CZECH MYCOLOGY 65(2): 193–218, DECEMBER 20, 2013 (ONLINE VERSION, ISSN 1805-1421)

Macrofungi in Mediterranean *Quercus ilex* woodlands: relations to vegetation structure, ecological gradients and higher-taxon approach

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Zotti M., Pautasso M. (2013): Macrofungi in Mediterranean *Quercus ilex* woodlands: relations to vegetation structure, ecological gradients and higher-taxon approach. – Czech Mycol. 65(2): 193–218.

Few studies have investigated the relationships between mycodiversity and plant communities in *Quercus ilex* (holm oak) woodlands. These are unique ecosystems in the Mediterranean basin of high mycological importance. The macrofungi of *Q. ilex* forests in Liguria, North-Western Italy, were studied: 246 species were observed in 15 permanent plots over four years. Some species were identified as typical of holm oak woodlands, e.g. *Hygrophorus russula*, *Leccinellum lepidum*, and *Lactarius atlanticus*. Correspondence analysis (CA) showed that the main ecological gradients shaping the fungal and plant communities are driven by soil pH and climatic factors. The CA confirms that the minimum sampling area for macrofungi is larger than for plant communities and that aggregation of multiple plots is suitable for data analysis. The data suggest that the higher-taxon approach can be successfully applied also to *Q. ilex* macrofungi, not only for total species and genus richness, but also within abundance classes. Further investigations are required to better characterise the mycodiversity of Mediterranean holm oak woodlands in relation to human impacts over various scales to plan effective conservation strategies.

Key words: conservation biology, ectomycorrhiza (ECM), fungal diversity, multivariate analysis.

Zotti M., Pautasso M. (2013): Makromycety mediterránních porostů *Quercus ilex*, jejich vztahy ke struktuře vegetace, ekologickým gradientům a „higher-taxon approach“. – Czech Mycol. 65(2): 193–218.

Jen pár prací bylo dosud věnováno studiu vztahů mezi diverzitou hub a rostlinnými společenstvy v porostech dubu cesmínovitého (*Quercus ilex*), i když tyto jedinečné mediterránní ekosystémy mají značný mykologický význam. Během čtyřletého výzkumu na 15 trvalých plochách v porostech *Quercus ilex* v Ligurii (severozápadní Itálie) bylo zjištěno celkem 246 druhů makromycetů, přičemž některé z nich se jeví typickými pro tyto porosty (*Hygrophorus russula*, *Leccinellum lepidum*, *Lactarius atlanticus*). Korespondenční analýza ukázala, že hlavní ekologické gradienty, které ovlivňují utváření houbových a rostlinných společenstev, jsou vytyčeny půdním pH a klimatickými faktory. Zároveň potvrzuje, že minimální plocha pro výzkum makromycetů je větší než v případě rostlinných společenstev a pro analýzy dat může být vhodné sloučení malých ploch. Získaná data též ukazují, že „higher-taxon approach“ (přístup zjednodušeního hodnocení vyšších taxonů bez bližšího určení) může být úspěšně aplikován i na houby v lesích *Q. ilex*, a to nejen ve vztahu k celkovému množství druhů a rodů, ale i napříč třídami abundance. V dalším výzkumu by měl být sledován vliv člověka na diverzitu hub v mediterránních porostech dubu cesmínovitého, aby bylo možno efektivně plánovat strategie jejich ochrany.

INTRODUCTION

Although macrofungi play a fundamental role in nature, we are still far from a satisfactory understanding of this important part of biodiversity (e.g. Mueller et al. 2007, Lonsdale et al. 2008, Peay et al. 2008). This is of concern given that fungi are one of the most species-rich taxonomic groups (Strong & Levin 1975, Hawksworth 2001, Dobson 2005). At the same time, many fungal species are currently threatened due to habitat degradation and land use change (e.g. Vasiliauskas et al. 2004, Berglund & Jonsson 2008, Molina 2008). Our knowledge is particularly inadequate as far as the biodiversity and ecology of macrofungi in Mediterranean environments are concerned. This is again a cause of concern for conservation biologists and fungal ecologists given that the available evidence suggests that ecosystems with a Mediterranean climate show a relatively high fungal biodiversity (e.g. Perini et al. 1993, Taylor et al. 2001, Bergemann & Garbelotto 2006, Lancellotti et al. 2007, Smith et al. 2007, Ali & Aschi-Smiti 2013, Rodriguez et al. 2013).

Within Mediterranean ecosystems, holm oak (*Quercus ilex*) forests have been particularly neglected from a mycological perspective. The relation between ectomycorrhiza (ECM) and host tree distributions has been investigated in old-growth *Q. ilex* forests of Corsica (France) from the point of view of fruiting patterns (Richard et al. 2004) and using molecular biology techniques (Richard et al. 2005, 2011). There was little overlap between the belowground ECM community and the one determined by aboveground fruit body surveys, although the number of fungal species was similar in the two cases. In Andalusia (Spain), macrofungal communities appeared to be well differentiated between cork oak (*Quercus suber*) and holm oak woodlands (Ortega & Lorite 2007). This study also showed the importance from a conservation perspective of the selection of single study sites with the presence of many rare species unrecorded at other sites.

Other mycocoenological surveys in the Mediterranean region have been carried out in Italian oak *(Quercus pubescens*, *Q. cerris)* and holm oak woodlands (De Dominicis & Barluzzi 1983, Barluzzi et al. 1983, Perini et al. 1989, Signorello 1996, Laganà et al. 1999). These studies have provided detailed lists of macrofungal species recorded, but apart from a study in Tuscany (Salerni et al. 2001), these have not used correspondence analysis to investigate whether species distributions are affected by environmental factors such as soil moisture and pH. Two studies of a number of forest plots (encompassing not only holm oak forests) in Tuscany found little evidence that vascular plant species richness can be used as a surrogate for macrofungal biodiversity (Chiarucci et al. 2005, Santi et al. 2010).

Ligurian holm oak woodlands are rarely investigated from a mycological viewpoint, and several studies have been limited to a detailed listing of the fungal species observed (Orsino & Traverso 1986, Orsino & Dameri 1991, Zotti & Orsino 2001, Zotti et al. 2008) and the evaluation of mycodiversity (Zotti 2004). In this re-

gion, the need to move from descriptive to predictive studies is even more important given that Liguria stands out from other Italian regions in terms of macrofungal biodiversity, possibly because of its high proportion of woodland area (Pautasso & Zotti 2009). The main aim of this study is to explore the fungal communities in woodlands dominated by *Quercus ilex* in Liguria. A secondary goal is to determine the principal environmental gradients shaping the fungal communities in the sampled areas and to identify species characteristic of any such gradients. Another purpose is to test whether macrofungal species richness can be predicted from the number of macrofungal genera observed not just for the whole community (Balmford et al. 2000), but also within abundance classes.

MATERIAL AND METHODS

Geographic localisation. Liguria is a coastal region in NW Italy bordering with France, which combines the influence of the Mediterranean Sea with a rugged topography. This is reflected in the climate, which ranges from Mediterranean to alpine within a few dozen kilometres (Vagge 1999, Rivas-Martínez 2004). Liguria thus shows a great variability in thermoclimatic and pluviometric conditions.

Fig. 1 shows the distribution of the study areas within Liguria. Specifically, the western stands (FFE and FAM) have a more characteristic Mediterranean climate (mean annual temperature 16.6 °C and mean annual rainfall 800 mm); stands SV and MUR are the coldest (mean annual temperature 15 °C and 12.7 °C, respectively) and more humid (mean annual rainfall 1303 and 1239 mm, respectively); finally the eastern plots (LG) are characterised by a mean annual temperature of 15.4 °C and a mean annual rainfall of 1174 mm (Vagge 1999).

Five localities (*Quercus ilex* stands) were selected and at each locality a number of permanent plots were set up. Stands were chosen both west and east of Genoa, although *Q. ilex* forests are better developed in the eastern belt (Barberis et al. 1992). However the eastern belt is strongly affected by human impacts. The stands and respective permanent plots are listed in Tab. 1 together with their altitude (70–400 m a. s. l.), geographic coordinates (geo-referenced by means of a GPS, Global Position System, adopting the World Geodetic Survey system, 1984 – WGS 84), and some environmental parameters. All the examined stands are characterised by the presence of *Quercus ilex*. The stands are located within various units of geo-pedological compositions, from calcareous or arenaceous to ophiolitic and sandstone substrates (Vanossi 1991).

Survey methods. The study was carried out over a period of four consecutive years (2003–2006). Fifteen permanent plots were delimited, almost square in shape, about 500 m^2 in size. The vegetation communities dominated by holm oak trees were surveyed according to the phytosociological methods of Braun-

Fig. 1. Geographic location of the studied plots.

Blanquet (1979). The Ligurian vegetation is rather fragmented and, in turn, areas homogeneous from a phytosociological point of view are limited in size. This fragmentation justifies the limited size of the selected plots.

The pH was measured with the potentiometric method: soil samples collected between 15 and 25 cm of depth were dried at 50 °C for 24 hours, passed through a sieve with openings 2 mm in size, mixed in a 1:2.5 soil-water suspension, agitated for 15 minutes, left to settle 30 minutes and measured with a glass electrode pH meter (10 replicates for each plot).

The mycological study was carried out both qualitatively (mycofloristic survey) and quantitatively [counts of sporomata, in other words ascomata and basidiomata, with the method described in Arnolds (1981, 1982); see the caption of Tab. 2 for the scale adopted for sporomata counts]. In this table the maximum density of sporomata during a single survey (mDCv) is given. The approach follows other studies conducted in Liguria (Zotti 2002, 2004, Zotti & Zappatore 2006, Zotti et al. 2013) and, in general, in Italian Mediterranean environments (De Dominicis & Barluzzi 1983, Perini et al. 1989, Salerni et al. 2001).

Tab. 1. Summary information of the studied localities (stands) and permanent plots. The table includes reference codes, GPS coordinates, altitude, slope, average trunk diameter, average tree, shrub and herbaceous cover, soil pH, and substrate (bedrock). Abbreviations: Alt. = Altitude, Exp. = Exposure, RMS = Root-Mean-Square.

Localities (stand types)	**Permanent plots**	**Geographic coordinates** (dd°mm.mmm')	**Alt.** (m above sea level)	**Slope** (°)	**Exp.**	**Average trunk diameter** (cm)	**Average tree cover** (%)	**Average shrub cover** (%)	**Average herbaceous cover** (%)	**pH** (pH RMS)	**Substrates**
Orco Feglino (FFE) (W Liguria)	**FFE1**	44°12.251' N 08°20.213' E	301	0	–	15	80	15	2	5.98 (0.11)	calcareous
	FFE2	44°12.139' N 08°19.953' E	248	5	S	12	70	20	40	6.30 (0.10)	calcareous
	FFE3	44°12.191' N 08°19.981' E	268	2	S	12	90	20	45	5.89 (0.09)	calcareous
	FFE4	44°12.207' N 08°20.083' E	270	0	–	20	60	10	10	6.01 (0.10)	calcareous
Altopiano delle Manie (FAM) (W Liguria)	**FAM1**	44°11.906' N 08°23.010' E	270	25	SE	18	75	5	5	5.67 (0.07)	calcareous
	FAM2	44°12.908' N 08°23.012' E	255	10	E	28	75	25	1	5.86 (0.05)	calcareous
San Bernardo (SV) (Central Liguria)	**SV1**	44°20.228' N 08°27.306' E	68	35	S	18	75	10	1	4.33 (0.09)	ophiolitic
	SV2	44°20.575' N 08°27.024' E	72	50	NNE	20	80	30	15	5.31 (0.07)	ophiolitic
	SV3	44°21.227' N 08°27.335' E	397	40	E	16	70	25	1	5.15 (0.06)	ophiolitic
Murta (MUR) (E Liguria)	**MUR1**	44°27.968' N 08°52.345' E	368	45	SSE	18	75	5	5	4.89 (0.08)	ophiolitic
	MUR2	44°27.909' N 08°52.289' E	375	35	SSE	18	80	40	3	4.30 (0.10)	ophiolitic
	MUR3	44°27.933' N 08°52.187' E	407	15	S	26	70	20	5	5.00 (0.07)	ophiolitic
Nozarego (LG) (E Liguria)	**LG1**	44°19.026' N 09°12.352' E	190	40	E	20	75	20	20	4.56 (0.09)	arenaceous – sandstone
	LG2	44°19.030' N 09°12.348' E	215	30	SW	16	70	10	20	4.25 (0.05)	arenaceous – sandstone
	LG3	44°19.003' N 09°12.364' E	185	62	SSW	30	95	15	20	4.48 (0.06)	arenaceous – sandstone

During the favourable fungal fruiting periods (March–May and October–December) of three consecutive years, each plot was sampled every 10–12 days. The fungi collected were identified according to their macroscopic and microscopic features. For taxa identification, specific European mycological literature was consulted (e.g. Basso 1999, Heilmann-Clausen et al. 2000, Bidaud et al. 2003, Breitenbach & Kränzlin 1981, Consiglio et al. 2003, Kuyper et al. 1995, Malençon & Bertault 1970, 1975, 2009).

The used systematics followed Hibbett et al. (2007) and Kirk et al. (2008). Nomenclature and author abbreviations are used in accordance with CABI, CBS and IMA (see www.indexfungorum.org, www.cbs.knaw.nl, www.mycobank.org).

Hypogeous macrofungi were not taken into account and only the common and abundant species of resupinate lignicolous fungi were considered (e.g. *Pulcherricium caeruleum* and *Steccherinum ochraceum*). Microscopic analyses were carried out on free hand sections, observed generally in pure water or in 3 % KOH or in a 0.1 % Congo Red ammonium solution. When necessary, more specific reagents (e.g. Melzer reagent, Cresyl blue) were employed.

All examined fungal material was deposited and kept at GDOR (Herbarium of the Museo Civico di Storia Naturale Giacomo Doria, Mycologia section, Genoa, Italy), and all the relevant taxa identified were entered into a specific database called A.L.C.E (Advanced Liguria Check-list of Ectomycorrhizal and other fungi).

D a t a a n a l y s i s. Data on the observed macrofungi were stored into a MySQL database and then processed using numerical ecology techniques. To determine the gradients of ecological factors related to the mycological communities in an indirect way, a correspondence analysis (CA) was performed on the data related to the sporomata (Kernaghan & Harper 2001, Férnandez-Toiran et al. 2006). The variables are represented by the species, the cases are represented by the plots. Data related to the number of sporomata were square-root transformed before performing the CA. Similarly, a CA was carried out on the data related to the vegetation.

The same data sets together with environmental data (slope, altitude, soil pH, average trunk diameter, average tree, shrub and herbaceous covers, see Tab. 1) were analysed with a canonical correspondence analysis (CCA) (Schmit & Lodge 2005). Both for CA and CCA, the Multivariate Statistical Package (MVSP) software version 3.12 of Kvach Computing Services was employed (for more information see http://www.kovcomp.co.uk).

The relationship between number of macrofungal genera and number of macrofungal species in the surveyed plots was analysed for all species/genera recorded and within particular abundance classes. This linear regression analysis was carried out in SAS 9.1 (Littell et al. 2006).

RESULTS

Mycological analysis

During the four years of research, 246 macrofungal species were observed (238 Basidiomycota and 8 Ascomycota) in the 15 plots. Two species (*Lyophyllum leucophaeatum* and *Russula subazurea*) represented the first records in Italy. (These species were not included in checklists by Onofri et al. 2005, Zotti & Orsino 2001, Zotti et al. 2008.) Some of the species recorded are considered very rare, and have been found in Italy in just a few regions (Onofri et al. 2005). Examples include *Agaricus xanthodermus* var. *lepiotoides* (Lombardy), *Russula hortensis* (Tuscany) and *Russula stenotricha* (Trentino-Alto Adige, and Lazio).

Tab. 2 lists the observed species (those with the symbol ^ were found for the first time in Italy) together with their abundance according to Arnolds' scale (1981). (See the caption of Tab. 2 for more details.) The majority of the observed species were ectomycorrhizal (60 %), followed by saprotrophs on soil or humus (23 %), wood saprotrophs (12 %), litter saprotrophs (3 %), and parasites (2 %).

The genera whose species were more frequently observed were (from more to less frequent): *Russula*, *Cortinarius*, *Amanita*, *Tricholoma*, *Lactarius*, *Agaricus*, *Inocybe*, *Xerocomus*, *Boletus*, *Lepiota*, and *Entoloma*. Most of these genera are ectomycorrhizal and, on the whole, ectomycorrhizal species represent 60 % of the total number of species recorded. This observation confirms the importance of ectomycorrhizal species in the studied woodlands. The ordination diagrams obtained with the CA and CCA are shown in Figs. 2 and 3, respectively. In these figures, the species with positions near the centre and some other species elsewhere are not shown since the diagram would have become too crowded. In CA, the first two axes explain 27 % of the total variance: a gradient of increasing pH along the first axis is suggested by the presence of acidophilic species in the 2nd quadrant [e.g., *Cortinarius obtusus*, *Russula fragilis*, *Russula vesca*, *Laccaria amethystina* (Thoen 1970, Lisiewska 1974, Marchand 1983, Arnolds et al. 1994, Sarnari 1998)], and by the presence of calciphilous species in the 1st quadrant [e.g., *Boletus pulchrotinctus*, *Russula maculata*, *Cortinarius calochrous*, *Amanita ovoidea*, and *A. echinocephala* (Thoen 1970, Sarnari 1998, Neville & Poumarat 2004, Muñoz 2005, Ortega & Lorite 2007)].

The gradient along the second axis appears to be correlated with variations in exposure and temperature. Decreasing temperature along the second axis is indicated by the presence of more thermophilous species in the 3rd and 4th quadrants [e.g. *Boletus aereus*, *Russula odorata*, *R. pseudoaeruginea*, *R. insignis*, *Lactarius atlanticus* (Bon & Gehu 1973, De Dominicis & Barluzzi 1983, Orsino 1991, Basso 1999, Richard et al. 2004, Muñoz 2005, Sarnari 2005)]. A similar conclusion can be drawn from the presence of more mesophilous species in the 1st and 2nd quadrants [e.g. *Lactarius camphoratus*, *Russula rubroalba*, *Russula gracillima* (Thoen 1970, Sarnari 1998, Basso 1999)].

Tab. 2. List of fungal species found in the 15 permanent plots. Arnolds' scale, used to estimate the density of the sporomata (Arnolds 1981), was adapted for this study; the abundance classes (1 for ≤3 sporomata; 2 for 4–10 sporomata; 3 for 11–30 sporomata; 4 for 31–100 sporomata; 5 for 101–300 sporomata; 6 for 301–1000 sporomata) are used for plots with a size of about 500 m^2.
^ indicates a new record for Italy.

Species	**SV1**	**SV2**	**SV3**	**MUR 1**	**MUR 2**	**MUR 3**	**FAM 1**	**FAM 2**	**FFE 1**	**FFE 2**	**FFE 3**	**FFE 4**	**LG 1**	**LG 2**	**LG 3**
Agaricus comtulus Fr.	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Agaricus impudicus (Rea) Pilát	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
Agaricus langei (F.H. Møller) F.H. Møller	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Agaricus moelleri Wasser	0	4	0	0	0	0	0	0	0	0	0	0	0	4	0
Agaricus porphyrizon P.D. Orton	0	2	0	4	0	3	0	0	0	0	0	0	5	4	0
Agaricus sylvaticus Schaeff.	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Agaricus xanthodermus Genev.	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Agaricus xanthodermus var. *griseus* (A. Pearson) Bon & Cappelli	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Agaricus xanthodermus var. *lepiotoides* Maire	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0
Amanita citrina (Schaeff.) Pers.	0	3	4	3	0	0	0	3	0	0	0	0	4	3	0
Amanita echinocephala (Vittad.) Quél.	0	0	0	0	0	0	3	0	0	0	3	0	0	0	0
Amanita excelsa var. *spissa* (Fr.) Neville & Poumarat	0	0	0	2	0	4	0	0	0	0	0	0	0	0	0
Amanita gemmata (Fr.) Bertill.	3	3	3	4	4	5	0	0	0	0	0	3	2	0	0
Amanita ovoidea (Bull.) Link	0	0	0	0	0	0	0	3	2	0	0	3	0	0	0
Amanita pantherina (DC.) Krombh.	3	3	4	4	0	0	4	4	0	2	4	0	5	4	2
Amanita phalloides (Vaill. ex Fr.) Link	3	0	2	4	3	5	3	3	3	2	3	2	4	0	2
Amanita proxima Dumée	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Amanita rubescens Pers.	4	4	4	5	4	6	4	0	2	0	0	4	4	3	2
Amanita rubescens var. *annulosulphurea* Gillet	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0
Amanita strobiliformis (Paulet ex Vittad.) Bertillon	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Amanita subfraudolenta Contu	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
Amanita vaginata (Bull.) Lam.	0	0	3	3	2	0	4	4	0	2	0	0	0	0	0
Amanita vaginata f. *avellanea* M. Traverso	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0
Amanita verna (Bull.) Lam.	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Armillaria mellea s. str. (Vahl) P. Kumm.	0	3	0	0	0	0	0	0	0	0	0	0	6	6	4
Astraeus hygrometricus (Pers.) Morgan	0	2	2	0	0	0	2	0	1	0	3	0	0	0	0
Aureoboletus gentilis (Quél.) Pouzar	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Auricularia auricula-judae (Bull.) Quél.	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Boletus aereus Bull.	0	0	2	0	0	3	0	0	0	0	0	0	3	3	0
Boletus comptus Simonini	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Boletus luridus Schaeff.	0	0	2	0	0	0	2	0	0	0	0	2	0	0	0
Boletus pulchrotinctus Alessio	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Boletus queletii Schulzer	0	0	0	0	0	0	3	0	2	2	0	2	0	0	0
Bovista plumbea Pers.	0	0	4	0	0	0	0	0	0	0	0	5	4	2	0
Byssomerulius corium (Pers.) Parmasto	0	6	0	0	0	0	0	0	5	0	0	0	0	0	0
Calocera viscosa (Pers.) Fr.	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Cantharellus cibarius Fr.	0	0	0	4	3	5	0	0	0	0	0	0	5	4	0

Species	SV1	SV2	SV3	MUR 1	MUR 2	MUR 3	FAM 1	FAM 2	FFE 1	FFE 2	FFE 3	FFE 4	LG 1	LG 2	LG 3
Chlorophyllum rachodes (Vittad.) Vellinga	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0
Chlorophyllum venenatum (Bon) Lange & Vellinga	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Clathrus ruber P. Micheli ex Pers.	0	2	0	0	0	0	0	0	0	0	0	0	3	2	0
Clavariadelphus pistillaris (L.) Donk	0	0	0	4	3	0	0	0	0	0	0	0	0	0	0
Clavulina coralloides (L.) J. Schroet.	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Clitocybe nebularis (Batsch) P. Kumm.	2	0	3	5	5	5	4	4	3	4	0	0	0	4	0
Clitocybe phaeophthalma (Pers.) Kuyper	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Clitocybe rivulosa (Pers.) P. Kumm.	0	0	0	0	0	0	0	0	4	0	3	0	0	0	0
Clitopilus prunulus (Scop.) P. Kumm.	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0
Coltricia perennis (L.) Murrill	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Coprinellus disseminatus (Pers.) J.E. Lange	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Coprinellus micaceus (Bull.) Vilgalys, Hopple & Jacq. Johnson	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Coprinopsis insignis (Peck) Redhead, Vilgalys & Moncalvo	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2
Coprinopsis picacea (Bull.) Redhead, Vilgalys & Moncalvo	0	0	0	0	0	0	0	0	2	3	4	3	0	0	0
Coprinopsis spilospora (Romagn.) Redhead, Vilgalys & Moncalvo	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coprinus comatus (O.F. Müll.) Pers.	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Cortinarius aleuriosmus Maire	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Cortinarius aurilicis Chevassut et Trescol	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Cortinarius calochrous (Pers.) Gray	0	0	0	0	0	0	3	0	4	0	5	0	5	0	0
Cortinarius cotoneus Fr.	0	3	3	0	0	0	0	0	0	0	3	0	0	0	0
Cortinarius cristallinus Fr.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Cortinarius elegantissimus Rob. Henry	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Cortinarius infractus (Pers.) Fr.	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Cortinarius livido-ochraceus (Berk.) Berk.	0	3	2	4	3	5	0	0	0	0	0	0	0	0	0
Cortinarius obtusus (Fr.) Fr.	0	0	0	3	4	3	0	0	0	0	0	0	0	0	0
Cortinarius olidus J.E. Lange	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Cortinarius orellanus Fr.	0	0	0	0	3	4	0	0	0	0	0	0	0	0	0
Cortinarius privignus (Fr.) Fr.	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Cortinarius rapaceus Fr.	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Cortinarius rigens (Pers.) Fr.	0	0	4	0	0	0	0	0	0	0	4	0	0	0	0
Cortinarius rufo-olivaceus (Pers.) Fr.	0	2	0	0	0	0	0	0	3	3	4	0	0	0	0
Cortinarius salor Fr.	0	0	0	0	3	4	0	0	0	0	0	0	0	2	0
Cortinarius splendens Rob. Henry	0	0	0	0	0	0	0	0	3	0	0	4	0	0	0
Cortinarius sulfurinus Quél.	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Cortinarius trivialis J.E. Lange	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Cortinarius velenovskyi Rob. Henry	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Craterellus cornucopioides (L.) Pers.	0	0	0	0	4	5	0	0	0	0	0	0	0	0	0
Delicatula integrella (Pers.) Fayod	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Echinoderma asperum (Pers.) Bon	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2
Entoloma clypeatum (L.) P. Kumm.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Entoloma conferendum (Britzelm.) Noordel.	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0

Species	SV1	SV2	SV3	MUR 1	MUR 2	MUR 3	FAM 1	FAM 2	FFE 1	FFE 2	FFE 3	FFE 4	LG 1	LG 2	LG 3
Entoloma incanum (Fr.) Hesler	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Entoloma rhodopolium (Fr.) P. Kumm.	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Ganoderma adspersum (Schulzer) Donk	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Ganoderma lucidum (Curtis) P. Karst.	2	2	2	3	0	4	6	6	3	5	5	4	3	0	2
Geastrum fimbriatum Fr.	0	2	2	0	0	0	0	0	3	2	4	0	3	2	0
Geopora arenicola (Lév.) Kers	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Gymnopus aquosus (Bull.) Antonín & Noordel.	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Gymnopus brassicolens (Romagn.) Antonín & Noordel.	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0
Gymnopus dryophilus (Bull.) Murrill	0	0	0	0	0	0	4	0	0	0	0	4	0	0	0
Gymnopus fusipes (Bull.) Gray	0	0	0	4	3	2	0	0	0	0	4	0	0	0	0
Gymnopus inodorus (Pat.) Antonín & Noordel.	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Gymnopus peronatus (Bolton) Antonín, Halling & Noordel.	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Gyroporus castaneus (Bull.) Quél.	0	0	0	3	0	3	0	0	0	0	0	0	4	0	0
Hebeloma crustuliniforme (Bull.) Quél.	2	0	2	0	0	0	0	3	2	2	3	3	0	0	0
Hebeloma laterinum (Batsch) Vesterh.	2	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Hebeloma sinapizans (Paulet) Gillet	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
Hebeloma truncatum (Schaeff.) P. Kumm.	0	0	3	0	0	0	0	0	0	0	0	0	3	0	0
Hebeloma versipelle (Fr.) Gillet	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Helvella crispa (Scop.) Fr.	0	0	0	3	0	4	0	0	0	0	0	0	0	0	0
Helvella lacunosa Afzel.	0	0	0	3	4	0	0	0	0	0	0	0	0	0	0
Hydnellum aurantiacum (Batsch) P. Karst.	0	0	4	0	0	0	0	0	0	0	0	0	0	4	0
Hydnellum compactum (Pers.) P. Karst.	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Hydnum repandum L.	0	0	4	2	4	4	4	0	0	0	0	0	0	4	0
Hydnum rufescens Pers.	0	0	3	0	0	0	0	0	0	0	0	0	5	3	0
Hygrocybe mucronella (Fr.) P. Karst.	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Hygrophorus eburneus (Bull.) Fr.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Hygrophorus leucophaeo-ilicis Bon & Chevassut	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Hygrophorus lindtneri M.M. Moser	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Hygrophorus nemoreus (Pers.) Fr.	0	0	0	0	2	5	0	0	0	0	0	0	3	0	0
Hygrophorus russula (Schaeff.) Kauffman	4	4	5	5	5	6	5	5	4	4	4	5	3	2	2
Hypholoma fasciculare (Huds.) Kühner.	0	0	5	3	0	0	0	0	0	0	0	0	4	4	0
Hypholoma lateritium (Schaeff.) P. Kumm.	0	0	0	5	0	5	0	5	0	0	0	0	0	3	0
Infundibulicybe geotropa (Bull.) Harmaja	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0
Inocybe asterospora Quél.	0	3	0	0	0	0	0	0	0	0	0	0	3	0	0
Inocybe brunnea Quél.	0	2	0	0	0	0	0	0	0	0	0	0	2	0	0
Inocybe brunneorufa Stangl & J. Veselský	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Inocybe cervicolor (Pers.) Quél.	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Inocybe dulcamara (Pers.) P. Kumm.	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0
Inocybe margaritispora (Berk.) Sacc.	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inocybe mixtilis (Britzelm.) Sacc.	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Inocybe rimosa (Bull.) P. Kumm.	0	0	0	0	0	0	3	3	3	0	3	4	3	2	0
Laccaria amethystina Cooke	0	0	0	3	3	3	0	0	0	2	4	0	0	0	0
Laccaria laccata (Scop.) Cooke	2	0	0	4	0	4	0	0	0	0	4	5	3	4	2

Species	**SV1**	**SV2**	**SV3**	**MUR 1**	**MUR 2**	**MUR 3**	**FAM 1**	**FAM 2**	**FFE 1**	**FFE 2**	**FFE 3**	**FFE 4**	**LG 1**	**LG 2**	**LG 3**
Lactarius atlanticus Bon	0	0	4	0	0	0	0	4	0	4	4	0	6	4	3
Lactarius camphoratus (Bull.) Fr.	0	0	0	3	0	5	0	0	0	0	0	0	0	0	0
Lactarius chrysorrheus Fr.	0	4	4	4	4	4	0	0	0	0	0	0	4	0	0
Lactarius mairei Malençon	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0
Lactarius quietus (Fr.) Fr.	3	0	3	0	4	0	3	0	3	2	4	0	0	0	0
Lactarius rugatus Kühner et Romagn.	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0
Lactarius scrobiculatus (Scop.) Fr.	0	0	0	0	0	0	0	0	0	0	0	0	5	4	0
Lactarius serifluus (DC.) Fr.	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Lactarius subdulcis (Pers.) Gray	0	0	0	0	0	0	0	0	0	0	0	0	5	3	0
Lactarius vellereus (Fr.) Fr.	0	0	5	0	3	3	0	0	0	0	0	0	0	0	0
Lactarius vellereus var. *hometii* (Gillet) Boud.	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Lactarius zonarius (Bull.) Fr.	0	3	0	0	0	0	3	3	0	0	0	0	0	0	0
Leccinellum lepidum (H. Bouchet ex Essette) Bresinsky & Manfr. Binder	1	3	5	4	4	6	0	0	0	0	0	0	5	3	2
Leotia lubrica (Scop.) Pers.	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Lepiota cristata (Bolton) P. Kumm.	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Lepiota cristata var. *exannulata* Bon	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Lepiota cystophoroides Joss. & Riousset	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Lepiota lilacea Bres.	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Lepiota rufipes Morgan	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Lepista flaccida (Sowerby) Pat.	0	0	0	5	3	4	4	0	2	0	0	0	3	2	2
Lepista nuda (Bull.) Cooke	4	3	5	2	4	4	0	0	0	0	0	0	6	4	2
Lepista sordida (Schumach.) Singer	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
Leucoagaricus leucothites (Vittad.) Wasser	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Leucopaxillus amarus (Alb. & Schwein.) Kühner	0	0	0	0	0	0	0	0	3	0	3	0	5	0	0
Leucopaxillus tricolor (Peck) Kühner	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0
Lycoperdon echinatum Pers.	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Lycoperdon perlatum Pers.	0	0	3	3	0	0	0	0	4	0	4	0	4	4	0
Lycoperdon pyriforme Schaeff.	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Lyophyllum decastes (Fr.) Singer	0	0	0	3	4	0	0	0	0	0	0	0	0	0	0
^*Lyophyllum leucophaeatum* (P. Karst.) P. Karst.	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Macrolepiota mastoidea (Fr.) Singer	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Macrolepiota procera (Scop.) Singer	3	2	3	4	4	4	0	0	3	0	4	4	5	4	0
Marasmiellus candidus (Fr.) Singer	0	0	0	0	0	0	0	0	5	6	6	0	0	0	0
Marasmiellus virgatocutis Robich, Esteve-Rav. & G. Moreno	0	0	0	0	0	0	0	0	0	0	0	0	5	3	0
Melanogaster variegatus (Vittad.) Tul. & C. Tul.	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Mycena galopus (Pers.) P. Kumm.	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0
Mycena inclinata (Fr.) Quél.	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Mycena pura (Pers.) P. Kumm.	0	0	0	0	4	0	0	0	2	2	3	0	4	2	0
Mycetinis scorodonius (Fr.) A.W. Wilson & Desjardin	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Myriostoma coliforme (Dicks) Corda	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Otidea cochleata (L.) Fuckel	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Paxillus involutus (Batsch) Fr.	0	0	3	0	0	0	0	3	6	0	0	0	0	0	0

Species	SV1	SV2	SV3	MUR 1	MUR 2	MUR 3	FAM 1	FAM 2	FFE 1	FFE 2	FFE 3	FFE 4	LG 1	LG 2	LG 3
Peziza badia Pers.	0	0	3	0	0	0	0	0	0	0	0	0	4	0	0
Peziza domiciliana Cooke	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Phallus impudicus L.	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Phellinus robustus (P. Karst.) Bourdot et Galzin	0	2	3	0	0	0	0	3	0	0	0	0	0	0	0
Phellinus torulosus (Pers.) Bourdot et Galzin	4	4	0	0	0	0	5	4	0	0	4	4	4	0	0
Phellodon niger (Fr.) P. Karst.	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pluteus cervinus (Schaeff.) P. Kumm.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Polyporus tuberaster (Jacq. ex Pers.) Fr.	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Psathyrella candolleana (Fr.) Maire	0	0	0	0	0	0	5	0	4	4	0	0	0	0	0
Psathyrella spadiceogrisea (Schaeff.) Maire	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Pulcherricium caeruleum (Lam.) Parmasto	0	6	6	0	0	0	6	0	0	0	0	0	0	0	0
Ramaria stricta (Pers.) Quél.	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0
Resupinatus applicatus (Batsch) Gray	0	6	0	0	0	0	0	0	0	0	6	0	0	0	0
Rhodocollybia butyracea (Bull.) Lennox	0	0	3	3	0	3	0	0	0	0	0	0	5	4	0
Rhodocybe gemina (Paulet) Kuyper & Noordel.	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Russula acrifolia Romagn.	0	0	0	0	0	3	0	0	0	0	0	0	4	0	0
Russula adusta (Pers.) Fr.	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Russula alutacea (Fr.) Fr.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Russula amoenicolor Romagn.	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Russula amoenolens Romagn.	0	0	0	2	3	2	0	0	0	0	0	0	0	0	0
Russula chloroides (Krombh.) Bres.	2	3	0	0	0	0	0	0	2	0	3	3	5	3	2
Russula cuprea (Krombh.) J.E. Lange	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Russula cyanoxantha (Schaeff.) Fr.	4	3	3	3	4	6	4	0	0	0	0	3	2	2	0
Russula decipiens (Singer) Bon	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Russula delica Fr.	2	2	0	0	0	4	3	3	3	0	0	4	0	3	0
Russula emetica (Schaeff.) Pers.	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Russula foetens Pers.	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Russula fragilis Fr.	0	0	0	3	3	2	0	0	0	0	0	0	0	0	0
Russula globispora (J. Blum) Bon	0	2	0	0	0	0	0	0	0	0	0	4	0	0	0
Russula gracillima Jul. Schäff.	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Russula graveolens Romell	0	0	0	3	0	3	0	0	0	0	0	0	0	2	0
Russula grisea Fr.	4	0	2	4	3	0	0	0	0	0	0	0	0	0	0
Russula helios Malençon ex Sarnari	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Russula heterophylla (Fr.) Fr.	2	3	3	4	0	5	0	0	0	0	0	0	4	0	0
Russula hortensis Sarnari	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Russula insignis Quél.	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Russula laurocerasi Melzer	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Russula lepida Fr.	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Russula luteotacta Rea	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Russula maculata Quél.	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0
Russula nigricans Fr.	0	0	0	0	4	0	0	0	0	0	0	0	5	4	0
Russula odorata Romagn.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Russula pseudoaeruginea (Romagnesi) Kuyper & Vuure	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0

Species	**SV1**	**SV2**	**SV3**	**MUR 1**	**MUR 2**	**MUR 3**	**FAM 1**	**FAM 2**	**FFE 1**	**FFE 2**	**FFE 3**	**FFE 4**	**LG 1**	**LG 2**	**LG 3**
Russula rubroalba (Singer) Romagn.	0	0	0	0	0	3	0	0	0	2	0	0	0	0	0
Russula rubroalba var. *albrocretacea* Sarnari	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Russula rutila Romagn.	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Russula stenotricha Romagn.	0	2	0	5	0	0	0	0	0	0	0	0	0	0	0
^*Russula subazurea* Bon	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Russula vesca Fr.	0	3	2	3	4	4	0	0	0	0	0	0	4	0	0
Russula vinosobrunnea (Bres.) Romagn.	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Russula virescens (Schaeff.) Fr.	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Schizophyllum commune Fr.	6	6	6	0	0	0	6	6	0	0	0	0	6	6	0
Scleroderma citrinum Pers.	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Scleroderma verrucosum (Bull.) Pers.	3	3	4	0	0	0	0	0	0	2	4	0	5	5	4
Steccherinum ochraceum (Pers.) Gray	6	6	0	0	0	0	0	0	0	6	0	6	0	0	0
Stereum hirsutum (Willd.) Pers.	6	6	6	6	6	0	6	6	0	0	0	0	6	6	6
Strobilurus stephanocystis (Kühner & Romagn. ex Hora) Singer	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Stropharia aeruginosa (Curtis) Noordel.	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0
Suillus bellinii (Inzenga) Watling	0	0	0	0	0	0	0	0	0	0	0	0	3	5	0
Suillus granulatus (L.) Roussel	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Trametes hirsuta (Wulfen) Lloyd	0	6	0	0	0	0	6	6	0	0	0	0	0	0	0
Trametes versicolor (L.) Lloyd	0	6	6	6	0	0	6	0	6	6	6	0	6	0	0
Tremella mesenterica Retz.	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Tricholoma acerbum (Bull.) Vent.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Tricholoma album (Schaeff.) P. Kumm.	0	0	0	4	0	2	0	0	0	0	0	0	0	0	0
Tricholoma atrosquamosum Sacc.	0	0	0	0	0	0	3	0	2	0	3	4	3	2	0
Tricholoma aurantium (Schaeff.) Ricken	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Tricholoma saponaceum (Fr.) P. Kumm.	0	0	0	4	3	4	0	0	0	0	0	0	5	3	0
Tricholoma sejunctum (Sowerby) Quél	0	0	0	0	0	0	0	4	0	2	0	0	0	0	0
Tricholoma squarrulosum Bres.	3	2	5	3	4	0	0	0	0	0	0	0	0	0	0
Tricholoma triste (Scop.) Quél.	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Tricholoma ustaloides Romagn.	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0
Tricholomopsis rutilans (Schaeff.) Singer	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Volvariella volvacea (Bull.) Singer	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Xerocomellus armeniacus (Quél.) Šutara	0	3	0	0	0	2	0	0	0	3	0	0	0	0	0
Xerocomellus chrysenteron (Bull.) Šutara	2	3	5	3	2	3	0	0	4	4	4	0	2	2	0
Xerocomellus pruinatus (Fr.) Šutara	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Xerocomellus rubellus (Krombh.) Šutara	0	2	0	0	0	0	6	6	3	4	4	4	0	3	2
Xerocomus dryophilus (Thiers) Singer	0	0	0	0	0	0	0	4	3	4	0	0	0	0	0
Xerocomus moravicus (Vacek) Herink	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Xerocomus persicolor H. Engel, Klofac, H. Grünert & R. Grünert	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Xerocomus subtomentosus (L.) Quél.	0	3	3	2	0	4	4	4	3	2	5	4	5	4	0
Xylaria hypoxylon (L.) Grev.	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0

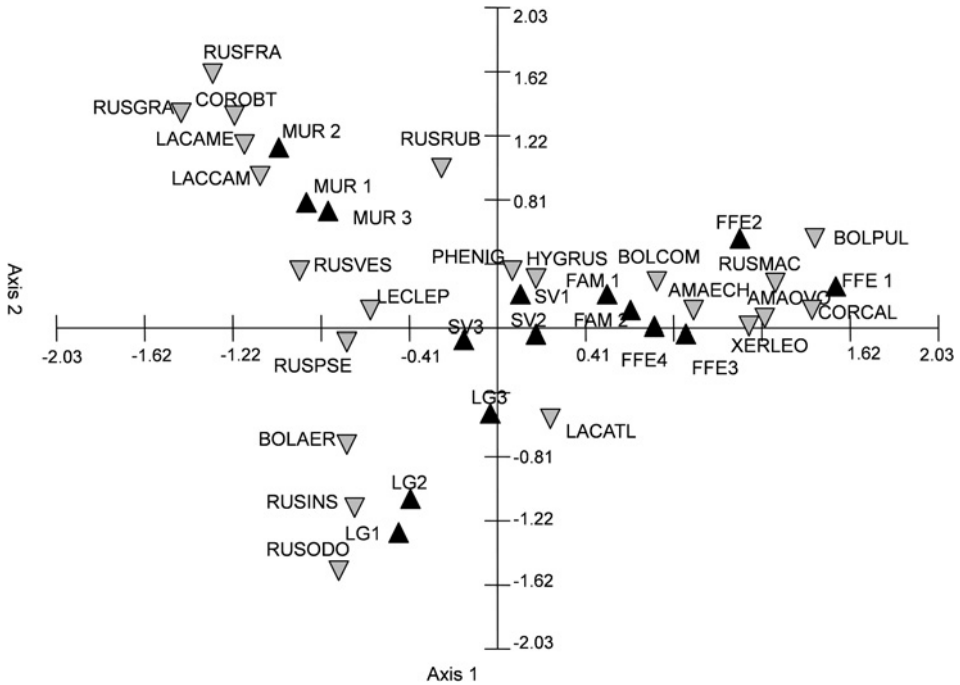

Fig. 2. Ordination diagram obtained through correspondence analysis applied to the observed fungal species. Species with a position near the centre and some other species elsewhere are not shown because the diagram would have become too crowded. The sample areas are indicated in black, while the fungal species are in grey. The eigenvalues associated to the first two axes are 0.53 and 0.44, respectively.

Abbreviations of fungal species (shown in the CA and CCA diagrams, Figs. 2–4): **AMACIT** – *Amanita citrina*; **AMAECH** – *Amanita echinocephala*; **AMAOVO** – *Amanita ovoidea*; **AMASUB** – *Amanita subfraudolenta*; **ASTHYG** – *Astraeus hygrometricus*; **BOLAER** – *Boletus aereus*; **BOLCOM** – *Boletus comptus*; **BOLPUL** – *Boletus pulchrotinctus*; **COPPIC** – *Coprinopsis picacea*; **CORCAL** – *Cortinarius calochrous*; **COROBT** – *Cortinarius obtusus*; **CORSPL** – *Cortinarius splendens*; **ECHASP** – *Echinoderma asperum*; **HYGRUS** – *Hygrophorus russula*; **LACAME** – *Laccaria amethystina*; **LACATL** – *Lactarius atlanticus*; **LACCAM** – *Lactarius camphoratus*; **LACCHR** – *Lactarius chrysorrheus*; **LECLEP** – *Leccinellum lepidum*; **PHENIG** – *Phellodon niger*; **RUSFOE** – *Russula foetens*; **RUSFRA** – *Russula fragilis*; **RUSGRA** – *Russula gracillima*; **RUSINS** – *Russula insignis*; **RUSMAC** – *Russula maculata*; **RUSODO** – *Russula odorata*; **RUSPSE** – *Russula pseudoaeruginea*; **RUSRUB** – *Russula rubroalba*; **RUSVES** – *Russula vesca*; **XERDRY** – *Xerocomus dryophilus*; **XERMOR** – *Xerocomus moravicus*. The abbreviations of the plots are listed in Tab. 1.

These interpretations of the CA ecological gradients are confirmed by the CCA, which is based on the environmental variables mentioned in the Material and methods. Fig. 3 shows that the vectors associated with the soil pH and the

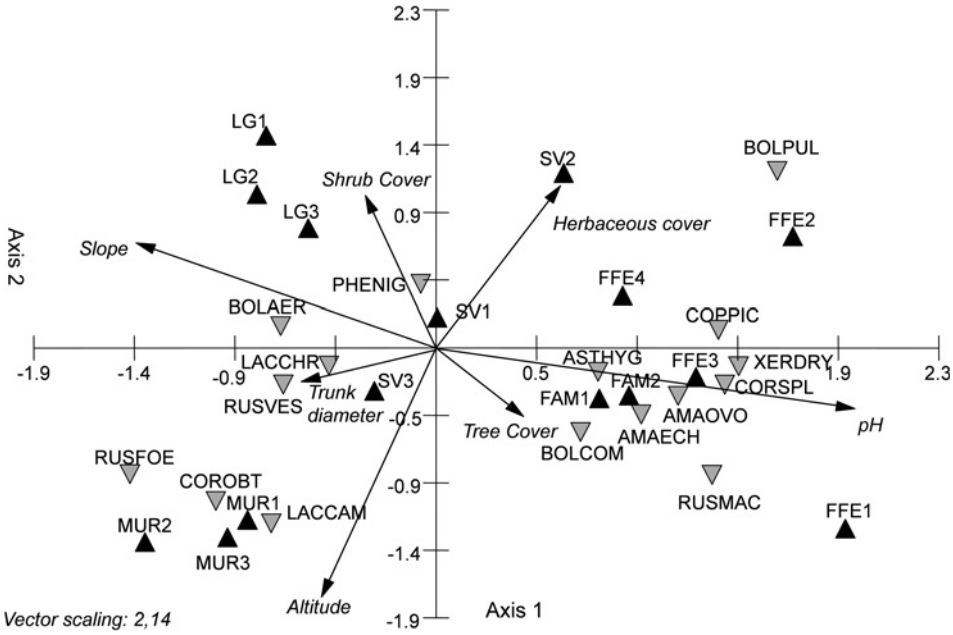

Fig. 3. Ordination diagram obtained through canonical correspondence analysis applied to the fungal species. The same limitations and conventions as in Fig. 2. Variables relative to environmental data are indicated by vectors whose length is proportional to the significance of the same variable. The variables considered are: slope, altitude, average trunk diameter, average tree, shrub and herbaceous covers, soil pH. The abbreviations of the plots are listed in Tab. 1, the fungal name abbreviations are given at Fig. 2.

slope are essentially parallel to the first axis, while the second axis seems to be associated mainly with altitude and tree and grass cover.

As the ordinations clearly segregate the different stands (localities), these analyses provide evidence for differences among the species composition of different stands. Based on this observation, an additional CA was performed aggregating plots belonging to the same stand. In this case, the first two axes explain 57 % of the total variance. This scatter plot is shown in Fig. 4. It should be highlighted that, in contrast to Fig. 2, the quadrants in Fig. 4 are rotated by 180°. However, the gradients previously identified can be easily re-discovered here.

The higher-taxon approach showed that a very high proportion of variance in total macrofungal species richness among the plots studied can be explained by the number of genera observed. This is true for the total number of species and genera, but also within abundance classes (Tab. 3).

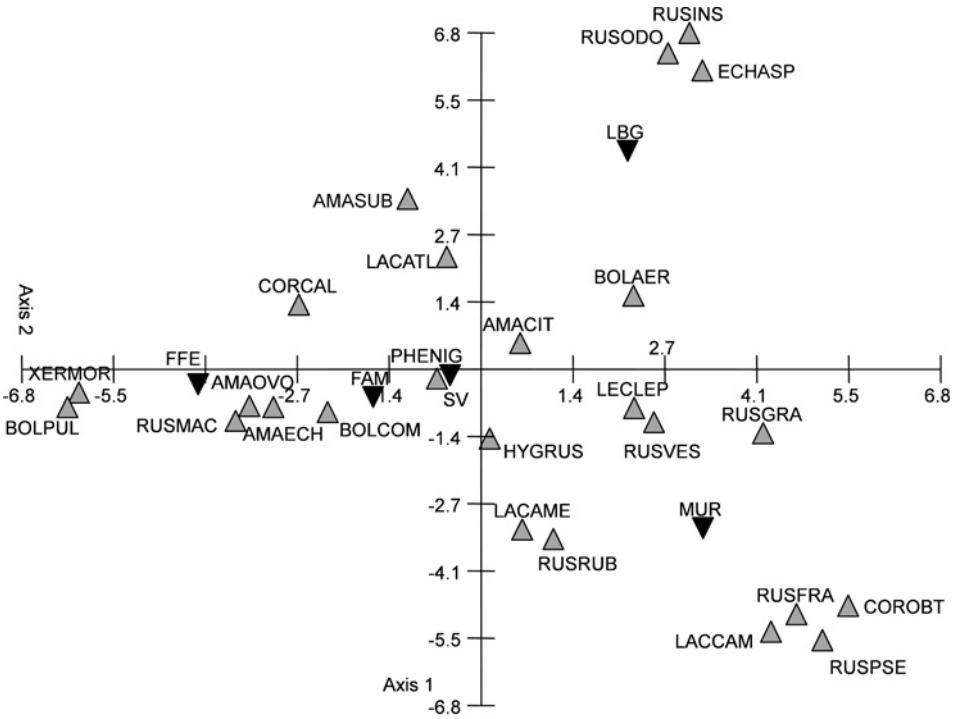

Fig. 4. Ordination diagram obtained through correspondence analysis after grouping the most similar plots. The same limitations and conventions as in Fig. 2. The eigenvalues associated to the first two axes are 0.49 and 0.42, respectively. The abbreviations of the plots are listed in Tab. 1, the fungal name abbreviations are given at Fig. 2.

Tab. 3. Regression of macrofungal species richness against number of genera for all fifteen plots and within abundance classes (abundance classes as in Tab. 2). Abbreviations: a = intercept, b = parameter estimate, SE = standard error.

	r^2	a	b ± SE	P
all species/genera	0.79	3.14	1.62 ± 0.23	0.001
1 (scarce)	0.89	0.00	1.50 ± 0.15	0.001
2	0.88	2.28	1.52 ± 0.15	0.001
3	0.85	–0.07	1.73 ± 0.20	0.001
4	0.80	5.13	1.13 ± 0.16	0.001
5	0.82	–0.37	1.83 ± 0.24	0.001
6 (abundant)	0.86	0.21	1.12 ± 0.12	0.001

Vegetation analysis

The surveys of the plant communities in the fifteen plots suggest that arboreous broad-sclerophyll populations, dominated by *Quercus ilex*, can be ascribed to association *Viburno-Quercetum ilicis* (Br.-Bl. 1936) Rivas-Martínez 1975. More in detail, this plant coenosis belongs to the more mesothermal aspects of the sub-associations *Viburno-Quercetum ilicis fraxino-ostryetosum* Mariotti 1984 and *Viburno-Quercetum ilicis pubescentetosum* Br.-Bl. 1936 (according to Mariotti 1984).

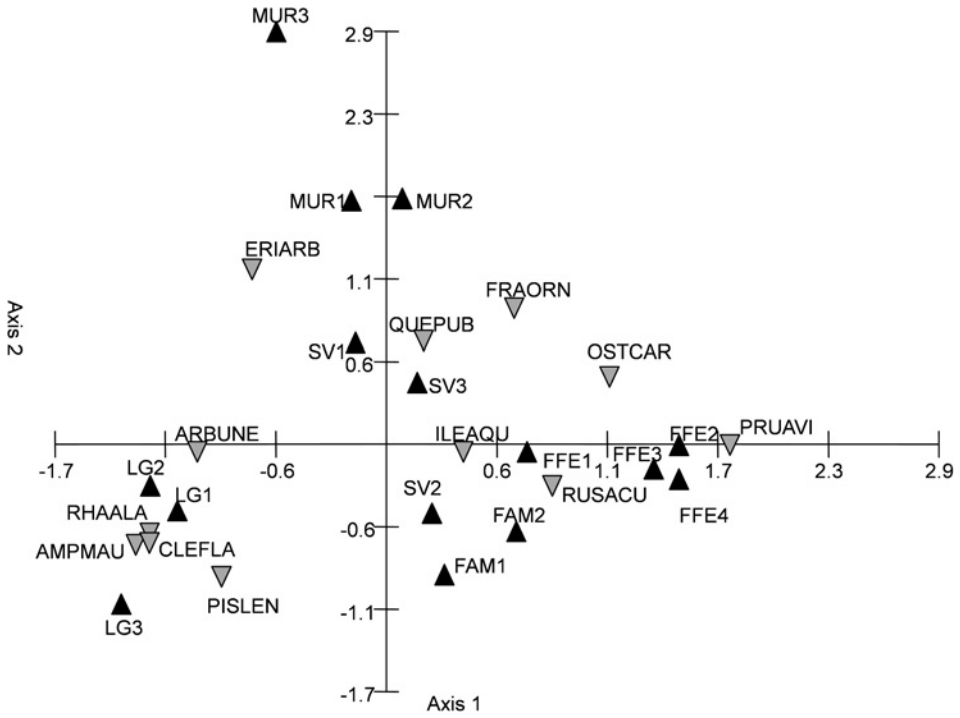

Fig. 5. Ordination diagram obtained through correspondence analysis applied to the observed plant species. The same limitations as in Fig. 2. The sample areas are indicated in black, the plant species in grey. The eigenvalues associated to the first two axes are 0.51 and 0.37, respectively

Abbreviations of plant species: **AMPMAU** – *Ampelodesmos mauritanicus*; **ARBUNE** – *Arbutus unedo*; **CLEFLA** – *Clematis flammula*; **ERIARB** – *Erica arborea*; **FRAORN** – *Fraxinus ornus*; **ILEAQU** – *Ilex aquifolium*; **OSTCAR** – *Ostrya carpinifolia*; **PISLEN** – *Pistacia lentiscus*; **PRUAVI** – *Prunus avium*; **QUEPUB** – *Quercus pubescens*; **RHAALA** – *Rhamnus alaternus*; **RUSACU** – *Ruscus aculeatus*. The abbreviations of the plots are listed in Tab. 1.

The floral composition of the different plots was analysed by means of CA (Fig. 5). The variance explained by the first two axes amounts to 38 % of the total one. As for the gradients shaping plant composition, they seem to be similar to those associated with the fungal communities. A gradient of decreasing temperature along the second axis is suggested by the presence of more thermophilous species (e.g., *Ampelodesmus mauritanicus*, *Arbutus unedo*, *Clematis flammula*, *Pistacia lentiscus*) in the 3rd quadrant, and by the presence of mesophilous species (e.g. *Ostrya carpinifolia*, *Ilex aquifolium*, *Fraxinus ornus*) in the 1st quadrant. A gradient of increasing pH along the first axis is suggested by the exclusive presence of acidophilous species, such as *Erica arborea* and *Arbutus unedo*, in the 2nd and 3rd quadrants.

DISCUSSION

Fungal diversity in holm oak woodlands

Fungi are a hyperdiverse kingdom, yet they are understudied compared to plants and vertebrates (Bissegger & Sieber 1994, Castello et al. 1994, Barengo et al. 2000, Müller & Hallaksela 2000, Unterseher et al. 2008, Woodward & Boa 2013). Moreover, a limited number of studies have dealt with mycobiota associated with *Quercus ilex* (Richard et al. 2004, 2005, 2011, Ortega & Lorite 2007, Gezer et al. 2007). The large number of fungal species reported here confirms that these Mediterranean ecosystems are important from a mycological viewpoint. This should encourage further investigations, not only of additional *Q. ilex* stands, but also of already available data from different countries in a meta-analytical way.

In all the sites and plots investigated here, there is a predominance of ectomycorrhizal species. The genera *Russula* and *Cortinarius* represent the greatest number of species. This result confirms the observations by Richard et al. (2004) in an old-growth Mediterranean forest dominated by *Quercus ilex*. Moreover, from an ecosystem perspective, this result is to be welcomed given the role played by these fungi as bio-indicators of forest perturbations (Amaranthus & Perry 1994, Molina et al. 1999, Laganà et al. 2000). Thus, it may be a good practice to monitor these fungi in order to gain a rapid evaluation of ecosystem health (Tedersoo et al. 2010, Toth & Barta 2010). The study of ECMs involves different environments, not only in Mediterranean areas: for instance, there is increasing interest in Chinese (oak) forests and their related fungal communities as testified by a number of papers recently published (Wu et al. 2013, Gao et al. 2013, Zhang et al. 2013).

Some of the observed macrofungal species are considered typical of holm oak woodlands in Italy. For instance *Hygrophorus russula* is present and abundant in all the plots. Other examples are *Leccinellum lepidum* and *Lactarius atlanticus*. These species, in addition to *Lactarius mairei*, were already identified by Orsino (1991) as characteristic of Ligurian holm oak woodlands. Other species such as *H. russula*, *Cortinarius calochrous* and *Agaricus impudicus* were described as having preference for these woodlands. Some other mycologists (De Dominicis & Barluzzi 1983, Barluzzi et al. 1983, Perini et al. 1989) also indicate *Phellinus torulosus* and *L. lepidum* as characteristic taxa for holm oak woodlands in Tuscany. In Corsica Richard et al. (2004) observed *Laccaria laccata*, *Lactarius chrysorrheus*, and *H. russula* among the most frequent taxa found in *Quercus ilex* woods. This demonstrates that a number of species are common to many Mediterranean holm oak woodlands.

Many macrofungal species growing in the surveyed holm oak woodlands of Liguria have a certain degree of thermophilia and are typical of the Mediterranean area (Lancellotti & Franceschini 2013). Examples are *Boletus aereus*, *B. luridus*, *Cortinarius rufo-olivaceus*, *C. ionochlorus*, *Lactarius rugatus*, and *Tricholoma squarrulosum* (Riva 1988, 2003, Basso 1999, Richard et al. 2004, Muñoz 2005, Zotti & Zappatore 2006, Ortega & Lorite 2007). Species with a different degree of thermophilia preferring calcareous soils, such as *Amanita echinocephala*, *A. ovoidea*, *A. proxima*, *Boletus pulchrotinctus*, *B. comptus*, *Russula maculata*, *Xerocomus dryophilus*, and *X. persicolor* (Traverso 1999, Neville & Poumarat 2004, Muñoz 2005, Sarnari 2005), were only found in our western plots.

Many of the observed species are ubiquitous and grow in deciduous, mixed, and coniferous forests and are more or less mesophilous [e.g., *Cantharellus cibarius*, *Hydnum repandum*, *Xerocomus chrysenteron*, *Mycena pura*, *Rhodocollybia butyracea*, *Clitocybe nebularis*, *Lepista nuda*, *L. flaccida*, *Amanita phalloides*, *A. citrina*, *A. muscaria*, *A. rubescens*, *Hypholoma lateritium*, *Russula nigricans*, *R. foetens*, *Lactarius vellereus*, and *Lycoperdon perlatum* (Thoen 1970, 1971, Lisiewska 1974, Adamczyk 1996, Zotti 2002)]. In permanent plots LG1 and LG2, where *Pinus pinaster* is present, various fungal species commonly associated with conifers were present. Examples are *Suillus granulatus*, *S. bellinii*, *Strobilurus stephanocystis*, *Tricholoma aurantium* and *Tricholomopsis rutilans* (Riva 1988, 2003, Bas et al. 1999, Muñoz 2005). These macrofungal species should be considered as occasional.

Comparisons with other holm oak mycobiota are difficult, since few previous analyses have addressed this issue using numerical ecology. Even if previous studies adopted different methodologies and pursued various aims, it is evident that Mediterranean woodlands dominated by *Q. ilex* are characterised by a high level of fungal biodiversity regardless of the structure and features of the investigated stands. This agrees with the observations by Richard et al. (2004) and Ortega &

Lorite (2007). The high macrofungal biodiversity of holm oak woodlands makes it necessary to preserve the remaining areas. Conservation will be complicated by the chronic fragmentation and impending climate change. It is thus important to establish priorities and strategies for the conservation of *Q. ilex* woodlands across the Mediterranean, and not only where they have been studied by mycologists (Ortega & Lorite 2007).

This task appears complex not only in Liguria, but throughout the distributional range of *Q. ilex*, as the Mediterranean basin is a region with a long history of human interference (e.g. Zavala et al. 2000, Butzer 2005, Blondel 2008). There is a need for a pan-Mediterranean assessment of whether also macrofungal communities of *Q. ilex* woodlands conform to the large-scale positive correlation between species richness and human population density (Pautasso & Zotti 2009, Barbosa et al. 2013), and whether, in turn, this correlation reverses to a negative one when analysed locally. It would be important to include in such a study how the macrofungal community is related to human impacts over various scales in relation to the vegetation.

Mycobiota and environmental conditions

As is the case for this study, it is likely that different holm oak woodlands will show variations in plant and fungal communities associated with edaphic features such as pH (Salerni et al. 2001). Indeed, Liguria shows a remarkable geopedological diversity in the areas studied: calcareous soils with neutral or more or less basic reaction in western Liguria; soils poor in calcium, more or less rich in silica, and therewith acidic or sub-acidic in other zones.

Another hypothesis is that species richness might track changes in environmental productivity and, ultimately, in climate. In this study, a climatic gradient can be observed, from strongly Mediterranean plots (FFE, FAM) to those with more temperate bioclimatic conditions (MUR and SV); this result agrees with what was affirmed by Blasi et al. (1999), Vagge (1999), and Rivas-Martínez (2004). Not only fungi, but also the flora are affected by this temperature gradient. In holm oak woodlands at higher altitudes, there is a greater number of mesophilous plant species. Moreover, such communities are impoverished, as they are characterised by dense coverage of *Q. ilex*, often along with *Fraxinus ornus* and *Ostrya carpinifolia* or, as in our case, with *Quercus pubescens*.

Plot size for mycocoenological analyses

As far as the size of the plots is concerned, we have come to an interesting conclusion. Although the surface of the minimum area suggested by Barkman (1973), Arnolds (1992), and Winterhoff (1992) ranges from 500 to 1000 m^2, Liguria lacks such extensive phytosociologically homogeneous areas. This is due to various

reasons, both natural processes (e.g. geo-morphological, topographic, microclimatic processes) and human activities (habitat fragmentation). As a consequence, mycocoenological analyses have to be carried out here in smaller plots (500 m^2) than recommended. This problem can be avoided if fungal surveys are carried out in multiple plots suitably aggregated. The overall variance of the CA associated with the first two axes is lower for fungal (27 %) than for plant (38 %) communities (Figs. 2 and 5). Aggregation of the closest plots (as resulting from the CA) leads to a CA (Fig. 4) explaining more variance (57 %) than the one applied to the individual plots. Although aggregating plots always results in an increase in variance, we think that the observed strong increase (from 27 % to 57 %) may not only be due to the reduced number of plots but also to the improved homogeneity of the aggregated plots. Furthermore, this agrees with the experience gained by Ligurian mycologists on the field.

Aggregating the closest original plots produces new wider plots whose areas range from 1000 to 2000 m^2. Consequently, it appears reasonable to affirm that the recommended minimum size for fungal studies in Mediterranean areas has to be larger than 1000 m^2. This agrees with Arnolds' consideration that the minimum area for macrofungal coenoses thus seems to have to be larger in comparison to the one for plant communities (Arnolds 1981).

Utility of higher-taxon approach

The higher-taxon analysis confirms the utility of the approach (see Tab. 3). The number of macrofungal species observed in various *Q. ilex* plots can be predicted with good confidence ($r^2 = 0.79$) from the number of genera observed. This result holds also within abundance classes (r^2 from 0.80 to 0.89), so that the number of macrofungal species observed within an abundance class (from scarce to medium-frequent to abundant) in *Q. ilex* plots can be predicted with reasonable confidence from the number of macrofungal genera observed within that abundance class in the same plots. This strengthens the generality of the higher-taxon approach for macrofungi, which can simplify the generally onerous identification work, although this approach needs further tests based on DNA methods. However, in order to establish the presence of rare species in a particular plot or set of plots, identification at the species level needs to be carried out.

ACKNOWLEDGEMENTS

Many thanks are due to Alfredo Vizzini, Mido Traverso, and Fabrizio Boccardo for their help with identification of the fungi, to Sandro Zappatore for his suggestions during the data analysis, to Ottmar Holdenrieder, Mike Jeger, David Lons-

dale, John Mansfield, Mauro Giorgio Mariotti, and Thomas Sieber for their advice, insights and discussion, and to anonymous reviewers for their helpful comments on a previous version of the manuscript.

REFERENCES

ADAMCZYK J. (1996): Les champignons supérieurs des hêtraies du nord du Plateau de Czestochowa (Pologne méridionale). – Lejeunia 150: 1–83.

ALI M.B.H.B., ASCHI-SMITI S. (2013): Mycocoenologic study of the macrofungi on the forest of Jbel elbir (Ađn Draham, Jendouba, Tunisia). – African Journal of Ecology, in press. DOI: 10.1111/aje.12080

AMARANTHUS M.P., PERRY D.A. (1994): The functioning of ectomycorrhizal fungi in the field – linkages in space and time. – Plant and Soil 159: 133–140.

ARNOLDS E. (1981): Ecology and coenology of macrofungi in grasslands and moist heathlands in Drenthe, the Netherlands, Part 1. Introduction and synecology. – Bibl. Mycol. 83: 1–410.

ARNOLDS E. (1982): Ecology and coenology of macrofungi in grasslands and moist heathlands in Drenthe, the Netherlands, Part 2. Autecology. Part 3. Taxonomy. – Bibl. Mycol. 90: 1–510.

ARNOLDS E. (1992): The analysis and classification of fungal communities with special reference to macrofungi. – In: Winterhoff W., ed., Fungi in vegetation science, p. 113–149, London.

ARNOLDS E., OPDAM A., VAN STEENIS W., DE VRIES B. (1994): Mycocoenology of stands of *Fagus sylvatica* L. in the northeastern Netherlands. – Phytocoenologia 24: 507–530.

BALMFORD A., LYON A.J.E., LANG R.M. (2000): Testing the higher-taxon approach to conservation planning in a megadiverse group: the macrofungi. – Biological Conservation 93: 209–217.

BARBERIS G., PECCENINI S., PAOLA G. (1992): Notes on *Quercus ilex* L. in Liguria (NW Italy). – Vegetatio 99–100: 35–50.

BARBOSA A.M., PAUTASSO M., FIGUEREIDO D. (2013): Species-people correlations and the need to account for survey effort in biodiversity analyses. – Diversity & Distributions 19: 1188–1197.

BARENGO N., SIEBER T.N., HOLDENRIEDER O. (2000): Diversity of endophytic mycobiota in leaves and twigs of pubescent birch (*Betula pubescens*). – Sydowia 52: 305–320.

BARKMAN J.J. (1973): Synusial approaches to classification. – In: Whittaker R., ed., Handbook of vegetation science 5. Ordination and classification of vegetation, p. 435–491, The Hague.

BARLUZZI C., DE DOMINICIS V., PERINI C. (1983): Primi risultati di indagini micologiche sulle leccete delle colline del litorale grossetano. – Micologia Italiana 12: 29–35.

BAS C., KUYPER T.W., NOORDELOOS M.E., VELLINGA E.C. (1999): Flora Agaricina Neerlandica, vol. 4. – 191 p. Rotterdam.

BASSO M.T. (1999): *Lactarius* Pers. Fungi Europaei, vol. 7. – 845 p. Alassio.

BERGEMANN S.E., GARBELOTTO M. (2006): High diversity of fungi recovered from the roots of mature tanoak (*Lithocarpus densiflorus*) in northern California. – Canadian Journal of Botany 84: 1380–1394.

BERGLUND H., JONSSON B.G. (2008): Assessing the extinction vulnerability of wood-inhabiting fungal species in fragmented northern Swedish boreal forests. – Biological Conservation 141: 3029–3039.

BIDAUD A., CARTERET X., EYSSARTIER G., MOËNNE-LOCCOZ P., REUMAUX P. (2003): Atlas des Cortinaires, vol. 13: p. 711–862. Lyon.

BISSEGGER M., SIEBER T.N. (1994): Assemblages of endophytic fungi in coppice shoots of *Castanea sativa*. – Mycologia 86: 648–655.

BLASI C., CARRANZA M.L., FILESI L., TILIA A., ACOSTA A. (1999): Relation between climate and vegetation along a Mediterranean-Temperate boundary in Central Italy. – Global Ecology and Biogeography 8: 17–27.

BLONDEL J. (2008): On humans and wildlife in Mediterranean islands. – Journal of Biogeography 35: 509–518.

BON M., GEHU J.M. (1973): Unités supérieures de végétation et récoltes mycologiques. – Documents Mycologiques 6: 1–40.

BREITENBACH J., KRÄNZLIN F. (1981): Champignons de Suisse, vol. 1 Les Ascomycètes. – 310 p. Lucerne.

BRAUN-BLANQUET J. (1979): Fitosociologia. Bases para el estudio de las comunidades vegetales. – 298 p. Madrid.

BUTZER K.W. (2005): Environmental history in the Mediterranean world: cross-disciplinary investigation of cause-and-effect for degradation and soil erosion. – Journal of Archaeological Science 32: 1773–1800.

CASTELLO J.D., BRUHN J.N., CUMMINGS-CARLSON J., HAIN F., THOMAS C. (1994): Protecting forest resources – the need for expertise in pathology and entomology. – Journal of Forestry 92: 22–25.

CHIARUCCI A., D'AURIA F., DE DOMINICIS V., LAGANA A., PERINI C., SALERNI E. (2005): Using vascular plants as a surrogate taxon to maximize fungal species richness in reserve design. – Conservation Biology 19: 1644–1652.

CONSIGLIO G., ANTONINI D., ANTONINI M. (2003): Il genere *Cortinarius* in Italia, parte prima. – 200 p. Trento.

DE DOMINICIS V., BARLUZZI C. (1983): Coenological research on macrofungi in evergreen Oak woods in the hills near Siena (Italy). – Vegetatio 54: 177–187.

DOBSON A. (2005): Monitoring global rates of biodiversity change: challenges that arise in meeting the Convention on Biological Diversity (CBD) 2010 goals. – Philosophical Transactions of the Royal Society London B 360: 229–241.

FÉRNANDEZ-TOIRAN L.M., AGREDA T., OLANO J.M. (2006): Stand age and sampling year effect on the fungal fruit body community in *Pinus pinaster* forests in central Spain. – Canadian Journal of Botany 84: 1249–1258.

GAO C., SHI N., LIU Y., PEAY K., ZHENG Y., DING Q., MI X., MA K., WUBET T., BUSCOT F., GUO L. (2013): Host plant genus-level diversity is the best predictor of ectomycorrhizal fungal diversity in a Chinese subtropical forest. – Molecular Ecology 22: 3403–3414.

GEZER K., ISILOGLU M., TURKOGLU A., ALLI H. (2007): Macrofungi of Honaz Mountain (Denizli). – Turkish Journal of Botany 31: 253–261.

HAWKSWORTH D.L. (2001): The magnitude of fungal diversity: the 1.5 million species estimate revisited. – Mycological Research 105: 1422–1432.

HEILMANN-CLAUSEN J., VERBEKEN A., VESTERHOLT J. (2000): The Genus *Lactarius*. Fungi of Northern Europe, vol. 2. – 287 p. Mundelstrup.

HIBBETT D.S., BINDER M., BISCHOFF J.F., BLACKWELL M., CANNON P.F., ERIKSSON O.E., HUHNDORF S., JAMES T., KIRK P.M., LÜCKING R., LUMBSCH T., LUTZONI F., MATHENY P.B., MCLAUGHLIN D.J., POWELL D.J., REDHEAD J., SCHOCH C.L., SPATAFORA J.W., STALPERS J.A., VILGALYS R., AIME M.C., APTROOT A., BAUER R., BEGEROW D., BENNY G.L., CASTLEBURY L.A., CROUS P.W., DAI Y-C., GAMS W., GEISER D.M., GRIFFITH G.W., GUEIDAN C., HAWKSWORTH D.L., HESTMARK G., HOSAKA K., HUMBER R.A., HYDE K., IRONSIDE J.E., KÕLJALG U., KURTZMAN C.P., LARSSON K-H., LICHTWARDT R., LONGCORE J., MIĄDLIKOWSKA J., MILLER A., MONCALVO J-M., MOZLEY-STANDRIDGE S., OBERWINKLER F., PARMASTO E., REEB V., ROGERS J.D., ROUX C., RYVARDEN L., SAMPAIO J.P., SCHÜßLER A., SUGIYAMA J., THORN R.G., TIBELL L., UNTEREINER W.A., WALKER C., WANG Z., WEIR A., WEIß M., WHITE M.M., WINKA K., YAO Y-J., ZHANG N. (2007): A higher-level phylogenetic classification of the Fungi. – Mycological Research 111: 509–547.

KERNAGHAN G., HARPER K.A. (2001): Community structure of ectomycorrhizal fungi across an alpine/subalpine ecotone. – Ecography 24: 181–188.

KIRK P.M., CANNON P.F., MINTER D.W., STALPERS J.A. (2008): Dictionary of the Fungi, 10th ed. – 771 p. Wallingford.

KUYPER T.W., NOORDELOOS M.E., VELLINGA E.C. (1995): Flora Agaricina Neerlandica, vol. 3. – 200 p. Rotterdam.

LAGANÀ A., LOPPI S., DE DOMINICIS V. (1999): Relationship between environmental factors and the proportions of fungal trophic groups in forest ecosystems of the central Mediterranean area. – Forest Ecology and Management 124: 145–151.

LAGANÀ A., SALERNI E., BARLUZZI C., PERINI C., DE DOMINICIS V. (2000): Mycocoenology in *Abies alba* Miller woods of Central-Southern Tuscany (Italy). – Acta Societatis Botanicorum Poloniae 69: 293–298.

LANCELLOTTI E., FRANCESCHINI A. (2013): Studies on the ectomycorrhizal community in a declining *Quercus suber* L. stand. – Mycorrhiza 23: 533–542.

LANCELLOTTI E., SCHIAFFINO A., FRANCESCHINI A., MARRAS F. (2007): Study of the ectomycorrhizal community in a cork oak stand of Sardinia. – Micologia Italiana 36: 89–98.

LISIEWSKA M. (1974): Macromycetes of beech forests within the eastern part of the *Fagus* area in Europe. – Acta Mykologica 10: 3–72.

LITTELL R.C., MILLIKEN G.A., STROUP W.W., WOLFINGER R.D., SCHABENBERGER O. (2006): SAS System for Mixed Models, 2nd ed. – 656 p. Cary.

LONSDALE D., PAUTASSO M., HOLDENRIEDER O. (2008): Wood-decaying fungi in the forest: conservation needs and management options. – European Journal of Forest Research 127: 1–22.

MALENÇON G., BERTAULT R. (1970): Flore des champignons supérieurs du Maroc. Vol. 1. *Agaricales* (Première partie). – 601 p. Rabat.

MALENÇON G., BERTAULT R. (1975): Flore des champignons supérieurs du Maroc. Vol. 2. *Agaricales* (Seconde partie). – 541 p. Rabat.

MALENÇON G., BERTAULT R. (2009): Complèments à la flores des champignons supèrieus du Maroc. – 775 p. Nice.

MARCHAND A. (1983). Champignons du Nord et du Midi. Les Cortinaires vol. 8. – 278 p. Perpignan.

MARIOTTI M. (1984): Ricerche sui boschi a *Quercus ilex* L. nella Liguria Orientale. – Not. Fitosoc. 19(1): 3–32.

MOLINA R. (2008): Protecting rare, little known, old-growth forest-associated fungi in the Pacific Northwest USA: a case study in fungal conservation. – Mycological Research 112: 613–638.

MOLINA R., O'DELL T., DUNHAM S., PILZ D. (1999): Biological diversity and ecosystem functions of forest soil fungi: management implications. – USDA Forest Service GTR 461: 45–58.

MUELLER G.M., SCHMIT J.P., LEACOCK P.R., BUYCK B., CIFUENTES J., DESJARDIN D.E., HALLING R.E., HYORTSTAM K., ITURRIAGA T., LARSSON K.H., LODGE D.J., MAY T.W., MINTER D., RAJCHENBERG M., REDHEAD S.A., RYVARDEN L., TRAPPE J.M., WATLING R., WU Q.W. (2007): Global diversity and distribution of macrofungi. – Biodiversity & Conservation 16: 37–48.

MÜLLER M.M., HALLAKSELA A.M. (2000): Fungal diversity in Norway spruce: a case study. – Mycological Research 104: 1139–1145.

MUÑOZ A.J. (2005): *Boletus* s. l. Fungi Europaei, vol. 2. – 952 p. Alassio.

NEVILLE P., POUMARAT S. (2004): Amaniteae. *Amanita*, *Limacella* & *Torrendia*. Fungi Europaei, vol. 9. – 1120 p. Alassio.

ONOFRI S., BERNICCHIA A., FILIPELLO V., PADOVAN F., PERINI C., RIPA C., SALERNI E., SAVINO E., VENTURELLA G., VIZZINI A., ZOTTI M., ZUCCONI L. (2005): Checklist of Italian fungi. – 380 p. Sassari.

ORSINO F. (1991): Ricerche micocenologiche in leccete della Liguria. – Micologia Italiana 22: 117–126.

ORSINO F., DAMERI R.M. (1991): Ricerche sulla flora micologica della Liguria. 3. I macromiceti delle leccete di Punta Manara (Liguria orientale). – Webbia 46: 125–149.

ORSINO F., TRAVERSO M. (1986): Ricerche sulla flora micologica della Liguria. I macromiceti della "Pietra del Finale" (Liguria occidentale). – Webbia 40: 301–322.

ORTEGA A., LORITE J. (2007): Macrofungi diversity in Cork-Oak and Holm-Oak forests in Andalusia (southern Spain); an efficient parameter for establishing priorities for its evaluation and conservation. – Central European Journal of Biology 2: 1–27.

PAUTASSO M., ZOTTI M. (2009): Macrofungal taxa and human population in Italy's regions. – Biodiversity & Conservation 18: 473–485.

PEAY K.G., KENNEDY P.G., BRUNS T.D. (2008): Fungal community ecology: a hybrid beast with a molecular master. – BioScience 58: 799–810.

PERINI C., BARLUZZI V., DE DOMINICIS V. (1989): Mycocoenological research on evergreen Oak woods in the hills of the Maremma coastline (NW of Grosseto, Italy). – Phytocoenologia 17: 289–306.

PERINI C., BARLUZZI C., DE DOMINICIS V. (1993): Fungal communities in Mediterranean and Submediterranean woodlands. – In: Pegler D.N., Boddy L., Ing B., Kirk P., eds., Fungi of Europe: Investigation, Recording and Conservation, p. 77–92, Kew.

RICHARD F., MILLOT S., GARDES M., SELOSSE M.A. (2005): Diversity and specificity of ectomycorrhizal fungi retrieved from an old-growth Mediterranean forest dominated by *Quercus ilex*. – New Phytologist 166: 1011–1023.

RICHARD F., MOREAU P.-A., SELOSSE M.A., GARDES M. (2004): Diversity and fruiting patterns of ectomycorrhizal and saprobic fungi in an old-growth Mediterranean forest dominated by *Quercus ilex* L. – Canadian Journal of Botany 82: 1711–1729.

RICHARD F., ROY M., SHAHIN O., STHULTZ C., DUCHEMIN M., JOFFRE R., SELOSSE M.A. (2011): Ectomycorrhizal communities in Mediterranean forest ecosystem dominated by *Quercus ilex*: season dynamics and response to drought in the surface organic horizon. – Annals of Forest Science 68: 57–68.

RIVA A. (1988): *Tricholoma* (Fr.) Staude. Fungi Europaei, vol. 3. – 618 p. Saronno.

RIVA A. (2003): *Tricholoma* (Fr.) Staude Supplemento. Fungi Europaei, vol. 3A. – 186 p. Alassio.

RIVAS-MARTÍNEZ S. (2004): Global Bioclimatics (Classificación Bioclimática de la Tierra). Versión 27-08-2004. – http://www.globalbioclimatics.org/book/bioc/global_bioclimatics_9.htm. [accessed 9 Oct. 2013]

RODRÍGUEZ M.H., ORIA-DE-RUEDA J.A., MARTÍN-PINTO P. (2013): Post-fire fungal succession in a Mediterranean ecosystem dominated by *Cistus ladanifer* L. – Forest Ecology and Management 289: 48–57.

SALERNI E., LAGANÀ A., DE DOMINICIS V. (2001): Mycocenological studies in deciduous Oak woods of central-southern Tuscany (Italy). – Cryptogamie Mycologique 22: 35–55.

SANTI E., MACCHERONI S., ROCCHINI D., BONINI I., BRUNIALTI G., FAVILLI L., PERINI C., PEZZO F., PIAZZINO S., ROTA E., SALERNI E., CHIARUCCI A. (2010): Simple to sample: vascular plants as surrogate group in a nature reserve. – Journal of Nature Conservation 18: 2–11.

SARNARI M. (1998): Monografia illustrata del Genere *Russula* in Europa. Vol. 1. – 799 p. Trento.

SARNARI M. (2005): Monografia illustrata del Genere *Russula* in Europa. Vol. 2. – 762 p. Trento.

SCHMIT J.P., LODGE J.D. (2005): Classical methods and modern analysis for studying fungal diversity. – In: Dighton J., White J.F., Oudemans P., eds., The Fungal Community, p. 193–214, Boca Raton.

SIGNORELLO P. (1996): Indagini micocenologiche sulle cenosi a *Quercus ilex* L. dell'Etna. – Micologia Italiana 25: 74–80.

SMITH M.E., DOUHAN G.W., RIZZO D.M. (2007): Ectomycorrhizal community structure in a xeric *Quercus* woodland based on rDNA sequence analysis of sporocarps and pooled roots. – New Phytologist 174: 847–863.

STRONG D.R., LEVIN D.A. (1975): Species richness of the parasitic fungi of British trees. – Proceedings of the National Academy of Sciences USA 72: 2116–2119.

TAYLOR J.E., LEE S., CROUS P.W. (2001): Biodiversity in the Cape Floral Kingdom: fungi occurring on *Proteaceae*. – Mycological Research 105: 1480–1484.

TEDERSOO L., MAY T.W., SMITH M. (2010): Ectomycorrhizal lifestyle in fungi: global diversity, distribution, and evolution of phylogenetic lineages. – Mycorrhiza 20: 217–263.

TÓTH B.B., BARTA Z. (2010): Ecological studies of ectomycorrhizal fungi: an analysis of survey methods. – Fungal Diversity 45: 3–19.

THOEN D. (1970): Etude mycosociologique de quelques associations forestières des districts picardo-brabançon, mosan et ardennais de Belgique. – Bulletin des Recherches Agronomiques de Gembloux 5: 310–326.

THOEN D. (1971): Etude mycosociologique de quelques associations forestières des districts picardo-brabançon, mosan et ardennais de Belgique [2 partie]. – Bulletin des Recherches Agronomiques de Gembloux 6: 215–243.

TRAVERSO M. (1999): Il genere *Amanita* in Italia. – 182 p. Roma.

UNTERSEHER M., SCHNITTLER M., DORMANN C., SICKERT A. (2008): Application of species richness estimators for the assessment of fungal diversity. – FEMS Microbiology Letters 282: 205–213.

VAGGE I. (1999): La diffusione del bioclima mediterraneo in Liguria (Italia Nord Occidentale). – Fitosociologia 36: 95–109.

VANOSSI M. (1991): Guide Geologiche Regionali, 11 itinerari, Alpi Liguri. – 293 p. Roma.

VASILIAUSKAS R., VASILIAUSKAS A., STENLID J., MATELIS A. (2004): Dead trees and protected polypores in unmanaged north-temperate forest stands of Lithuania. – Forest Ecology & Management 193: 355–370.

WINTERHOFF W. (1992): Fungi in vegetation science. – 258 p. Dordrecht.

WOODWARD S., BOA E. (2013): Dieback in the UK: a wake-up call. – Molecular Plant Pathology, in press. DOI:10.1111/mpp.12084

WU Y.T., WUBET T., TROGISCH S., BOTH S., SCHOLTEN T. (2013): Forest age and plant species composition determine the soil fungal community composition in a Chinese subtropical forest. – PLoS One 8: e66829.

ZAVALA M.A., ESPELTA J.M., RETANA J. (2000): Constraints and trade-offs in Mediterranean plant communities: the case of holm oak-Aleppo pine forests. – Botanical Review 66: 119–149.

ZHANG J., TANIGUCHI T., TATENO R., XU M., DU S., LIU G., YAMANAKA N. (2013): Ectomycorrhizal fungal communities of *Quercus liaotungensis* along local slopes in the temperate oak forests on the Loess Plateau, China. – Ecological Research 28: 297–305.

ZOTTI M. (2002): Mycological researches in beech woods in Western Ligurian Apennines, province of Savona (Italy). – Cryptogamie Micologie 23: 135–162.

ZOTTI M. (2004): Valutazione della micodiversità in leccete della Liguria. – Informatore Botanico Italiano 36: 542–545.

ZOTTI M., DI PIAZZA S., AMBROSIO E., MARIOTTI M.G., ROCCOTIELLO E., VIZZINI A. (2013): Macrofungal diversity in *Pinus* plantations in Northwest Italy (Liguria). – Sydowia 65(2), in press.

ZOTTI M., ORSINO F. (2001): The check-list of Ligurian macrofungi. – Flora Mediterranea 11: 115–294.

ZOTTI M., VIZZINI A., TRAVERSO M., BOCCARDO F., PAVARINO M., MARIOTTI M.G. (2008): The macrofungi checklist of Liguria (Italy): the current status of surveys. – Mycotaxon 105: 167–170.

ZOTTI M., ZAPPATORE S. (2006): Mycodiversity in beech woods of Western Liguria (Italy). – Plant Biosystems 140: 27–33.