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**Research article**

# 1,302 fungal species published on the global IUCN Red List: what patterns occur for those found in Italy?

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## Abstract

Fungi are an integral part of the rich biodiversity and cultural heritage of Italy but are often overlooked in conservation efforts. Here, we explore how Red Lists have increased our knowledge of Italian fungi in a conservation context. We focus on species of fungi found in Italy on the global IUCN Red List of Threatened Species™, but also draw on national, and subnational Red List projects for comparisons and to highlight other fungal assessment work completed in the country. Often, more localized assessments, such as for Boletales and Pezizomycotina species, fill in taxonomic or economically important gaps present on the global Red List. From the species assessed on the global Red List found in Italy, we found that 62.7% are assessed as Least Concern and that 73.4% are mycorrhizal. Similar to the global scale, Ascomycota are poorly represented (3.2%) among assessed Italian fungal species, and the most common threats to species are habitat loss due to development, timber harvesting, changes in forestry management practices, and harvesting of the fungi themselves. Translating these Red List assessments into conservation actions and policy for individual species and habitats to protect the Italian funga, along with flora and fauna, are a goal moving forward.

## Keywords

assess, conservation, edible fungi, lichen, mushroom, truffle

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## Introduction

Italy is characterized by high environmental heterogeneity. Its territory includes the Alps and the Apennine, the Po Valley Plain, and the Tyrrhenian Islands with Sardinia, Sicily and smaller islands forming various archipelagos that are all considered hot spots of species richness and endemic biota (Chiarucci et al., 2024). The mountains, vast hilly territories, plains, and sandy and rocky coasts result in bioclimatic regions varying from temperate oceanic to mediterranean oceanic (Blasi et al., 2014)



and contribute to its exceptional biodiversity. The numerous ecoregions and smaller subregions defined by climate, physiography, biogeography, vegetation, and land cover use reflect the rich and diverse array of habitats in Italy (Blasi et al., 2014, 2018). This habitat variability leads to high species richness and large changes in the fauna and flora across the Italian landscape. The country has both the highest absolute number and density of plant and animal species in the European Union: approximately 61,000 animal species and 8,200 plant species, of which 30% and 15%, respectively, are endemic to Italy (Ministero dell’Ambiente e della Tutela del Territorio e del Mare, 2019). Presumably, this high habitat heterogeneity across the country results in a high species richness of fungi as well.

Although fungi have a vast species richness (e.g., Niskanen et al., 2023) and play fundamental roles as decomposers and symbionts in ecosystems, they generally have received less attention (study) than plants and animals (Heilman-Clausen et al., 2015). As far as the Italian Funga is concerned, 300,000 species have been estimated (Onofri et al., 2005) based on a minimum 1:5 plant-fungus ratio (Hawksworth, 2001). A species inventory in a Mediterranean evergreen-oakwood habitat with 36 vascular plant species reported 309 epigeous macromycetes (Perini et al., 1989), indicating that at least in some Italian habitats, a 1:5 ratio may be a large underestimation, even when only macrofungal species are considered. The most recent Italian checklist of Basidiomycota lists 4296 taxa (Onofri et al., 2003) and there are no modern checklists at the national level of Italian fungi for other phyla.

The history of Italian mycology dates back very far and contains many important contributions at a global scale. Federico Cesi (1585–1630), an Italian naturalist searching for how “plants” reproduced, can be seen as the forerunner of the microscopic analysis of fungi (Perini and Salerni, 2006). His studies were made possible after the inventions of Galileo. A century later, Pier Antonio Micheli (1679–1737) continuing the search for reproductive structures in fungi, observed “seeds” of more than 30 fungal genera and was the first scientist to describe asci and ascospores (Ricci and Adversi, 1999). Pier Andrea Saccardo’s (1845–1920) 25 volumes of the “*Sylloge fungorum omnium hucusque cognitorum*” was the first global inventory of all known fungal species and was used to create modern, digital lists that are regularly consulted today, such as IndexFungorum (Montemartini, 1999; Petersen and Hawksworth, 2016). The late twentieth and the early twenty-first centuries were characterized by well-illustrated monographs on various groups of fungi with information on the distribution and ecology of species, newer aspects that little by little became as important as the former description and naming.

Various efforts have been made to assess the conservation status of some fungal species and to map key areas for protecting fungi for their *in situ* conservation in Italy. One such effort was the Important Plant Areas IPAs program of the Planta Europa Network, sponsored by the Italian Ministry for the Environment and Protection of the Land and Sea (Blasi et al., 2014; Venturella et al., 2011). Thanks to the collaboration with the Italian Botanical Society, and again the Ministry, researchers assessed various Italian habitats and species. Overall, 197 Policy Species (PS) are listed in the Habitat Directive 92/43/CEE and Bern Convention, and another 114 Non-Policy Species (NPS) are taxa to be considered for conservation interest. Data sheets were compiled for some of these species (Perini and Venturella, 2008) and finally 13 fungal NPS appeared in the Red List of the Italian Flora (*Lista rossa della flora italiana*) together with vascular plants, bryophytes, and lichens (Rossi et al., 2013). This was an important step, because Red Lists provide a scientific inventory of national or global

conservation status and extinction risk of species, and can help to influence policy change and conservation action (Rodrigues et al., 2006).

Although first published in 1964, the global Red List only listed animal and plants until 2003 when two lichens were assessed (Scheidegger, 2003; Yahr, 2003). A few years later, *Pleurotus nebrodensis*, endemic to Sicily (Italy), was listed among the “Top 50 Mediterranean Island Plants” threatened with extinction (de Montmollin and Strahm, 2005). It became the first non-lichenized macromycete to be assessed on the global Red List and was evaluated as critically endangered (CR) (Venturella, 2006). Currently, it is considered a subspecies, *Pleurotus nebrodensis* (Inzenga) Quél. subsp. *nebrodensis*, and a reassessment is underway (Venturella et al., 2016; Gargano et al., 2024).

In 2026, the number of fungi on the global Red List has grown to 1,302 species (IUCN 2025). Although still < 1% of the > 171,000 animals and plants that have been assessed, fungal Red List assessments are growing exponentially and garnering more attention (Mueller et al., 2022). The significant increase in the number of listed fungi is due to a concerted effort by the global mycological community. In 2011, guidelines to facilitate interpreting and using IUCN Red List assessment criteria for fungi were published (Dahlberg and Mueller, 2011) whereafter numerous workshops and regional initiatives has taken place to build capacity and accomplish fungal assessments. In 2013, the Global Fungal Red List Initiative (<https://redlist.info/en>) was launched by the fungal specialist groups within the IUCN’s Species Survival Commission in collaboration with experts and citizen scientists from all parts of the globe (Mueller et al., 2014). The initiative’s interactive website aimed to facilitate both the compilation of information for the assessments and to engage mycologists to participate worldwide. Members of the development team (Fig. 1) presented preliminary results at the XVIII Congress of European Mycologists in Warsaw, Poland in 2019. Improvement of guidelines and best practices for assessing certain groups of fungi is ongoing, for example, for lichenized fungi (Yahr et al., 2024).

With a significant number of fungal species being assessed, patterns of species of conservation interest can be analysed, such as for tropical fungi (Stallman et al., 2024), or fungi occurring in a single country, like Brazil (Drechsler-Santos et al., 2025). In this paper we examine these data and patterns for Italy; for example, how many assessed species are present, what are their taxonomies and ecologies, and why they are threatened with extinction? We note that completing Red List assessments is largely voluntary. Therefore, the species assessed are subjectively chosen based on the assessors’ knowledge and interest. Therefore, examining only these species may not be representative for the status and threats for fungi in general.

## Materials and Methods

Data and associated metadata of globally assessed fungal species present in Italy were downloaded from the IUCN Red List of Threatened Species v. 2025-2 (<https://www.iucnredlist.org/>) in January 2026. The resulting spreadsheet provides information for all fungi specifically present in Italy: taxonomic notes, assessment justification, information on geographic range, population, habitat and ecology, threats, use and trade, and conservation actions. It was analysed for: 1) Species occurring in Italy, 2) Species occurring in Europe and worldwide, 3) Taxon, 4) Trophic mode, 5) Red List category, 6) habitat(s), and 7) threat(s). Bar graphs, Venn diagrams, and pie chart visualizations were created in R version 4.4.3 (R-Core Team, 2026). package ggplot2 version 3.5.1 (Wickham., 2016). and package ggVennDiagram version 1.5.4 (Gao and Dusa, 2025), Supplementary Table 1S reports

the taxon name as used on the Red List, the authority, whether the species is lichenized, Red List category, the trophic mode, and the link to the IUCN assessment from whether this information was gathered. In addition to ecological data from the Red List assessment, trophic modes were also checked via FunGuild (<https://www.funguild.org/>) when this was unclear (Nguyen et al., 2016).



**Fig. 1** - Members of the development team of the Global Fungal Red List Initiative at the XVIII Congress of European Mycologists in Warsaw Poland, September 16–21, 2019

## Results and discussion

### *Geography, taxonomy, and ecology of assessed species*

Out of the 1302 fungi assessed globally, 444 species occur in Europe, and 282 in Italy. Concerning the taxonomy of assessed fungal species present in Italy (Supplementary Table S1), there are few ascomycetes: seven lichens and two non-lichenized fungi. Among the 273 species of basidiomycetes, the most represented order is Russulales with 119 species, 115 of which are Russulaceae. Previous analyses of the conservation status of milkcaps (*Lactarius* and *Lactifluus*) in fungal Red Lists worldwide showed that 26 species were present in Italy (Leonardi et al., 2021). The order Agaricales, containing most of the other gilled fungi, is represented by 89 species, including 29 Hygrophoraceae. Cantharellales is represented by 22 species, including 11 in Hydnaceae. Finally, 20 Boletales species from Italy have been assessed on the global Red List.

The relatively low number of Boletales species may be considered surprising because it is relatively well-known group to Italian naturalists and the public due to the fleshy and often colourful fruiting bodies, some of which are of valuable edible interest. A regional assessment following IUCN methodology was made in central Italy of 100 Boletales species, 67 of which were classified as

threatened (Wagensommer et al., 2022). Regarding trophic modes, 17 species are pathotrophs, 68 species are saprotrophs, 207 species are mycorrhizal, and 19 species are other symbiotrophs (lichens or *Hygrocybe* spp.) (Supplementary Table S1). Note that this number totals higher than 282 as some species are considered in multiple categories.

#### Red List categories of assessed species

Concerning the IUCN categories (Table 1, Fig. 2), out of the 1302 fungal species assessed globally, circa 22% are species for which the available information is not sufficient (data deficient, DD) while for the 282 Italian species, this is only 2%. Among these, three were evaluated as part of the comprehensive evaluation of *Cantharellus* and *Craterellus* (Westrip et al. 2026): *Cantharellus fulvocaerulescens* Valenti has taxonomic doubts (Westrip, 2025a), *C. subcarneus* Fayod is known only from the type description in the Italian Alps (Westrip, 2025b), and *Craterellus cyathiformis* Pers. was collected in the early 19<sup>th</sup> century near the river Arno (Italy), but has not been reported since (Westrip, 2025c).

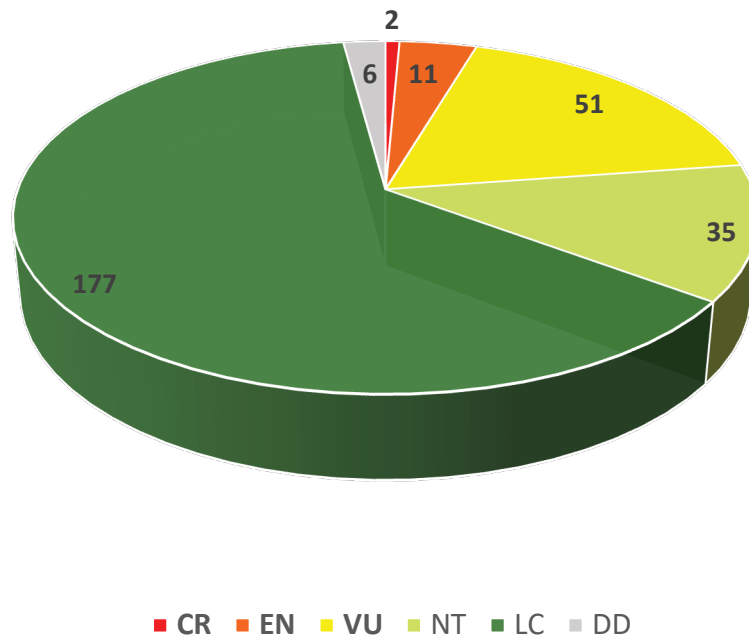
Least concern (LC) species that are not data deficient nor meet the criteria for inclusion in any threatened categories make up most of the Italian fungal species on the Red List (177 species =62.7%), higher than in the global and European-only species (Table 1). Similarly, the percentage of near threatened (NT) species, what are those close to being at risk, which in the absence of adequate countermeasures, may become threatened in the near future, was higher in Italy than in Europe or at the global scale. Thirty-five NT species occur in Italy, including *Rhodotus palmatus* (Bull.) Maire. This species is also present in North America, northern Africa, northern Asia and other parts of Europe where it inhabits trunks and branches of dead deciduous trees. Due to a decline of its primary hosts, elm and ash, the European population specifically is considered threatened, and is regionally assessed as vulnerable (VU) (Iršénaitė et al., 2019).

**Table 1** - Percentage of evaluated species globally, in Europe, and in Italy in each Red List category (DD = data deficient; LC = least concern; NT = near threatened; VU = vulnerable; EN = endangered; CR = critically endangered)

Red List Category	Global	Europe	Italy
CR	3.6%	0.9%	0.7%
EN	9.9%	5.6%	3.9%
VU	17.9%	19.3%	18%
NT	8.4%	10.5%	12.4%
LC	37.7%	44.8%	62.7%
DD	22.2%	18.6%	2.1%

Among the assessed species, at least 411 are threatened with extinction (classified as Vulnerable (VU), Endangered (EN), or Critically Endangered (CR)) at a global level, 115 in Europe, and 64 in Italy. Of the two CR species, the Starry Breck Lichen (*Buellia asterella* Poelt and Sulzer), was previously found in Italy and is restricted to isolated, temperate dry grasslands in western Europe. Negatively impacted by habitat changes and degradation, competition of grasses and shrubs, and by trampling by humans or ungulates, this crustose lichen has rarely been observed. It is now known only in Germany and Norway and has been extirpated from numerous localities in France, Italy, Switzerland, and the United Kingdom (Spribille et al., 2015). The second CR species, *Arrasia rostrata* Bernicchia, Gorjón and Nakasone, is a small, corticioid basidiomycete that grows on old

growth trees of *Juniperus phoenicea* and *Cupressus sempervirens*. Even though the two hosts plants are common in the Mediterranean Basin, very old trees are rare, and this inconspicuous fungus has seldom been observed and is only known from Italy (Sardinia and Tuscany) and in Spain (Ibiza). The threat of extinction to this fungus is high due to the presence of few old growth juniper and cypress trees that break down on the landscape as they are often harvested and used by people (Perini et al., 2025).



**Fig. 2** - Threat category of the 282 species assessed on the global Red List that occur in Italy

Six Agaricales, four Polyporales and one Russulales species are assessed as endangered (EN): *Antrodia alpina* (Litsch.) Gilb. and Ryvar den, *Calocybe favrei* (R. Haller Aar. and R. Haller Suhr) Bon, *Clitocybe glareosa* Röllin and Monthoux, *Cortinarius tiliae* Brandrud, *Echinodontium ryvar denii* Bernicchia and Piga, *Fomitopsis officinalis* (Vill.) Bondartsev and Singer, *Hyphoderma etruriae* Bernicchia, *Laccariopsis mediterranea* (Pacioni and Lalli) Vizzini, *Neolentiporus squamosellus* (Bernicchia and Ryvar den) Bernicchia and Ryvar den, *Pseudotrachelium metapodium* (Fr.) Sánchez-García and Matheny, and *Squamanita schreieri* Imbach. Except for *F. officinalis* (EN), which is present across the Northern Hemisphere, the other species are endemic to Europe. Distributions range from south-east Norway to Greece, but species are often found in fragmented or limited areas, such as alpine zones. The rare ectomycorrhizal *C. tiliae* is strictly associated with linden, as the name suggests, precisely within calcareous *Tilia cordata* forests. This kind of forest, and consequently the rare fungus, has its main distribution in south-east Norway and only a few other sites have been recorded in Europe (Brandrud et al., 2021). The survival of the parasite *S. schreieri*, growing mainly in alluvial forests on *Amanita solitaria* (Bull.) Fr. and *A. strobiliformis* (Paulet ex Vittad.) Bertill., is principally dependent on water levels in these forests, which have been mismanaged and no longer have natural flood regimes (Kautmanova, 2019). For *L. mediterranea*, records come principally from the coasts of Italy where it was described, but it is also reported from

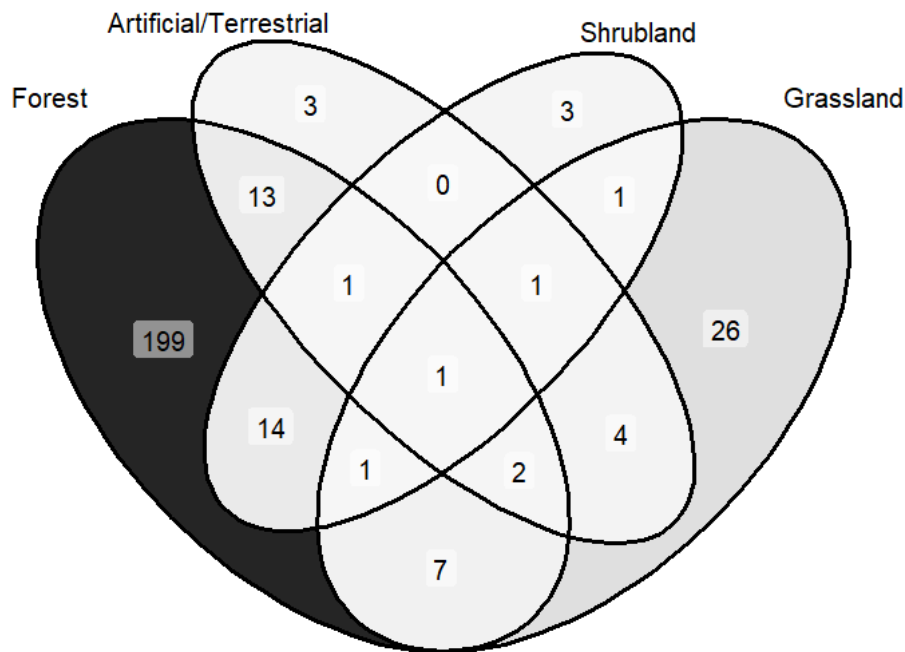
the Atlantic of Portugal, through Spain and France into Greece, including Crete, and Tunisia (Gisotti, 2019). Suitable habitats for this species, such as coastal dunes with *Juniperus* spp., are severely disturbed by erosion, climate change, and human activities (Picchi, 2008).

Fifty-one Italian species are listed as VU. Among these there are *Entoloma bloxamii* (Berk. and Broome) Sacc., *Hygrocybe calyptriformis* (Berk.) Fayod and *Alessioporus ichnusanus* (Alessio, Galli & Littini) Gelardi, Vizzini & Simonini that were also assessed as EN at the national level (Rossi et al., 2013). The latter, with the addition of new data, was later re-assessed and downgraded to VU at the national level (Angelini et al., 2021). *Lepiota brunneolilacea* Bon & Boiffard, *Hohenbuehelia culmicola* Bon, *Hygrocybe quieta* (Kühner) Singer, and *Romagnesiella clavus* (Romagn.) Contu, Matheny, P.-A. Moreau, Vizzini and A. de Haan occur in threatened coastal habitats like *L. mediterranea*, mentioned above. Unsustainable harvest is a threat to *Hygrophorus marzuolus* (Fr.) Bres., a prized edible mushroom, as in some Italian regions the numerous mushroom hunters, more than a reduction of its potential habitat, are the primary threat. In the past it could be bought also in markets in Austria, France, Germany, Italy, and Switzerland (Kautmanova, 2025). *Ramaria roellinii* Schild is restricted to semi-natural calcareous xerophytic grasslands, a habitat rapidly declining all over Europe. The species was described from near Geneva but seems now to be extirpated from Switzerland. Other known localities are in France, Germany and Sweden, while its presence in Italy today is uncertain (Knutsson, 2020). Northern and central Italy are thought to comprise the largest subpopulation of *Cyanoboletus poikilochromus* (Pöder, Cetto & Zuccher.) Simonini, Gelardi and Vizzini (Cunha and Gonçalves, 2024). Finally, endemic to Sardinia is the extremely rare crustose *Caloplaca rinodinae-albae* Poelt and Nimis, parasitic on another rare lichen, *Rinodina alba* Metzler ex Arnold. It grows in very small patches on sun-exposed rocks along the coasts of the type locality, Isola dei Cavoli, in southern Sardinia (Ravera, 2017). A new site was recently observed near to Santa Teresa di Gallura in northern Sardinia, and this supports the need to search throughout the Mediterranean wherever the host, *R. alba*, is present.

#### *Habitats and threats of assessed species*

Regarding habitats of assessed Italian species, they are primarily observed in forests (199 species), described as stands where the tree cover is continuous, but they can often be found in more than one habitat (Fig. 3).

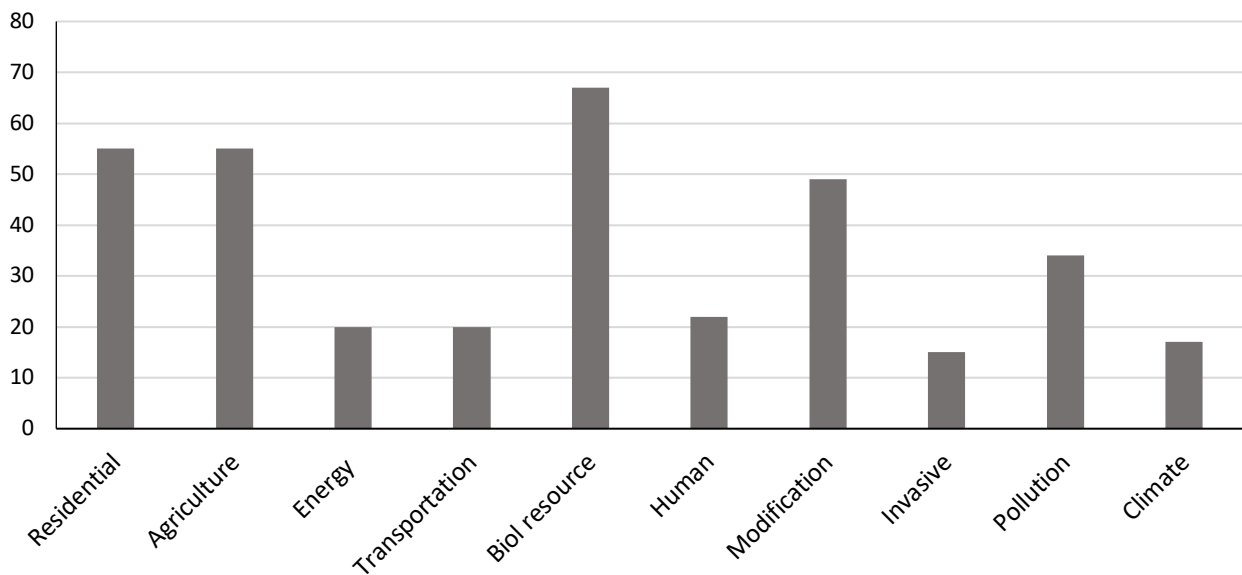
A small number of fungi (13 species) can also grow in parks, tree plantations, and other human-made habitats; among these are various *Suillus* species including *S. bovinus* (L.) Roussel, *S. granulatus* (L.) Roussel, *S. grevillea* (Klotzsch) Singer, *S. luteus* (L.) Roussel, *S. variegatus* (Sw.) Richon and Roze, and *S. americanus* (Peck) Snell. Likewise, some forest fungi (14 species) can occur also in areas dominated by shrubs, with only a scattered presence of trees; among these are *Alessioporus ichnusanus* (Alessio, Galli & Littini) Gelardi, Vizzini and Simonini, *Amanita torrendii* Justo, *Cortinarius ionochlorus* Maire, *C. murellensis* Cors. Gut., Ballarà, Cadiñanos, Palazón and Mahiques, *C. odoratus* (Joguet ex M.M.Moser) M.M.Moser, and *C. splendidificus* Chevassut and Rob. Henry. Seven species were reported from the margin of forests and in grasslands, including *Agaricus arvensis* Schaeff., *Hygrocybe intermedia* (Pass.) Fayod, *H. mucronella* (Fr.) P. Karst., and *H. quieta* (Kühner) Singer. *Lycoperdon perlatum* Pers. is the only species reported from all four main habitats.



**Fig. 3** - Venn diagram showing the number of assessed Italian species growing in different habitats. Coastal dunes and wetlands, which contain very few species, are not included

Threats to assessed fungi are similar to those reported for animals and plants (Mueller et al., 2022) and are often associated with loss or changes of the habitat and its quality. A threat shared by all 67 threatened Italian fungal species is biological resource use (Fig. 4); this includes gathering fungi for food or other uses, and more often, logging and wood harvesting that can remove host trees, coarse woody debris, and standing and lying trunks, eliminating fungal habitat. Fifty-five species are impacted by residential and commercial development, activities that eliminate habitat for housing, commercial or industrial areas, or tourism and recreation areas. Fifty-five species are also impacted by agriculture, including wood plantations resulting in monocultures replacing native forests, and livestock farming. Among the so-called natural system modification category, the increased frequency and intensity of fires, particularly in Mediterranean ecosystems, is high, threatening 49 species (Fig. 4). In forests and woodlands, important threats include not only inappropriate management and wildfires, but also invasive species (15 species). For example, die-back of host trees due to *Phytophthora* spp. and other pathogens caused *Cortinarius murellensis* Cors. Gut., Ballarà, Cadiñanos, Palazón and Mahiques to be assessed as VU (Brandrud, 2019). Seven ectomycorrhizal species are threatened by alien species, including introduced pathogens killing host trees, and invasive plants displacing these hosts: *Rubroboletus dupainii* Boud., *Cyanoboletus poikilochromus* (Pöder, Cetto & Zuccher.) Simonini, Gelardi and Vizzini, *Cortinarius ionochlorus* Maire, *C. eucaeruleus* Rob. Henry, *C. bulliardii* (Pers.) Fr., *Amanita friabilis* (P.Karst.) Bas, *A. torrendii* Justo. We are also learning that trees like the black locust change the epigeous macro-fungal community, with a strong decrease of symbionts (Conti et al., personal communication). In seminatural grasslands, the abandonment of traditional land use with the intensification of farming processes and increased use of fertilizer and/or pesticides is also often listed as a threat to *Hygrocybe* spp. (waxcap fungi). For fungi linked to coastal dunes and wetlands, such as the VU *Lepiota brunneolilacea* Bon & Boiffard and *Bovista paludosa* Lév., climate and water level and quality play a particularly important role with

changes in offshore dredging, rise of sea-level, modification of surface water and water management, and building of dams all being important threats (Arnolds et al., 2019; Kałucka, 2019).



**Fig. 4** - Number of threatened Italian fungal species by IUCN threat types (1 Residential & commercial development; 2 Agriculture & aquaculture; 3 Energy production & mining; 4 Transportation & service corridors; 5 Biological resource use; 6 Human intrusions & disturbance; 7 Natural system modifications; 8 Invasive & other problematic species, genes & diseases; 9 Pollution; 11 Climate change & severe weather)

## Conclusion

Red Lists provide a baseline for examining threats to species. Even though most fungal species remain undescribed, and of these < 1% are assessed, the information in these assessments brings attention to threatened fungi and provides recommendations for mitigating these threats when feasible. While 282 globally assessed fungi also occur in Italy, most of these are relatively widespread in Europe (or beyond) and are of least concern (62.7%). Additionally, while most fungal species are ascomycetes (Dissanayake and Liu, 2025), these make up only 193 of 1302 (14.8%) fungi on the global Red List and nine of 282 (3.2%) Italian species. This is a large knowledge gap as culturally and economically important ascomycetes in Italy, such as truffles (Mello et al., 2006), are not yet globally or nationally assessed. Being ectomycorrhizal, these species may be impacted by some of the other (major) threats impacting Italian fungal species: harvesting, changes in forest practices, or loss of habitat.

In some cases, these knowledge gaps are complemented by regional or national assessments. For example, an assessment of Pezizomycotina species for the central Italian region of Umbria (Wagensommer et al., 2018) assessed five of thirteen truffle (*Tuber*) species as threatened. Although only seven lichens occurring in Italy are on the global Red List, Nascimbene et al. (2012) assessed 368 epiphytic lichens at the national level, finding that likely more than 25% were threatened. As noted previously, only 20 Boletales spp. are on the global Red List, but 100 spp. were assessed in the regions of Umbria and Tuscany (Wagensommer et al., 2022). Therefore, the global Red List is a tool that can inform or provide a starting point for national or regional information on a species, but the local context of population sizes, threats, or other variables may often differ at different spatial scales, and the species may not be assessed on the global Red List. Examples include *R. palmatus* which is

globally NT but considered VU in Europe, and *B. asterella*, which is globally CR but likely extirpated from Italy.

There is a pressing need to interpret and communicate fungal Red List assessments into actions to help reduce threats to the species. In Italy, there are laws to regulate the collection and marketing of edible mushrooms, with particular attention given to truffles. Although there are ongoing attempts to assess the conservation status of fungi and identify key areas for their protection, these attempts have not sufficiently animated public and policymaker awareness on the importance of fungi, including non-edible species, for the health of ecosystems. We hope that information on the threatened fungi on the global Red List that occur in Italy, along with national and regional Red List assessments will stimulate action for fungal conservation action.

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### Author Contributions

Conceptualization, C.P. and A.D.; methodology, C.P.; software, E.S.; validation, C.P., A.D. and G.M.; formal analysis, C.P. and E.S.; data curation, C.P. and J.S.; writing—original draft preparation, C.P. and G.M.; writing—review and editing, C.P., J.S. and A.D.; supervision, G.M.; project administration, C.P.; funding acquisition, C.P. All authors have read and agreed to the published version of the manuscript.

### Conflicts of Interest

The authors declare no conflicts of interest.

### Data Availability Statement

The data supporting the results (supplementary Table S1, reporting the list of fungal species globally assessed present in Italy with some information) is archived in Zenodo <https://doi.org/10.5281/zenodo.20412393>.

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