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Biodiversity of wood-decay fungi in Italy


Abstract

Current knowledge about Italian wood-decay fungi (Basidiomycota and Ascomycota) is surveyed: 1582 taxa belonging to Ascomycota (341) and Basidiomycota (1241) have been reported, including 23 species new to science of Basidiomycota described from Italy within the last five years. Evaluating diversity of wood-decay fungi can provide a more accurate estimation of species richness for fungi which are an important functional component of ecosystems. Aphyllophoroid and Ascomycota species play an important role in habitat conservation and management. Sardinia, Sicily, the Alps and the Apennines are “hot spots” for wood-decay Basidiomycota in Italy.

Keywords: Ascomycota, Basidiomycota, biodiversity, Italy, wood-decay fungi.

Introduction


Ecology, systematics and distribution of wood-decay basidiomycetes in Italy


The up-to-date total number of wood-decay Basidiomycota in Italy are 1241 taxa, which represent 78% of the fungal taxa listed in this work. Among them, 770 species are aphyllorophoroid and 471 species are non-aphyllorophoroid. This number is continuously changing and at least 23 taxa new to science of Basidiomycota have been described during the last five years in Italy.

The study of aphyllorophoroid wood-inhabiting fungi enjoyed a golden period in Bresadola's time and the town of Trento became a datum point for all the contemporary mycologists. Later, this branch of mycological research was neglected for many decades. Only since the beginning of the 1980s of the last century this important and numerous group of fungi has been consistently studied again. Some mycologists, both academics and amateurs, kept alive the tradition begun by the Italian mycologists. Before 2005, we only have reprints listing observations of species from forests and reserves, although these cover many Italian regions. The aphyllorophoid fungi are included in a heterogeneous group composed generally of species ranging from resupinate to effuse-reflexed or pileate. During the last decades, with the introduction of the use of molecular data in taxonomy, the classification of the Aphyllorophorales has dramatically changed. They form highly polyphyletic groups distributed over several families and orders among the homobasidiomycetes and most of them form basal clades among the major groups of Agaricales and Boletales (Binder & Hibbett 2002 Binder, M and Hibbett, D S. 2002. Higher-level phylogenetic relationships of homobasidiomycetes (mushroom-forming fungi) inferred from four rDNA regions. Mol Phylogenet Evol, 22: 76–90.; Hibbett et al. 2007 Hibbett, D S, Binder, M, Bischoff, J F, Blackwell, M, Cannon, P FÉriksson, O E. 2007. A higher-level phylogenetic classification of the Fungi. Mycol Res, 111: 509–547.; Larsson 2007 Larsson, K H. 2007. Re-thinking the classification of corticioid fungi. Mycol Res, 111: 1040–1063.; Binder et al. 2010 Binder, M, Larsson, K H, Matheny, P B and Hibbett, D S. 2010. Amylocorticales ord. nov. and Jaapiiales ord. nov.: Early diverging clades of Agaricomycetidae were dominated by corticioid forms. Mycologia, 102: 865–880.).
In this article, we update the Italian data of aphylloporoid wood-decay fungi to 770 species (online Appendix A) (456 corticioid, 265 polypores, 45 tomentellloid, 4 cyphelloid). They are distributed in the following orders: Agaricales (49), Amylocorticatales (8), Atheliales (42), Boletales (12), Cantharelles (43), Corticales (15), Gloeophyllales (8), Gomphales (3), Hymenochaetales (137), Jaapiales (1), Polyporales (290), Russulales (89), Thelephorales (41), and Trechisporales (32).

The aphylloporoid fungi include organisms with several ecological strategies. Most are saprobic while some are mycorrhizal (some tomentellloid species, the genera Albatrellus Gray and Boletopsis Fayod) or parasites. Among the polypores, it is worth highlighting some species because of their pathogenicity. These include Heterobasidion annosum (Fr.) Bref., H. abietinum Niemelä & Korhonen, Inonotus hispidus (Bull.) P. Karst., Laetiporus sulphureus (Bull.) Murr., Phaeolus schweinztii (Fr.) Pat., Phellinus chrysoloma (Fr.) Donk, P. tuberulosus (Baumg.) Niemelä, and Porodadalea pini (Brot.) Murril. Polypores and corticioid fungi colonize wood of a very wide range of plants during all decay stages; some are strictly specific and grow only on a single plant family or more rarely, on a sole species. They have been recorded mainly on the following substrata (online Appendix B): 267 species on Quercus spp., 238 on Pinus spp., 210 on Abies alba Mill., 186 on Fagus sylvatica L., 170 on Picea abies (L.) H. Karst., 70 on Castanea sativa Mill., 115 on Juniperus spp., 67 on Ulmus spp., 64 on Salix spp., 55 on Arbutus unedo L., 35 on Taxus baccata L.

More than 20 species new to science have been described during the last five years; they have been recorded in just a few Italian regions and several species have been described and successively recorded exclusively in Italy, such as Aleurodiscus ilexicola Bernicchia & Ryvarden, Antrodia macrospora Bernicchia & De Dominis, Antrodialla semistipitata Bernicchia & Ryvarden, Botryobasidium sassoarintoense Bernicchia & G. Langer, Byssomerulius pirottae (Bres.) Hjortstam, Ceriporia sulphuricolor Bernicchia & Niemelä, Ceriporiopsis guidella Bernicchia & Ryvarden, Cristinia artheniensis Baic & Hjortstam, Echinodontium ryvardenii Bernicchia & Piga, Fomitopsis labirynthica Bernicchia & Ryvarden, Hyphoderma etruriae Bernicchia, Lindtneria brevispora Bernicchia & Gorjón, L. hydnoidea Bernicchia & Ryvarden, Phanerochaete parvispora Sheng H. Wu & Losi, Phlebia capitata Bernicchia & Gorjón, Tomentellopsis pulchella K[otilde]lb[otilde]lg & Bernicchia and Vararia maremmana Bernicchia (Bernicchia 2005 Bernicchia, A. 2005. Polyporaceae s.l. Fungi Europaeet, 10. Ed, 808Alassio, Italy: Candusso. ; Bernicchia & Gorjón 2010 Gorjón, S P and Bernicchia, A. 2010. The genus Dendrothele (Basidiomycota) in Italy, an update with notes on European species. Nova Hedwigia, 90: 233–250.). Some species, described for the first time in Italy, have a distribution limited to certain Mediterranean or central European countries. Antrodia sandalae Bernicchia & Ryvarden has been collected only from dead branches of Arbutus unedo L. in Mediterranean forests of Sardinia and central-west Spain. Antrodialla ichnusana Bernicchia, Renvall & Arras has been recorded also from Finland and France. Dendrothele wojewodae Pouzar was recorded in Italy, the Czech Republic and Ukraine (Gorjón & Bernicchia 2010 Gorjón, S P and Bernicchia, A. 2010. The genus Dendrothele (Basidiomycota) in Italy, an update with notes on European species. Nova Hedwigia, 90: 233–250.). The new species Fibroporia bohemica Bernicchia, Vampola & Prodi has been recently described morphologically and on a molecular basis, using specimens previously ascribed to F. radiculosa (Peach. Gilbn. & Ryvarden (Bernicchia et al. in press); so far, it is known from Bohemia in the Czech Republic and the Italian Alpes. Lindtneria panphyliensis Bernicchia & M.J. Larsen has a well-documented distribution in Czech Republic, France, Italy and UK. Fibroporia citrina (Bernicchia & Ryvarden) Bernicchia & Ryvarden, Hyphoderma crustulinum (Bres.) Nakasone, Neolentiporus squamosellus (Bernicchia & Ryvarden) Bernicchia & Ryvarden, Phellinus juniperinus Bernicchia & S. Curreli and P. rosmarinii Bernicchia have also been recorded from France.

Among the group of species sharing a Mediterranean distribution and thus penetrating only into the warmer European areas the following are present in Italy: Acanthophysellum dextrinoideocerussatum


The total number of wood-decay non-aphyllophoroid taxa in Italy is 471 (online Appendix C), belonging to the orders Agaricales (351 taxa), Auriculariales (36), Dacrymycetales (14), Tremellales (14), Cantharellales (11), Polyporales (9), Russulales (8), Boletales (8), Gloeophyllales (4), Gomphales (4), Exobasidiales (3), Platigloeales (6), Septobasidiales (2) and Geastrales (1). Genera with higher numbers of taxa are Mycena (Pers.) Roussel (56), Pluteus Fr. (34), Pholiota (Fr.) P. Kumm. (24), Psathyrella (Fr.) Quél. (17), Crepidotus (Fr.) Staude (16), Marasmiellus Murrill (11), Exidia Fr. (10), Gymnopilus P. Karst. (10), Tremella Pers. (10), and Dacrymyces Nees (9).

Candidate species included in the draft European red list

Taking into account their distribution and ecological value, a significant number of these species, can be considered for inclusion in the draft European red list.

Of the wood-decay Basidiomycota (online Appendix D) 194 species are among the 1644 candidates for the European red list (http://www.wsl.ch/eccf/). Among them, the following species, because of their environmental importance and rarity in Italy, should be included in the future European red list:

Ryvarden, Vuilleminia megalospora Bres., and V. pseudocystidiata, Lanq. & Gilles. In addition, there are some very rare and interesting species absent from the preliminary list, including Chaetoderma luna (Romell ex D.P. Rogers & H.S. Jacks.) Parmasto, C. candidissimum, Dendrothele nivosa (Berk. & M.A. Curtis ex Höhn. & Litsch.) P.A. Lemke, Dendrothele wojewodae, F. fennae, Lindneria panphylensis, M. virgatocutis, P. porrigens and Vararia maremmana.

Focal species for habitat conservation


A group of species growing on specific endangered substrata are the most useful way to drive the conservation of forest ecosystems. In Italy, many interesting and rare fungal species are linked to a specific substratum and can be used, as usually happens for mammals or birds, as “umbrella species”, which provide for conservation of the entire ecosystem.

A significant number of Basidiomycota were found in plant communities included in the priority Habitats of Annex I of the Directive 92/43/EEC and its interpretation manual for Italy (Blasi et al. 2007 Blasi, C, Boitani, L, La Posta, S, Manes, F and Marchetti, M. 2007. “Biodiversity in Italy”. In Contribution to the national biodiversity strategy, 460Roma: Palombi & Partner S.r.L.) and most of these belong to the aphyllophoroid group. The most significant habitats for their conservation are “Endemic forests with Juniperus spp. (*9560)” “Quercus suber forests (9330)”, “Quercus ilex and Quercus rotundifolia forests (9340)”, “Alpine Larix decidua and/or Pinus cembra forests (9420)” and “Apennine beech forests with Abies alba and beech forests with Abies nebrodensis (*9220)”.

The cases of juniper and cork oak forests are highlighted as follow. Old Sardinian juniper (Juniperus phoenicea L. and J. oxycedrus L.) forests very often are selective substrata for very rare species such as E. ryvardenii, Hyphoderma etruriae, Lenzitopsis oxycedri, Neolentiporus squamosellus, Piloporia sajanensis (Parmasto) Niemelä and Trametes junipericola. Most species associated with ancient juniper forests occur in the Urzulei-Piraoanni-Orgosolo-Lanaittu area, where some outstanding examples have been recorded. Juniper trees are an irreplaceable substratum, and for this reason survival of many wood-inhabiting Italian aphyllophoraceous species has become uncertain. Many polypores restricted to old specimens of Juniperus L. follow the host genus wherever it occurs, with a scattered distributional pattern. They may therefore be considered threatened species, and old juniper trees should be protected (Bernicchia & Ryvarden 1988 Bernicchia, A and Ryvarden, L. 1988. Aleurodiscus ilexicola Bernicchia & Ryvarden sp. nov. from Sardinia. Mycol Helv, 3: 83–88. ).

Mediterranean oak forests and shrublands are fragile ecosystems and some aphyllophoroid species connected with these habitat need to be protected. A species growing specifically or preferentially on Quercus suber L., Odonticum flavicans, is a good indicator of cork oak forests which should be conserved.

Hot spots for wood-decay Basidiomycota in Italy
Some areas such as the Alps and the Apennines, present a notable diversity of polypores and corticioids. Several aphyllophoroid fungi have been recorded exclusively from the Alps. These include Antrodia alpina, Antrodia semistipitata, A. serpula (P. Karst.) Spirin & Niemelä, Asterodon ferruginosus Pat., Atheloderma mirabile, Athelopsis lembospora (Bourd.) Oberw., Ceratobasidium anceps (Bres. & Syd.) H.S. Jacks., Dendrothele amygdalispora and Xanthopus syringae. Some areas of the Alps show a high fungal diversity (Bernicchia 2005 Bernicchia, A. 2005. Polyporaceae s.l. Fungi Europaei, 10. Ed, 808Alassio, Italy: Candusso. ; Bernicchia & Gorjón 2010 Gorjón, S P and Bernicchia, A. 2010. The genus Dendrothele (Basidiomycota) in Italy, an update with notes on European species. Nova Hedwigia, 90: 233–250.), for example “Val Casies”, “Val d'Ultimo” and “Val di Genova” in the Trentino Alto-Adige Region. From the last of these, recently, Antrodia semistipitata has been described as a species new to the science (Bernicchia et al. 2007a Bernicchia, A, Ryvarden, L and Gibertoni, B T. 2007a. Antrodia semistipitata (Basidiomycetes, Polyporales) a new species from Italy. Mycotaxon, 99: 231–237.). Some species have been exclusively recorded from the Apennines. The “Sasso Fratino” Reserve, for example, is a very interesting area for aphyllophoroid fungi, with two endemic polypores, Ceriporiopsis guidella (Bernicchia & Ryvarden 2003 Bernicchia, A and Ryvarden, L. 2003. A new white-rot polypore from Italy. Mycotaxon, 88: 219–224.), Fomitopsis lauritana, one corticioid, Botryobasidium sassofratinoense Bernicchia & G. Langer (Bernicchia et al. 2010 Bernicchia, A, Langer, G and Gorjón, S P. 2010. Botryobasidium sassofratinoense sp. nov. (Chantarellesas, Basidiomycota) from Italy. Mycotaxon, 111: 403–409.), and several rare species such as Ceriporia herinkii Vampola, Crustomyces expallens (Bres.) Hjorstam, C. subabruptus (Bourd & Galzin) Jülich, Dentipellis fragilis, Hyphodontia latitans (Bourdot & Galzin) Ginnns & M.N.L. Lefebvre, Parvobasidium cretatum (Bourd & Galzin) Jülich, Podofomes trogii (Fr.) Pouzar, Steccherinum robustius, and Xyodon nudisetus (Warcup & P.H.B. Talbot) Hjorstam & Ryvarden.

Sardinia and Sicily, the two major Italian islands, provide a refuge for many interesting species. Mediterranean forests and shrublands, typically consisting of densely or sparsely growing evergreen shrubs and trees, constitute a complex ecological system inhabited by some recently recognized species, many of them rare or very rare lignicolous fungi. In Sardinia, ancient juniper forests are a most remarkable ecosystem because of their many rare aphyllophoroid fungi already discussed. Some areas are notable for their fungal diversity. These include “Badde Salighes” (Bernicchia & Ryvarden 1988 Bernicchia, A and Ryvarden, L. 1988. Aleurodiscus ilexicola Bernicchia & Ryvarden sp. nov. from Sardinia. Mycol Helv, 3: 83–88.), “Valle di Lanaquitu”, “Supramonte di Orgosolo” and “Urzulei” in Nuoro province. In Ogliastra province, there is the “Montarbu forest”, the only known location of Antrodia sandaliae, and “Baccu Gerduri forest” where Antrodia ichnusana can be found. Several species have been recorded on Juniperus spp.: E. ryvardenii, collected in Sardinia on Juniperus phoenicea and J. oxycedrus subsp. macrocarpa, Sibth. & Sm., is very interesting because it is the first and so far the only known collection area of Echinodontium Ellis & Everh. in Europe: all previously known species are North American or Asiatic (Bernicchia & Piga 1998 Bernicchia, A and Piga, A. 1998. A new species of Echinodontium from Italy. Mycotaxon, 68: 483–491.). Piloporia sajanensis, recorded on J. oxycedrus subsp. oxycedrus L. is a boreal species, found in Scandinavia and central to eastern Russia. Its presence in Sardinia can be regarded as a relic from the last glacial period when ice reached most of central Europe and coniferous forest covered most of the higher areas in the Mediterranean region.

In Sicily, assessment of wood-decay fungi is still in progress and new distributional and ecological information is being acquired with the frequent discovery of previously unrecorded taxa. A huge number of species have been found in Quercus ilex L. and Q. suber woods. These include Ceriporia griseoviolascens, Gloeodonta columbiensis Burt ex Burds. & Lombard, Lindmeria chordulata (D.P. Rogers) Hjorstam, Odonticiun flavicans, Phellinus erectus A. David, Dequatre & Fiasson, Phlebia nothofagi, Sarcodontia crocea (Schwein.) Kotl., Trechispora stevensonii (Berk. & Broome) K.H.
Ecology, systematics and distribution of wood-decay ascomycetes


Currently, Ascomycota is divided into three monophyletic subphyla: Pezizomycotina, Saccharomycotina, and Taphrinomycotina. Pezizomycotina is the largest subphylum and includes the vast majority of filamentous, fruit-body-producing species (James et al. 2006 James, T Y, Kauff, F, Schoch, C, Matheny, P B, Hofstetter, V Cox, C J. 2006. Reconstructing the early evolution of Fungi using a six-gene phylogeny. Nature, 443: 818–822.). Within this subphylum, in the Sordariomycetes clade there are fungi significant in a range of major ecologies including wood-decay (e.g. Xylariales) (Spatafora et al. 2006 Spatafora, J W, Sung, G H, Johnson, D, Hesse, C, ORourke, BSerdani, M. 2006. A five-gene phylogeny of Pezizomycotina. Mycologia, 98: 1018–1028.).


Many species of wood-decay fungi have preference for trees in a particular age class. In addition, the fungal communities in decomposing wood differ according to the particular decay classes (e.g. Heilmann-Clausen & Boddy 2008; Fukasawa et al. 2011 Fukasawa, Y. 2011. Wood decomposing abilities of diverse lignicolous fungi on nondecayed beech wood. *Mycologia*, 103: 474–482[Web of Science ®]). The occurrence of different fungal communities with different abilities to cause decay and with different ecological specialization defines the trophic fungal succession as a sequential colonization of the substratum. Fungal succession on wood is indirectly driven by wood properties (resource quality) and environmental factors (microclimate), and directly driven by fungal ecological strategies (pioneer, combative) (Boddy 1992 Boddy, L. 1992. “Development and function of fungal communities in decomposing wood”. In *The fungal community: Its organisation and role in the ecosystem.* , 2nd ed, Edited by: Carroll, G C and Wicklow, D T. 749–782. New York, NY: Marcel-Dekker. , 2001). Many studies have reported that the *Basidiomycota* and *Xylariaceae* account for most lignocellulose decomposition in wood debris. Many authors (e.g. Worrall et al. 1997 Worrall, J J, Anagnost, S E and Zabel, R A. 1997. Comparison of wood decay among diverse lignicolous fungi. *Mycologia*, 89: 199–219.; Fukasawa et al. 2011 Fukasawa, Y. 2011. Wood decomposing abilities of diverse lignicolous fungi on nondecayed beech wood. *Mycologia*, 103: 474–482) have investigated wood decaying abilities of fungi using pure culture tests under laboratory conditions with the aim of understanding the role of fungi in wood decomposition in nature as well as the biological applications of these abilities. Weight losses caused by members of *Ascomycota* were generally moderate to low, but in the *Xylariales* and *Sordariales* approached 40%. All ascomycetes that caused weight loss exceeding 2% caused decay features characteristic of soft rot (Worrall et al. 1997 Worrall, J J, Anagnost, S E and Zabel, R A. 1997. Comparison of wood decay among diverse lignicolous fungi. *Mycologia*, 89: 199–219.). For several *Ascomycota*, such as some *Xylariales*, these authors reported the same complement of tested phenoloxidase activities (gallic and tannic acid, laccase, and peroxidase) as did typical white-rot fungi. White-rot fungi can progressively utilize all major cell wall components, including both the carbohydrates and the lignin.

Members of the *Xylariaceae* and *Chaetomiaceae* G. Winter and a few additional species showed other advanced decay features, including relatively high weight loss and lignin degrading ability. Fukasawa et al. (2011 Fukasawa, Y. 2011. Wood decomposing abilities of diverse lignicolous fungi on nondecayed beech wood. *Mycologia*, 103: 474–482) reported among the *Xylariaceae [Hypoxylon fragiforme* (Pers.) J. Kickx f. and *Kretzschmaria deusta* (Hoffm.) P.M.D. Martin], a greater weight loss for non-decayed beech wood than for intermediate and well-decayed wood. The weight losses were higher in intermediately or well-decayed wood in some anamorphic *Ascomycota*.

This first survey of wood-decay *Ascomycota* (excluding anamorphs) from Italy is based on species reported in the available literature which was largely contributed by Medardi (2006 Medardi, G. 2006. *Ascomiceti d'Italia. Trento: A.M.B. Centro Studi Micologici*, 454Trento: Associazione Micologica Bresadola ). Saitta et al. (2004 Saitta, A, Bernicchia, A and Venturella, G. 2004. Contributo alla conoscenza dei funghi lignici della Sicilia. *Inform Bot Ital*, 36: 192–202. ) for Sicily, and unpublished data resulting from surveys carried out on coarse woody debris in the Cilento and Vallo di Diano National Park, (Campania) southern Italy (A. M. Persiani, personal communication). Collectively, these constitute a total of 341 taxa within the *Pezizomycotina*, with information about their distribution and substratum associations. It is far from exhaustive, but represents a good start for assessing the status of knowledge about Italian wood-decay *Ascomycota* diversity, for determining threats to that diversity, and promoting the most appropriate actions to be taken for its conservation within with forest ecosystems. The nomenclatural sources adopted were the Dictionary of the Fungi (Kirk et al. 2008 Kirk, P M, Cannon, P F, Minter, D W and Stalpers, J A. 2008. *Dictionary of the*
fungi. , 10th ed, 771UK: CABI Europe. ) and IndexFungorum, the de facto global nomenclator for fungal names, http://www.indexfungorum.org/names/Names.asp.

The 341 species of wood-decay Ascomycota (Pezizomycotina) in Italy (i.e. only those species for which a woody substratum has been reported, belong in 24 orders, 57 families and 138 genera. The species are listed in the online Appendix E, in which are also reported their references published and/or unpublished in the case of research in progress. In respect of the biogeographic regions of Europe, and in the context of Alpine/Continental regions assigned to Italy, Lombardy is the most widely studied with 287 taxa, followed by Trentino and Veneto, with 85 and 71 taxa, respectively. In the Mediterranean region, Tuscany with 38 taxa, and Campania and Sicily, both with 36 taxa are the regions most studied. However, this dataset may reflect the distribution of researchers and of investigations carried out as well.

The best represented orders, as a percentage of the 341 species are: Helotiales Nannf. 30.5%, Xylariales Nannf. 18.8%, Pezizales J. Schröt. 12.3%, Hypocreales Lindau 6.7%, Diaporthales Nannf. 6.7%, Pleosporales Lutt. ex M.E. Barr 5.0% and Orbiliales Baral, O.E. Erikss., G. Marson & E. Weber 3.5%. The best represented families are: Xylariaceae 11.4%, Helotiaceae Rehm 10.9%, Hyaloscyphaceae Nannf. 7.9%, Diatrypeaceae Nitschke 6.7%, Pezizaceae Dumort. 5.3% and Dermateae Fr. 5.3%. The best represented genera are: Peziza Fr. (14 taxa), Xylaria Hill ex Schrank (14), Orbilia Fr. (11), Scutellinia (Cooke) Lambotte (10), Hymenoscyphus Gray (9), Lachnellula P. Karst. (9), Hypocrean. (Fr.) P. Karst. (8), Nectria (Fr.) Fr. (7), Lachnum Retz. (6), Hypoxylon Bull. (6), and Phaeohelotium Kanouse (6).

The high richness in species of Mollisia agrees with reports for boreal forests. In fact Mollisia includes species growing on plant debris as well as on decaying wood, and some are also obviously biotrophs. Kauserud et al. (2005) sampled fungal spores from air in three boreal forest sites and phylogenetic analyses were used to obtain a molecular characterization. Mollisia was the most abundant genus within Helotiales and was especially frequent in old-growth forest sites and lowest in the most disturbed clear-cut forests.

The results for the Pezizomycotina can also be correlated with various plant taxa (more than 50), including conifers, and broad-leaved, deciduous and evergreen shrubs, and trees. In most cases, these represent the most relevant vegetational aspects relative to the “forests, wood and scrubs” macro category of the Directive's habitats (92/43/EEC) and its interpretation manual for Italy (Blasi et al. 2007 Blasi, C, Boitani, L, La Posta, S, Manes, F and Marchetti, M. 2007. “Biodiversity in Italy”. In Contribution to the national biodiversity strategy, 460Roma: Palombi & Partner S.r.L. ).

The highest number of Pezizomycotina taxa was associated with Fagus sylvatica wood substrata (73), and in decreasing order Quercus spp. (70), Alnus spp. (42) and Populus spp. (36). Records from woody substrata of F. sylvatica and Quercus spp. will now be discussed.

In Europe, the southern limit of F. sylvatica is found in Italian beech forest stands and for this reason, these stands are of particular interest, particularly since, in Mediterranean Europe, forest exploitation has been going on for thousands of years, and during the 20th century a lot of deforestation took place (Gilg 2004 Gilg, O. 2004. Forêts a caractère naturel: Caractéristiques, conservation et suivi, 96Aten, Montpellier: Cahiers Techniques de l’ATEN, 74. ).

Of the 73 species reported as occurring on dead wood of F. sylvatica, around 70% are attributable to investigations in beech forests of protected areas in Italy (online Appendix F). With respect to some
of these areas, two priority habitats indicated by the Habitat Directive (European Commission DG Environment, Nature and Biodiversity, 2003 – Interpretation Manual of European Union Habitats – EUR25) are relevant, both phytogeographically and ecologically. They are: “Apennine beech forests with Taxus and Ilex” (*9210) for the PNCVD and “Apennine beech forests with Abies alba and beech forests with Abies nebrodensis” (*9220) for Sicily (Madonie Park).

Of the Pezizomycotina recorded on F. sylvatica dead wood, four genera are the most represented, each with four species: Hymenochaetus calyculus (Sowerby) W. Phillips, H. imberbis (Bull.) Dennis, H. serotinus (Pers.) W. Phillips, H. sublateritius (Berk. & Broome) Dennis, Hypocre aereoviridis Plowr. & Cooke, H. citrina (Pers.) Fr., H. gelatinosa (Tode) Fr., H. rufa (Pers.) Fr., Hypoxylon fragiforme, H. fuscum (Pers.) Fr., H. rubiginosum (Pers.) Fr., H. rutilum Tul. & C. Tul., Xylaria hypoxylon (L.) Grev., X. juruensis Henn., X. longipes Nitschke, and X. polymorpha (Pers.) Grev. Diatrype Fr. is represented by three species: D. bullata (Hoffm.) Fr., D. disciformis (Hoffm.) Fr., and D. stigma (Hoffm.) Fr.

This survey is the first Italian contribution about species of Pezizomycotina associated with beech wood to highlight the key importance of dead wood for biodiversity in these forests and its availability to possible specific species' demand.

The occurrence of wood-inhabiting fungi can be considered as an indicator of the natural value of European beech forests, and some authors (e.g. Christensen et al. 2004 Christensen, M, Heilmann-Clausen, J, Walley, R and Adamik, S. Wood-inhabiting fungi as indicators of nature value in European beech forests. EFI Proceedings No. 51. Edited by: Marchetti, M. pp.526Finland Joensuu: European Forest Institute. Monitoring and indicators of forest biodiversity in Europe e from ideas to operationality) have proposed a set of fungal indicator species, predominantly Basidiomycota, to be considered in setting conservation priorities in European beech forests.

In respect of the Pezizomycotina recorded on Quercus spp. dead wood (online Appendix G) four genera are strongly represented. Hypoxylon has five species: Hypoxylon fragiforme, H. fuscum, H. howeae num Peck, H. rubiginosum and H. rutilum. Mollisia has four species: M. cinerea (Batsch) P. Karst., M. discolor var. longispora Le Gal, M. ligni (Desm.) P. Karst., M. ramealis P. Karst. The genera Daldinia Ces. & De Not. and Lachnum are both represented by three species: D. concentrica (Bolton) Ces. & De Not., D. martini M. Stadler, Venturell a & Wollw., D. raimundi M. Stadler, Venturella & Wollw., L. bicolor (Bull.) P. Karst., L. brevipilosum Baral and L. virgineum (Batsch) P. Karst. Among Quercus species, Q. ilex is notable as representative of the Mediterranean sclerophyllous forests so widely characteristic of Italy. Prolonged exploitation of forests in Italy favors this species which is more adapted to xeric environments than deciduous Quercus species like Q. pubescens Willd. and Q. ceras L. The highest number of taxa were recorded from Q. ilex (26) (online Appendix H), compared to 70 species for all species of Quercus combined.

Of the 341 species reported in this study, 20 (online Appendix I) appear in red lists of other European countries (http://www.wsl.ch/eccf/). Among those 20 species we wish to highlight Biscogniauxia mediterranea (De Not.) Kunz, Hymenochaetus monticola (Berk.) Baral and Chlorociboria aeruginosa (Oeder) Seaver ex C.S. Ramamurthi, Korf & L.R. Batra, all on woody substrata of F. sylvatica and Quercus spp.

Focal species for habitat conservation

In Italy, an integrated research project has been carried out in the Cilento and Vallo di Diano National Park on broad-leaved forests with varying management histories (Burrascano et al. 2009 Burrascano, S, Rosati, L and Blasi, C. 2009. Plant species diversity in Mediterranean old-growth forests: A case
study from central Italy. *Plant Biosyst*, 143: 190–200.). As part of this, the diversity of wood-inhabiting fungi and beetles was also surveyed (Persiani et al. 2010 Persiani, A M, Audisio, P, Lunghini, D, Maggi, O, Granito, V MBiscaccianti, A B. 2010. Linking taxonomical and functional biodiversity of saproxylic fungi and beetles in broad-leaved forests in Southern Italy with varying management histories. *Plant Biosyst*, 144: 250–261.).

This project carried out multi-taxon and forest structure sampling to identify indicators and monitor growth forest. *Plant Biosyst*, 144: 160–170.). Among other taxa, three Pezizomycotina, Ascomycota, cylichnium (Tul.) Korf, Xylaria polymorpha and Hymenoscyphus serotinus, were shown to be old-growth forest indicators, albeit with an only marginally significant indicator value, using the indicator species analysis (ISA) and the software PC-ORD 5 (McCune & Mefford 2006 McCune, B and Mefford, M J. 2006. “PC-ORD. Multivariate analysis of ecological data”. In Version 5.10, Glenden Beach, OR, USA: MjM Software. ). Xylaria polymorpha was also considered to be an old-growth indicator species by Schmid and Helfer (1999 Schmid, H and Helfer, W. 1999. Die Bedeutung der Naturwaldreservat für den Pilzartenschutz. Seminarbericht der Natur-und Umweltschutzakademie des Landes Nordrhein-Westfalen (NUA), 4: 140–146. ) and Parmasto (2001 Parmasto, E. 2001. “Fungi as indicators of primeval and old-growth forests deserving protection”. In *Fungal conservation, issues and solutions*, Edited by: Moore, D, Nauta, M N, Evans, S E and Rotheroe, M. 81–88. Cambridge, UK: Cambridge University Press.).

Referring to our dataset, all three are among the species associated with beech wood; their occurrence thus plays a vital role to indicate the natural value of Italian/European beech forests.

**Documenting and conserving Italian fungal biodiversity**

Mycology has a long tradition in Europe and hence knowledge of species, their distribution, ecology and status in Europe is the most extensive in the world. On this basis it would be feasible to analyze the status of European fungal diversity to establish conservation priorities for fungi as part of national and the European conservation priorities also applying IUCN red-listing priorities (Dahlberg & Mueller 2011 Dahlberg, A and Mueller, G M. 2011. Applying IUCN red-listing criteria for assessing and reporting on the conservation status of fungal species. *Fungal Ecol*, 4: 147–162.). On the other hand, the large number of species, and in some cases, a lack of synergy between professional and amateur mycologists, has meant that, to date, this knowledge (particularly within anamorphic and teleomorphic ascomycetes) is low, compared with more well-known groups of species (Senn-Irlet et al. 2007 Senn-Irlet, B, Heilmann-Clausen, J, Genney, D R and Dahlberg, A. 2007. *Guidance for conservation of macrofungi in Europe*, 34 Strasbourg: ECCF. ).

In Italy there are still limits to the knowledge of wood-decay *Pezizomycotina* impeding compilation of the regional and national level check-lists which would allow characterization of declining, rare and threatened populations. The set of data presented in this survey represents the first major contribution to the knowledge of the distribution of these species and their relationship with their substrata in Italy. We believe the present contribution will be useful at a European scale too.

According to the Ascomycete Conservation Specialist Group (http://www.cybertruffle.org.uk/ascos/index.htm) ascomycetes have been seriously overlooked in conservation while, at the same time, it is becoming clear that this largest single group of fungi may be adversely affected by human activities. We also hope for an increase in Italian research to determine the threats *Pezizomycotina* are facing and the development of long-term programs to assess the status of individual species. This will contribute to the conservation of fungi in Europe and will

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