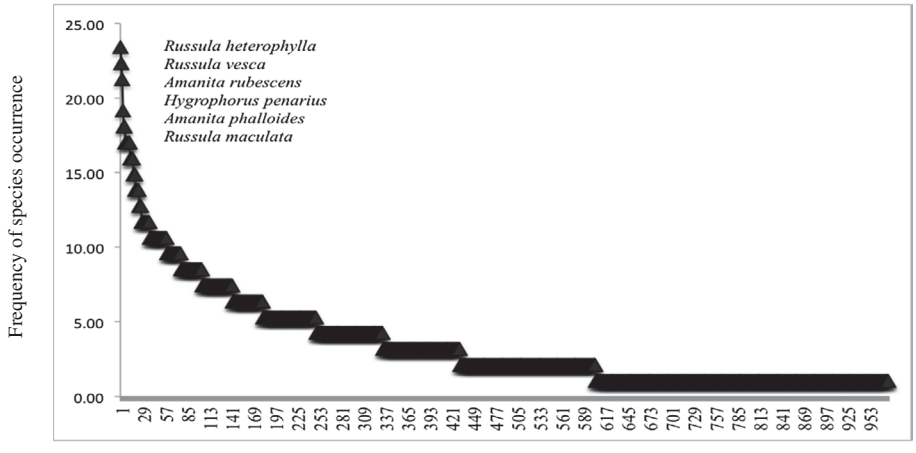

Figure 3. Dominance–diversity curves for Umbrian macrofungal species based on frequency of occurrence. Most occurring species to least occurring species are ordered from left to right.

The genera *Russula* and *Cortinarius*, with 106 and 52 species, respectively, (Supplemental Annex 1), described for Umbria, are those with the largest number of species. Such data are not surprising considering that these genera are also two of the most diverse of the *Agaricales* in Italy with about 227 and 416 species, respectively (Onofri et al. 2005). Despite their high diversity, 27 species of *Russula* (i.e. *Russula acetolens*, *Russula amoenolens*, *Russula badia*, *Russula cavipes*, *Russula clariana*) and 24 species of *Cortinarius* (i.e. *Cortinarius betuletorum*, *Cortinarius brassicolens*, *Cortinarius caesiocanescens*) were found only in one locality and considered rare/or rarely reported.

Because in Umbria little is yet known about the distribution of fungi (with the exception of a few localities such as Collestrada, Castel Rigone, Melezzole and Isola Polvese), the assigned categories should be considered provisional and the accuracy will increase as new records will be collected and evaluated. In fact, except from a few threatened rare species and common species, many taxa in the checklist are supported with inadequate amount of data. This is due to the paucity of fungal recorders (compared to the numbers of people recording plants), and the lack of knowledge of fruiting patterns which is generally restricted to a very short time for the majority of fungal species. Due to the previously mentioned problems, for many species, it is difficult to discern whether a "rare" fungus is truly rare, or if it only produces fruiting bodies rarely.

Although the list displayed in the Supplemental Annex 1 might appear extensive, it is needless to say that it presumably covers only a small part of the macrofungal diversity in Umbria. Most of the surveys were concentrated on a limited, accessible portion of the Region, rich in forests and thus hosting many macrofungal species. The large Monti Sibillini National Park, for example, has been poorly explored, despite the fact that it accounts for about 17.790 ha of Umbria's landscape (http://geo.umbria-territorio.it/umbriageo/ppr/QC_1_5_Relazione.pdf).

In conclusion, this paper demonstrates that "the mycological research" in Umbria, even if the data are still partial, has revealed quite a high level of taxonomic richness (i.e. high number of species). This considering that the current observed macrofungal taxonomic richness differs among Italian regions from 198 (Molise) to 2186 (Emilia Romagna), with an average taxonomic richness of 1095 (Patusso & Zotti 2009).

The compiled checklist will be continuously updated in the future, thus, it obviously has a significance limited in time, but presently, it will certainly be useful to those who are interested in mycology, representing a good starting point for further mycological studies and becoming a valuable source of information for the drafting of a national checklist.

Presence of fungal species, their ecology and conservation status has been evaluated in other Italian regions and in different European countries, and it appears that these kind of studies may be influenced by the distribution of mycologists and the particular species and/or localities under study (Senn-Irlet et al. 2007). Notwithstanding these limitations, the published checklists (e.g. Laviano 1983; Venturella

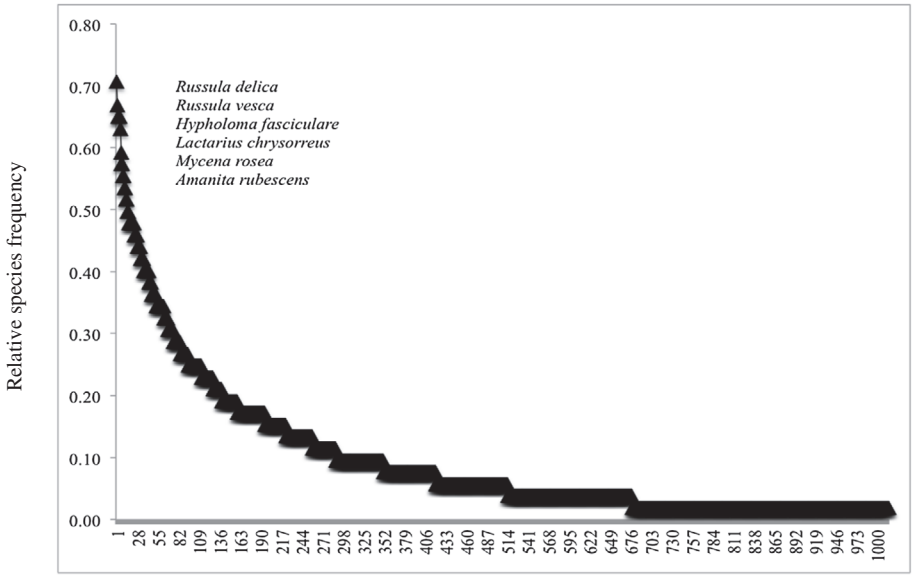

Figure 4. Dominance–diversity curves for Umbrian macrofungal species based on relative frequency. Most occurring species to least occurring species are ordered from left to right.

1991; Candusso 1992; Perini et al. 1999; Violante et al. 2002; Perini et al. 2004; Padovan 2006; Zotti et al. 2008) and those under compilation represent fundamental instruments to improve the knowledge of the Italian fungi and their conservation.

Supplemental data

Supplemental data for this article can be accessed here. [http://dx.doi.org/10.1080/11263504.2016.1265609].

ORCID

P. Angelini http://orcid.org/0000-0002-6862-1079
A. Rubini http://orcid.org/0000-0003-3988-6294
R. Venanzoni http://orcid.org/0000-0002-7768-0468
C. Perini http://orcid.org/0000-0003-2617-7587

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