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The economic potential of mushrooms in an artificial *Pinus nigra* forest

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Abstract

Mushroom community in artificial *Pinus nigra* forest in Amiata mount (Tuscany, Italy) was described. 3220 fruit bodies belonging to 106 different species were found during five surveys from autumn 2014 to spring 2015. The biodiversity indices and the dominance–diversity curves indicate a discrete fungal diversity with the dominance of few species. Edible mushrooms such as *Hydnum repandum*, *Lactarius deliciosus*, *L. sanguifluus*, *Suillus granulatus S. luteus* and truffles (*Tuber aestivum*, *T. borchii* and *T. macrosporum*) were found in the study area. These fungi are traditionally harvested and are an important complementary economical source for local population. Considering the economic importance of these non-wood forest products, forest management should play major attention to their safeguard.

Keywords: macrofungal biodiversity; non-wood forest products; forest management; black pine; Tuscany.

Riassunto

La comunità macromicetica di alcuni habitat, come i rimboschimenti di *Pinus nigra*, impiegati spesso in progetti di ripristino ambientale, è ad ora poco studiata. Questo lavoro ha avuto lo scopo di iniziare lo studio della micodiversità in un impianto artificiale di pino nero sul Monte Amiata in Toscana.

In quest'area, dall'autunno 2014 alla primavera 2015, in soli 5 rilievi, sono state censite 106 specie, con un totale di 3220 carpofori, di cui *Phellodon niger* è stata la più abbondante. Dalla ripartizione in gruppi trofici risulta che 31 sono le specie simbionti, 52 quelle saprotrofe umicole, 17 quelle lignicole, 3 di lettiera e 3 sono quelle parassite.

Gli indici di biodiversità (Pielou (E) = 0,67, Shannon (H) = 1,62 e Simpson (D') = 0,66) e la curva di rango-abbondanza rivelano un discreto grado di biodiversità, ma con la dominanza di alcune specie sulle altre. All'interno dell'area di studio sono state censite anche specie eduli di macrofunghi epigei (*Hydnum repandum, Lactarius deliciosus*, *L. sanguifluus, Suillus granulatus* e *S. luteus*) e anche alcune specie di *Tuber* (ad esempio *Tuber aestivum*, *T. borchii* and *T. macrosporum*), la cui raccolta nell'area del Monte Amiata, è consolidata da antiche tradizioni.

Considerata l'importanza economica di questi prodotti non legnosi del bosco, la gestione forestale dovrebbe tenere conto della loro presenza e garantirne la salvaguardia.

Parole chiave: diversità macrofungina; prodotti del bosco non legnosi; gestione del bosco; pino nero; Toscana.

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Introduction

Forest management is traditionally focused to wood production (Bengstonn et al., 2000; Farrell et al., 2000). Recently, as consequence of the major attention given to the environment, the conservation of forest biodiversity, and of its capacity to maintain ecosystem processes and services (Bonet et al., 2010) are pursued. Moreover, no wood forest products (NWFP) are an economically important forest resource which can be exploited for rural income and sustainable forestry. In the Mediterranean region the estimated value of the NWFP is about 822.4 million of euros, and about 245.6 million of euros only in Italy (Masiero et al., 2016). For these reasons, the new techniques of forest management are devoted to safeguard and increase the wood production and the NWFP are considered an important business nowadays.
Mushrooms are one of the most important NWFP (Boa, 2004) for their economic, ecologic and social value. In several countries mushroom picking has become a widespread recreational activity providing an alternative or complementary source of income to timber (Molina et al., 1993; Pilz et al., 1998; Sisak, 1998; Nanagulyan, 2000; Manzi et al., 2001; Bonet et al., 2004; 2010; 2014). Fungi have also an important ecological role in forest ecosystem: most of the marketable edible forest mushrooms are mycorrhizal and promote plant growth (Trappe, 1987; Trappe & Luoma, 1992; Smith & Read, 1997; Luoma et al., 2004) improving the plant nutrition (Marks & Kozlowski, 1973; Smith & Read, 1997; Luoma et al., 2004; Martín-Pinto et al., 2006). Mycorrhizal fungi facilitate tree establishment in the primary succession (Schram, 1966; Miller, 1987) and improve soil structure contributing to form a relatively stable aggregate; subsequently they increase soil aeration and porosity (Tisdall & Oades, 1979; Fernández-Toirán et al., 2006). On the other hand, saprobic fungi are able to decompose plant and animal dead matter recycling nutrients back into the soil (Ferrisa et al., 2000).
Pinus nigra Arnold, a typical pioneer species, has been widely used across Italy for reforest Apennine mountainous areas in the 20th century. The commercial value of these pine forests was not a priority; the main purpose of establishing pine forests in Italy was both, to protect the soil from erosion, and to facilitate the natural succession toward mixed forests with a strong component of deciduous species (Cantiani et al., 2010). Because of the scarce economic value of these pine forests for timber production, silvicultural treatments are not applied regularly (Cantiani & Chiavetta, 2015), and limited to the more accessible areas which can be mechanically treated.
In this context the NWFP add an important value to the *Pinus nigra* forests. The aim of this work was to study the mushroom diversity in a plantation of *P. nigra* located on Amiata mount in Tuscany, and to evaluate their potential economic value.

Materials and methods

The study area is located on Amiata mount in Castiglion d'Orcia municipality (Siena, Italy) (latitude 42°56'8''N, longitude 11°38'13''E,) inside the forest called "Madonna delle Querce". The mean altitude is 780 m a.s.l., the prevalent exposition is N-E with slope inclination of 15%.
It is situated on a long and wavy side and shows various geological formations of clay, including the so called "Unità delle Argille a Palombini", calcareous and marly lithofacies, lithological formation by fissile clays, silty clays, marly clays. Occasionally there are rock outcrops and stoniness of medium and large size, while a small surface stoniness is common. Phenomena of erosion are apparently lacking. The soils in the sampling area are deep with high content in organic matter in A horizon, predominantly loamy silty clay and clay, from weakly to moderately calcareous, slightly alkaline, with high-level of bases saturation. According to the Köppen and Geiger climate classification its rank is Csb. The average temperature is 12.5°C, with July the hottest month (mean temperature 21.7 °C) and January the coldest month (mean temperature 4.5 °C). The average rainfall is 687 mm, with November the wettest month. The forest is prevalently composed of *P. nigra* (more than of 90% of plants) of 44 years of age and of *Quercus cerris* L., *Quercus robur* L. and other sporadic species typical of deciduous oak forests (Cantiani, 2016; Cantiani et al., 2017) (Fig. 1).

Fig. 1. *Pinus nigra* forest on Amiata mount.
Fig. 1. Foresta di *Pinus nigra* sul monte Amiata.

The mushroom survey was carried out in 27 round plots (radius 10 m) covering a total area of 8478 m^2. Mushrooms were harvested in autumn (01/10/2014; 15/10/2014; 27/10/2014; 11/11/2014; 24/11/2014) and late spring (10/06/2015). Hypogeous fungi were collected using a trained dog. Fruit bodies were counted, and weighted (when dimensions are > 1 mm) as suggested by Arnolds (1981). Identification was performed with the usual morphological techniques and employing general analytic keys and monographs (Salerni et al., 2010). Each species was classified in different trophic categories: M = Mycorrhizal; Sh = saprobic humicolous; Sl = saprobic litter decaying; Sw = saprobic wood decaying; P = parasite, following Arnolds et al. (1995) and on the basis of field direct observations. Most of the collected specimens were conserved in *Herbarium Universitatis Senensis* (SIENA). The fungal nomenclature follows CABI list (http://www.indexfungorum.org/Names/NAMES.ASP) updated at July 2015.
To estimate the mushroom communities, Pielou (E = 0 → 1), Shannon Wiener (H' = 0 → ∞), and Simpson ((D' = 1/D) indices (Magurran, 2004) were calculated using software package PcOrd (McCune & Mefford, 2011). The dominance–diversity curves were constructed by ranking the abundance values of the mushroom species from the highest to the lowest (Magurran 1988).

Results and discussion

During six surveys from the autumn 2014 to the spring 2015, 3220 fruit bodies were collected belonging to 106 different fungal species (Tab. 1). Seven species (*Phellodon niger*, *Gymnopus brassicolens*, *Hydnellum ferrugineum*, *Galerina marginata*, *Lycoperdon perlatum*, *Hemimycena cucullata* e *Hypholoma fasciculare*) produced more than 100 fruit bodies, whereas 32 taxa were observed only once. The most abundant species was *P. niger*, with 660 fruit bodies (Tab. 1).

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Tab. 1. Results of mycocoenological surveys in the study area.
Tab. 1. Sintesi dei rilievi micocenologici effettuati nell'area di studio.

TC	SPECIES	Edibility	Fruit bodies n.	Weight (g)
Sh	*Agaricus comtulus* Fr.	NE	1	2,42
Sh	*Arrhenia velutipes* (P.D. Orton) Redhead, Lutzoni, Moncalvo & Vilgalys	NE	1	0,02
Sh	*Artomyces pyxidatus* (Pers.) Jülich	NE	2	8,32
Sl(Sh)	*Atheniella flavoalba* (Fr.) Redhead, Moncalvo, Vilgalys, Desjardin & B.A. Perry	NE	23	0,7
Sw	*Auriscalpium vulgare* Gray	NE	35	15,45
Sw	*Baeospora myosura* (Fr.) Singer	NE	7	0,51
M	*Balsamia vulgaris* Vittad.	NE	1	2,34
M	*Chroogomphus rutilus* (Schaeff.) O.K. Mill.	E	10	85,76
Sh	*Clitocybe brumalis* (Fr.) Quél.	NE	7	5,22
Sh	*Clitocybe fragrans* (With.) P. Kumm.	E	3	4,94
Sh	*Clitocybe odora* (Bull.) P. Kumm.	E	1	4,28
Sh	*Clitocybe phaeophthalma* (Pers.) Kuyper	NE	2	1
Sh	*Clitocybe vibecina* (Fr.) Quél.	NE	3	5,76
Sh	*Conocybe filipes* (G.F. Atk.) Kühner	NE	1	0,09
Sw	*Cyathus striatus* (Huds.) Willd.	NE	11	1,87
Sh	*Cystolepiota sistrata* (Fr.) Singer ex Bon & Bellù	NE	47	1,83
Sw(Sh)	*Delicatula integrella* (Pers.) Fayod	NE	10	0,167
Sh	*Entoloma cetratum* (Fr.) M.M. Moser	NE	1	1,22
Sh	*Entoloma farinasprellum* Arnolds	NE	1	0,47
Sh	*Entoloma hirtipes* (Schumach.) M.M. Moser	NE	1	0,15
Sh	*Entoloma xanthochroum* (P.D. Orton) Noordel.	NE	1	0,83
P	*Fomitopsis pinicola* (Sw.) P. Karst.	NE	1	277,24
Sh	*Galerina badipes* (Pers.) Kühner	NE	4	0,38
Sw	*Galerina marginata* (Batsch) Kühner	NE	219	84,509
P	*Ganoderma resinaceum* Boud.	NE	1	70,49
Sh	*Geastrum fimbriatum* Fr.	NE	3	2,42
Sh	*Geastrum quadrifidum* DC. ex Pers.	NE	3	0,32
Sh	*Geastrum triplex* Jungh.	NE	1	0,93
M	*Genea verrucosa* Vittad.	NE	1	0,3
Sl	*Gymnopus brassicolens* (Romagn.) Antonín & Noordel.	NE	500	302,04
Sh	*Gymnopus dryophilus* (Bull.) Murrill	E	85	137,98
Sh	*Gymnopus ocior* (Pers.) Antonín & Noordel.	E	1	0,23
Sh	*Gymnopus peronatus* (Bolton) Gray	NE	31	8,49
M	*Hebeloma crustuliniforme* (Bull.) Quél.	NE	37	330.41
M	*Hebeloma laterinum* (Batsch) Vesterh.	NE	2	8
M	*Hebeloma sacchariolens* Quél.	NE	7	15.6
Sh	*Hemimycena cryptomeriae* Noordel. & Antonín	NE	4	0.1
Sw(Sh)	*Hemimycena cucullata* (Pers.) Singer	NE	212	27.183
Sl	*Hemimycena delectabilis* (Peck) Singer	NE	1	0.0072
Sh	*Hemimycena gracilis* (Quél.) Singer	NE	31	0.985
Sh	*Hemimycena lactea* (Pers.) Singer	NE	51	1.572
Sh	*Hemimycena pithya* (Fr.) Dörfelt	NE	8	0.61
P	*Heterobasidion annosum* (Fr.) Bref.	NE	1	1.04
M	*Hydnellum ferrugineum* (Fr.) P. Karst.	NE	309	1183.33
M	*Hydnum repandum* L.	EMI	37	144.22

TC	SPECIES	Edibility	Fruit bodies n.	Weight (g)
Sh	*Hydropus floccipes* (Fr.) Singer	NE	1	0.1
M	*Hygrophorus agathosmus* (Fr.) Fr.	NE	8	73.34
Sw(P)	*Hymenopellis radicata* (Relhan) R.H. Petersen	E	1	6.73
Sw	*Hypholoma fasciculare* (Huds.) P. Kumm.	NE	178	561.66
Sh	*Infundibulicybe alkaliviolascens* (Bellù) Bellù	NE	1	10.54
M	*Inocybe geophylla* (Bull.) P. Kumm.	NE	17	22.3
M	*Inocybe mixtilis* (Britzelm.) Sacc.	NE	2	1.58
M	*Inocybe splendens* R. Heim	NE	1	2.1
M	*Lactarius deliciosus* (L.) Gray	EMI	4	86.1
M	*Lactarius sanguifluus* (Paulet) Fr	EMT	18	443.39
Sh	*Lepiota griseovirens* Maire	NE	1	0.07
Sh	*Lepista nuda* (Bull.) Cooke	E	17	280.91
Sh	*Lycoperdon perlatum* Pers.	E	213	535.26
Sh	*Lycoperdon umbrinum* Pers.	E	2	1.08
Sh	*Lyophyllum semitale* (Fr.) Kühner	E	5	15.25
Sh	*Lyophyllum transforme* (Sacc.) Singer	E	1	16.16
Sh	*Marasmiellus pseudogracilis* (Kühner & Maire) Singer	NE	3	0.019
Sh	*Melanoleuca cavipes* Métrod ex Bon	NE	1	1.25
Sh	*Melanoleuca graminicola* (Velen.) Kühner & Maire	NE	9	88.25
Sh	*Melanoleuca melaleuca* (Pers.) Murrill	E	1	10.58
Sw	*Merulius tremellosus* Schrad.	NE	19	311.21
Sh	*Mutinus caninus* (Huds.) Fr.	NE	2	1.55
Sh(Sw)	*Mycena abramsii* (Murrill) Murrill	NE	8	0.73
Sw	*Mycena acicula* (Schaeff.) P. Kumm.	NE	3	0.033
Sh	*Mycena aetites* (Fr.) Quél.	NE	17	0.773
Sh	Mycena amicta (Fr.) Quél.	NE	4	0.09
Sw(Sh)	*Mycena arcangeliana* Bres.	NE	35	1.783
Sh	*Mycena epipterygia* (Scop.) Gray	NE	1	0.2
Sh	*Mycena galopus* (Pers.) P. Kumm.	NE	39	3.392
Sh	*Mycena metata* (Secr. ex Fr.) P. Kumm.	NE	6	0.132
Sw	*Mycena olida* Bres.	NE	3	0.082
Sh	*Mycena olivaceomarginata* (Massee) Massee	NE	1	0.1
Sh	*Mycena pelianthina* (Fr.) Quél.	NE	5	9.39
Sh	*Mycena pura* (Pers.) P. Kumm.	NE	1	2.25
Sw	*Mycena stipata* Maas Geest. & Schwöbel	NE	2	0.44
Sh	*Mycena vitilis* (Fr.) Quél.	NE	2	0.13
Sh (Sc)	*Panaeolus ciNEtulus* (Bolton) Sacc.	NE	3	2.14
M	*Phellodon niger* (Fr.) P. Karst.	NE	660	1871.56
Sw	*Pholiota gummosa* (Lasch) Singer	NE	24	27.58
Sh	*Ramaria flaccida* (Fr.) Bourdot	NE	1	6.62
Sh	*Rickenella fibula* (Bull.) Raithelh.	NE	15	0.621
M	*Russula atropurpurea* (Krombh.) Britzelm.	NE	7	96.54
M	*Russula fragilis* Fr.	NE	2	16.51
M	*Russula torulosa* Bres.	NE	6	84.11
Sh	*Stropharia aeruginosa* (Curtis) Quél.	NE	7	22.03
M	*Suillus granulatus* (L.) Roussel	EMI	9	214.63
M	*Suillus luteus* (L.) Roussel	EMI	25	762.01

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TC	SPECIES	Edibility	Fruit bodies n.	Weight (g)
Sw	*Tapinella atrotomentosa* (Batsch) Šutara	NE	9	171.97
Sw	*Tapinella panuoides* (Fr.) E.-J. Gilbert	NE	27	35.61
M	*Tricholoma aurantium* (Schaeff.) Ricken	E	3	26.21
M	*Tricholoma fracticum* (Britzelm.) Kreisel	NE	3	31.59
M	*Tricholoma pessundatum* (Fr.) Quél.	NE	1	38.22
M	*Tricholoma psammopus* (Kalchbr.) Quél	NE	37	159.09
Sw	*Tricholomopsis rutilans* (Schaeff.) Singer	NE	3	27.3
M	*Tuber aestivum* Vittad.	EMI	10	137.53
M	*Tuber borchii* Vittad.	EMI	1	1.14
M	*Tuber dryophilum* Tul. & C. Tul.	E	2	1.73
M	*Tuber excavatum* Vittad.	NE	7	61.34
M	*Tuber macrosporum* Vittad.	EMI	1	1.12
M	*Tuber puberulum* Berk. & Broome	NE	1	1.4
M	*Tuber rufum* Pico	NE	5	15.49

(TC: trophic category; M = mycorrhizal; P = parasite; Sh = saprobic humicolous; Sl = saprobic litter decaying; Sw = saprobic wood decaying;E: edible species; EMI: edible species marketable at national level; EMT: edible species marketable only in Tuscany; NE: not edible species)
(TC: gruppo trofico; M: micorrizici; P: parassiti; Sh: saprotrofi umicoli; Sl: saprotrofi di lettiera; Sw: saprotrofi lignicoli; E: specie commestibili; EMI: sp. commestibili e commercializzabili a livello nazionale; EMT: sp. commestibili e commercializzabili solo in Toscana; NE: sp. non commestibili).

P. niger, *H. ferrugineum*, *S. luteus*, *H. fasciculare* and *L. perlatum* contributed with 54 % to the total fungal biomass (Tab. 1). The weight of the collected fruit bodies was 1871.56 g for *P. niger*, 1183.33 g for *H. ferrugineum* and 762.01g for *S. luteus*. These species are reported to fructify abundantly in favorable conditions (Jülich, 1989; Galli, 1998). *P. niger* and *H. ferrugineum* are both common species in Europe in broadleaves forests. Although they have monomitic hyphal system their consistency is woody-corky (Jülich, 1989). In contrast *S. luteus* is a mycorrhizal species specifically associated to *Pinus* spp. it is the biggest species inside the genus *Suillus* with a cap till 20 cm in diameter (Galli, 1998).
The following common species have a wide ecological range and can grow in both coniferous and broad leaves forests: *Hemimycena gracilis*, *Mycena aetites*, *M. arcangeliana*, *M. galopus* (Antonìn & Noordeloos, 2004; Breitenbach & Kränzlin, 1986, 1991; Maas Geesteranus, 1992; Moser, 1980; Robich, 2003). It is not surprising that several species such as *Chroogomphus rutilus*, *Galerina marginata*, *H. ferrugineum*, *L. sanguifluus*, *S. luteus* and *Tricholoma psammopus*, are typically associates with coniferous forest and in particular *Pinus* spp. (Alessio, 1985; Basso, 1999; Breitenbach & Kränzlin, 1986; 1991; 2000; Moser, 1980; Riva, 1988). The presence of *Gymnopus brassicolens*, *Hebeloma sacchariolens*, *Inocybe splendens*, *Lepiota griseovirens*, *Mycena acicula*, *M. olida*, *M. pelianthina*, etc. associated at broad leaved forests (Breitenbach & Kränzlin, 1991; 1995; 2000; Maas Geesteranus, 1992; Robich, 2003) is related to the natural regeneration of the pine forest with native broad leaved species.
Most of the fungi were saprobic (72 species), 31 were mycorrhizal and only 3 parasitic (Tab.2). Some species are assigned to more trophic categories (Tab.1) because they combine different nutritional strategies (Arnolds et al.,1995). Sh (saprobic humicolous species) is the most common trophic group (49%), probably due to the deep soil rich in organic matter (http://www.selpibio.eu/pubblicazioni/item/46-le-aree-d-indagine-del-progetto-selpibiolife.html).
Symbionts of pine are considered by various authors (Angelini et al., 2015) as fungi with a good invasive ability, but in this study their percentage is rather low. In order to better represent the mycorrhizal fungal community, we should have added below ground assessment, such as mycorrhizal root tip and soil mycelium analyses, as suggested by some authors (Richard et al., 2005; Salerni et al., 2014; Smith et al., 2007). In fact fruit bodies formation by mycorrhizal species is more related to the environmental parameters (altitude, number of tree species and tree cover) and in particular to the climate (above all rainfall) than those of saprobic or parasitic species (Laganà et al., 1999; Salerni et al., 2002; Salerni & Perini, 2004).

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Tab. 2. Fungal community diversity in the study area.
Tab. 2. Sintesi dei principali caratteri della compagine macrofungina rilevata nell'area di studio

	M*	P*	Sh*	Sl*	Sw*	Total
Species n.	31	3	52	3	17	106
Fruit bodies n.	1234	3	661	524	798	3220
Weight (g)	5919	349	1200	303	1274	9045
Edible species n.	11	0	10	0	1	22
Edible fruit bodies n.	120	0	329	0	1	450
Weight of edible fruit bodies (g)	1904	0	1007	0	7	2917
Marketable species n.	8	0	0	0	0	8
Marketable fruit bodies n.	105	0	0	0	0	105
Weight of marketable fruit bodies (g)	1790	0	0	0	0	1790
Pielou index (E)	0,56	-	0,64	0,03	0,60	0,67
Shannon index (H)	0,82	-	1,03	0,02	0,70	1,62
Simpson index (D' = 1/D)	0,42	-	0,50	0,01	0,39	0,66

*M = mycorrhizal; P = parasite; Sh = saprobic humicolous; Sl = saprobic litter decaying; Sw = saprobic wood decaying;
*M: micorriziche; P: parassiti; Sh: saprotrofi umicoli; Sl: saprotrofi di lettiera; Sw: saprotrofi lignicoli.

The diversity indices indicate that there is a discrete degree of biodiversity (H = 1.62), a good species repartition (E = 0.67), and a partial dominance of few species (D'= 0.66) in the study area in respect to other unpublished studies carried out in Italian *Pinus nigra* forest (Zotti et al., 2013). The dominance–diversity curves (Fig. 2) confirm these results, showing that there are few dominant species. The species with a major relative abundance are *Phellodon niger*, *Gymnopus brassicolens* and *Hydnellum ferrugineum* followed by *Lycoperdon perlatum*, *Galerina marginata*, *Hemimycena cucullata* and *Hypholoma fasciculare*. The not uniform distribution of the fungal species, with few dominants is a typical characteristic of fungal communities (Tofts & Orton, 1998). *Phellodon niger* and *Hydnellum ferrugineum* are reported to be synergic in forest poor of nutrients (Pegler et al., 1997), and they have a tendency to dominate on other fungal species.

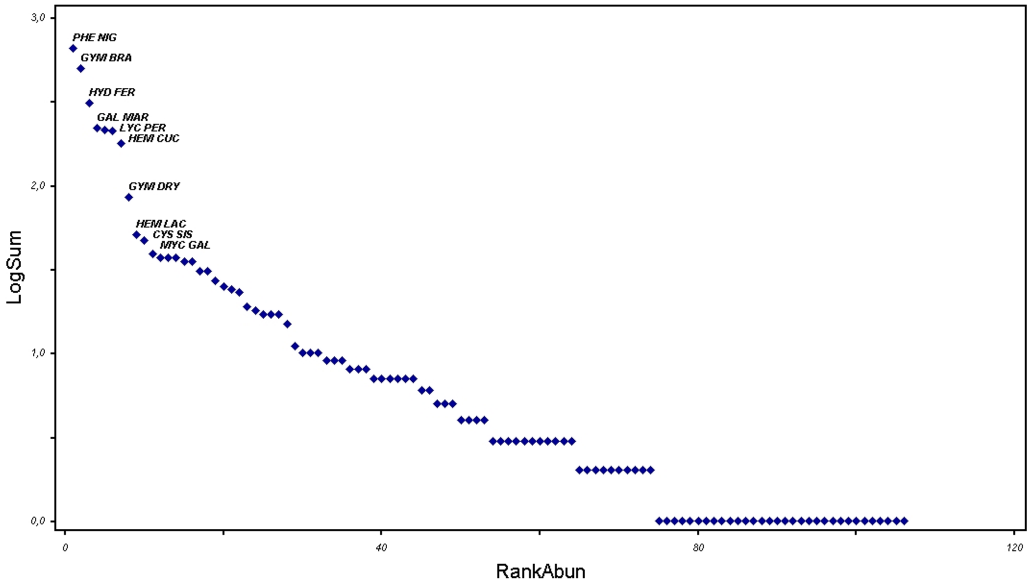

Fig 2. Dominance–diversity curves of the fungal species found in this study.
Fig.2. Curva di rango abbondanza delle specie rinvenute all'interno di tutti i plot campionati. A sinistra si posizionano le specie più abbondanti ed a destra quelle meno abbondanti.
(CYS SIS - *Cystolepiota sistrata*; GAL MAR - *Galerina marginata*; GYM BRA - *Gymnopus brassicolens*; GYM DRY - *Gymnopus dryophilus*; HEM CUC - *Hemimycena cucullata*; HEM LAC - *Hemimycena lactea*; HYD FER - *Hydnellum ferrugineum*; LYC PER - *Lycoperdon perlatum*; MYC GAL - *Mycena galopus*; PHE NIG - *Phellodon niger*)

Fig. 3. Some of the edible fungi found in this study.
Fig. 3 – Alcune delle specie eduli reperite in questo studio.
Hydnum repandum (a), *Lactarius deliciosus* (b), *Suillus luteus* (c.), *Tuber aestivum* (d); *Tuber macrosporum* (e) e *Tuber borchii* (f).

30% of the 106 fungal species found in this study are edible (Tab. 1), with a total weight of 5 kg (Tab. 2), and 8 of these are commercialized in Italy.
In table 3, the marketable species found in this study, their common Italian name, and the price on Italian markets are reported. Whereas the prices of truffles (*Tuber* spp.) are published and updated every year (for example in the following websites: http://acqualagna.com/fiere-tartufo/borsa-tartufo/ http://www.tuber.it/it/borsino-del-tartufo.php, http://www.fieradeltartufo.org/2016/it/borsino-tartufo-

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2015.php.), the commercial value of other fungal species was obtained by a market survey with the most important Italian companies specialized in commercialization and transformation of wild edible mushrooms (Masiero et al., 2016; Vidale et al., 2014).

Tab. 3. Market prices for the edible species found in the study area
Tab. 3. Quotazioni di mercato per le specie commmercializzabili rinvenute nell'area di studio

Scientific name	**Italian common name**	**Price /kg**
Hydnum repandum L.	Steccherino dorato, dentino	€ 8,00
Lactarius deliciosus (L.) Gray	Sanguinello, pennecciola	€ 15,00
Lactarius sanguifluus (Paulet) Fr	Sanguinello, pennecciola	€ 15,00
Suillus granulatus (L.) Roussel	Pinarolo, pinarello	€ 5,00
Suillus luteus (L.) Roussel	Pinarolo, pinarello	€ 5,00
Tuber aestivum Vittad.	Tartufo scorzone	€ 350,00
Tuber borchii Vittad.	Tartufo bianchetto	€ 300,00
Tuber macrosporum Vittad.	Tartufo nero liscio	€ 400,00

The prices reported in table 3 are the average prices and they can vary depending on the annual seasonal trend, with a considerable increasing when the mushrooms production is scarce. The prices vary also in relation to the local use. For example, *Lactarius deliciosus* is scarcely appreciated in Italy, with the exception of some small local market, whereas it is the most appreciated mushroom in Spain (Bonet et al., 2012). The species of the genus *Suillus*, not commercialized as fresh product in Italy, are used by the Italian companies to prepare mixed frozen cubes of mushrooms; consequently these species are imported from South America. In contrast, the truffles are highly appreciated around the world. Because the most expensive *Tuber* spp. naturally grow only in Mediterranean countries and their production is decreasing due several anthropic and natural factors, they command very high prices (Donnini et al., 2008).

Conclusions

This study confirm that mushrooms are no wood forest products with an important economic value (Merlo & Croitoru, 2005; Bonet et al., 2010; Oria de Rueda et al., 2010). In a rather small area less than 1 ha of forest and in only 5 surveys, we found almost 5 kg of edible mushrooms. The most economically important species found were *Lactarius sanguifluus*, *Suillus granulatus* and several *Tuber* spp., such as *Tuber aestivum*, *Tuber macrosporum* and *Tuber borchii* which are traditionally harvested in this area and become an important complementary sources of income for local population. However till now the mushrooms are not considered as an economically important NWFP, and the Italian forest management politics do not play enough attention at their safeguard and valorization. In particular forest cultural practices should also consider the effects on mushroom production. The ongoing LIFE project (project SelPiBioLife, LIFE13 BIO/IT/000282) devoted to study the effects of innovative selvicultural management considers also this important aspect.

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