Join our sampling campaign on *Hygrophorus* spp. associated with firs

Project FunDive

In FunDive we work towards putting fungal diversity on the map to enhance European conservation efforts. Fungi are essential for our ecosystems but have often been neglected in monitoring efforts and conservation practices, leaving them vulnerable to threats and habitat loss. We would like to engage you to change this.

For more information, please visit https://fun-dive.eu/

FunDive is a pan-European initiative funded by Biodiversa+ that brings together 33 partners in 22 countries to improve fungal monitoring across the continent. The goal of FunDive is to close the knowledge gap dealing with fungal distributions to improve fungal conservation using the help from you and other citizen scientists.

Why is fungal monitoring important?

Fungi are generally under-studied. Their global distribution patterns are poorly resolved. Also in Europe, despite centuries of fungal research, there is a lack of the distribution patterns of many fungal species. However, this knowledge is very important for effective conservation practices. For example, assessments of species for the IUCN Red List require an understanding of the distribution of said species.

What can you do?

FunDive is structured in different projects, each focusing on a specific target group of fungi. You can engage in each project by documenting and collecting fungal specimens. The process is simple:

- **Select** the project you would like to join
- **Join** the 'Citizens for FunDive' project in PlutofGO app, following FunDive step-by-step joining guide:
  https://fun-dive.eu/wp-content/uploads/2024/08/FunDive_Joining-guide.pdf

  In some countries you can use dedicated country-level recording apps instead of PlutofGo. Check it with your country-level coordinator.
- **Find** target species
- Make an informative **photo** of your finding, following FunDive step-by-step Photo guide:
  https://fun-dive.eu/wp-content/uploads/2024/08/How-to-photograph.pdf
- **Register** your specimen in PlutofGO app, completing as mach metadata as possible and following the FunDive step-by-step Specimen registration guide:
  https://fun-dive.eu/wp-content/uploads/2024/08/How-to-register-specimen.pdf

  Remember, that the better metadata provided for collected specimens, the bigger is the chance they will be included in the DNA barcoding.
- **Collect** a specimen and prepare it for transfer, following theFunDive step-by-step Collection guide:
  https://fun-dive.eu/wp-content/uploads/2024/08/prepare-for-transfer.pdf
- **Send** your specimen for barcoding.
  If your collected specimen is prepared for transfer, registered in PlutoF, and visible in the FunDive records (https://fun-dive.eu/en/dataportal/) it is ready for barcoding! In order to get your specimen sequenced, get in touch with your country-level point of contact (https://fun-dive.eu/get-involved/fundive-national-points-of-contact/) to receive shipment instructions.
- When received your specimen will be processed and identified based on molecular information. You can follow your fungus on FunDive records: https://fun-dive.eu/dataportal/.
- In case of any questions feel free to contact your country representatives.

Remember, to have all permits needed before sampling!

For more information on how to document your records, please visit https://fun-dive.eu/get-involved/how-to-engage/	

Hygrophorus marzuolus (Fr.) Bres. and *Hygrophorus* associated with *Abies* spp. stands

is one of the targets for the 2025 FunDive projects which aim to investigate fungal biodiversity and distribution patterns in Europe

The genus *Hygrophorus* (Hygrophoraceae, Agaricales) comprises species commonly found in the temperate regions of the Northern Hemisphere (Huang et al., 2021; Tedersoo et al., 2009) and are distinguished by features such as a slightly sticky to slimy cap, adnate to decurrent gills, and a divergent hymenophoral trama (Arnolds, 1990; Candusso, 1997; Hesler and Smith, 1963; Lodge et al., 2014). Most of *Hygrophorus* form symbiotic relationships with either broad-leaved or coniferous trees, a few, such as *Hygrophorus olivaceoalbus* Krieglst. ex Gröger & Bresinsky and *Hygrophorus penarius* Fr., are parasitic (Agerer, 2012; Marino, 2008).

Some of these species form ectomycorrhizal symbiosis with *Abies* spp. The genus *Abies* is classified in 10 sections, of which two include the circum-Mediterranean fir species (e.g. *Abies alba* Mill., *Abies cephalonica* Loudon, *Abies pinsapo* Boiss) mainly restricted to Southern Europe (Eckenwalder, 2009; Farjon, 2010; The Gymnosperm Database, 2025). Generally, the circum-Mediterranean firs occur in mountain habitats at altitudes of above 400 m, up to 2400 m on deeper acid soils with high water reserves (Aussenac, 2002). In fact, they are located in humid or even very humid climates with an annual precipitation over 700-800 mm, concentrated principally during the winter period (Awad et al., 2014; Schuck HJ et al., 2008; Tinner et al., 2013). These firs commonly form pure stands in their optimal habitat, while at the borders they can be mixed with other tree species, such as beech (*Fagus* spp.), deciduous and evergreen oaks (*Quercus* spp.), pines (*Pinus* spp.) and junipers (*Juniperus* spp.) (Arista et al., 1997; Kaya and Raynal, 2001).

Among *Hygrophorus*, *Hygrophorus marzuolus* (Fr.) Bres. primarily forms ectomycorrhizal associations with coniferous trees of the Pinaceae family, most commonly with *Abies* (*alba*, x *borisii-regis*) and *Picea*, but also with *Pinus* (Pinus *mugo* Turra, *P. mugo* subsp. u*ncinate* (Ramond ex DC.) Domin, Pinus *nigra* J.F.Arnold, *Pinus sylvestris* L.) and *Pseudotsuga menziesii* (Mirb.) Franco (in France). Less frequently, it is associated with deciduous trees such as *Fagus sylvatica* L., *Castanea sativa* Mill. and *Quercus* spp. (Bingham, 2023; Fraiture and Otto, 2015). The fungus is almost exclusively found in natural or semi-natural forests and only rarely in plantations. It has been documented on calcareous, acidic, and sandy soils (Fraiture and Otto, 2015). This species is particularly noteworthy due to its distinctive ecological traits, including a vernal fructification period shortly after the first snow melts and a semi-subterranean growth habit (Boccardo et al., 2013; Candusso, 1997; Fraiture and Otto, 2015). Additionally, it holds culinary significance in certain countries. It is known that *H. marzuolus* is distributed across temperate Europe, particularly around the Pyrenees, Alps, and Carpathians (Fraiture and Otto, 2015; *Hygrophorus marzuolus* (Fr.) Bres. in GBIF Secretariat, 2023). Although few pertinent records were known from Greece until the end of the 20th century (Zervakis et al. 1998), it was later shown that it is a widely distributed species in the continental part of the country occurring in firs and in mixed forests of firs and beech (Dimou et al. 2008, Konstantinidis 2014); recently, it was also found in the United Kingdom (Bingham et al.,2023). Nevertheless, the European distribution of *H. marzuolus* and other *Hygrophorus* associated with European *Abies* spp. formations (either pure or mixed) has not been specifically investigated to date. These include species such as the above-mentioned *H.*

marzuolus (Fig. 1a), and *Hygrophorus abieticola* Krieglst. ex Gröger & Bresinsky (synonymy with *Hygrophorus persicolor* s. auct. plur., non Fr.) (Fig. 1b), *Hygrophorus camarophyllus* (Alb. & Schwein.) Dumée, Grandjean & Maire (Fig. 1c), H*ygrophorus capreolarius* (Kalchbr.) Sacc (Fig. 1d) and others.
In FunDive, our primary sampling focus is to investigate the geographic distribution of *H. marzuolus* in different habitats, as well as investigate the biodiversity and distribution of *Hygrophorus* species associated with *Abies* spp. stands across Europe.

Figure 1 Examples of the most representative species involved in this study. a) *Hygrophorus marzuolus* (Fr.) Bres. (photo of Simone Graziosi); b) *Hygrophorus abieticola* Krieglst. ex Gröger & Bresinsky (synonymy with *Hygrophorus persicolor* s. auct. plur., non Fr.); c) *Hygrophorus camarophyllus* (Alb. & Schwein.) Dumée, Grandjean & Maire; d) H*ygrophorus capreolarius* (Kalchbr.) Sacc. The last three photos were taken by Alessandro Valdagni

By reporting your findings, you will add to the knowledge of this species group and your records will be important contributions to nature conservation.

Purpose of mission and how to contribute

The primary objective of this study is to explore the geographic range of *H. marzuolus* across Europe in diverse environments, with the goal of enhancing our knowledge of its ecological needs and distribution trends. This includes examining its associations with specific hosts, soil preferences, and its responsiveness to natural disturbances and forestry management practices. Furthermore, this work addresses the need to preserve *H. marzuolus* as a species and its habitats, since it is nationally red-listed in several European countries where it occurs. It is classified as Endangered (EN) in Austria, the Czech Republic, and Germany; Vulnerable (VU) in Hungary, North Macedonia, Serbia, and Slovakia; and Near Threatened (NT) in Switzerland (Dämmrich et al., 2016; Dämon and Krisai-Greilhuber, 2017; Fraiture and Otto, 2015; Karadelev et al., 2024; Kasom and Milickovic, 2006). Additionally, since it has traditionally harvested from local population, it is legally protected in a few countries, including Croatia, Germany, Serbia, and Slovakia, and is locally protected or subject to harvesting restrictions in certain regions of Italy (Fraiture and Otto, 2015; Onofri, 2005). In fact, the species is confined to mature forests and has experienced a population decline over the past 50 years, likely due to the loss of its suitable habitat in old-growth forests and possibly as a result of nitrogen deposition (The Global Fungal Red List Initiative, 2025). In fact, the main host of *H. marzuolus*, silver fir (*A. alba*), show a strong dieback in the 1980s in its range of occurrence in Europe (Tinner et al., 2013). This is also the case for *A. cephalonica* and *A. borisii-regis*, which are the main associated trees for *H. marzuolus* in Greece.

Additionally, the study focuses on the biodiversity of the *Hygrophorus* genus within *Abies* spp. stands. Considering the rarity of these species, their restricted habitats, and the scarcity of specific data on their distribution (The Global Fungal Red List Initiative, 2025), their protection could be an important mission for European biodiversity conservation initiatives. Since sampling will also take place during spring, an uncommon season for fungal fructification, and in specific habitats, we aim to map the diversity of potentially undescribed species and report the presence of known species in areas where they have not yet been reported (especially *H. marzuolus*).

Regarding *H. marzuolus*, it can be sampled in various habitats, not limited to *Abies*, as explore its host preferences is crucial. For other *Hygrophorus* species, the presence of *Abies* spp. is a mandatory criterion for site selection, although the co-occurrence of other tree species is acceptable up to 50% in an area (20 m radius) around the collection point. Since this study focuses primarily on the biodiversity of *Hygrophorus* species in *Abies* spp. stands, rather than their fructification abundance, it is preferable to explore the maximum number of different wooded regions to identify as many *Hygrophorus* species as possible.

The best choice is to visit habitats and *Abies* spp. stands that cover a wide spatial distribution, ranging from north to south and east to west of your country. To ensure comprehensive data collection, it is essential to document the characteristics of each sampling site using the PlutoF GO app. In the “Habitat description” section (Fig. 2), users should note:

- The most likely host tree species associated with the specimen;
- The percentage presence of *Abies* spp. and other tree species (with a minimum diameter at breast height of 10 cm) within a circular area (radius 20m) surrounding the specimen collection point;
- Successional stage of the tree formation (e.g., old, mature, young);

- Natural disturbances (e.g., wind, wildfire, landslide).

Data should be formatted as in the following example:

WP3 Hygrophorus, host tree species: *Abies alba*, **Abies alba:** 80%, **Fagus sylvatica:** 20%, **successional stage:** mature, **natural disturbances:** landslide

The putative host tree species should be chosen based on the closest tree to the collected basidiomata and the co-occurrence of other tree species in the surrounding area. Selecting specimens from a pure area is preferable, to reduce errors in the host-tree hypothesis. Furthermore, it is necessary to complete the “Substrate Taxon” and “Substrate Type” fields to provide a detailed context for the collected specimens. Furthermore, adding pictures of each sampling area is required. Pictures should be uploaded to the specimen page in the PlutoF GO app (Fig. 2).

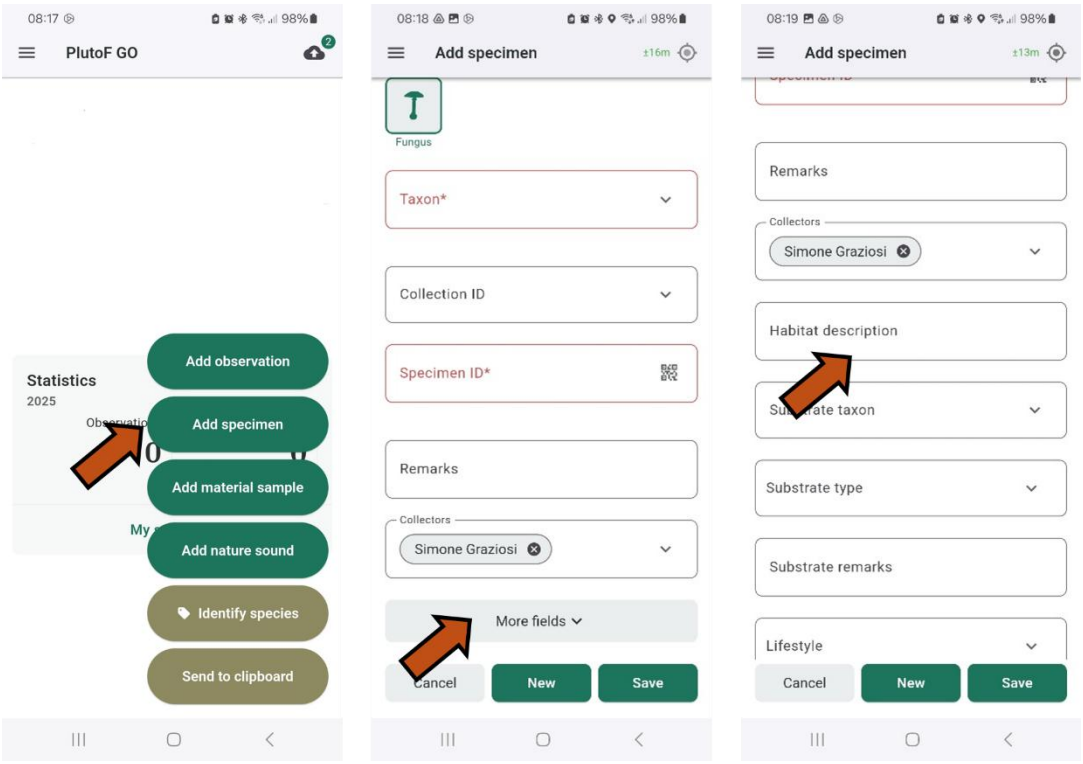


Figure 2 To register detailed information about the habitat of a specimen follow these instructions on the PlutoF GO app

The sampling will focus on two main fructification periods: spring (from the end of February to June, especially for *H. marzuolus*) and autumn, depending on the climatic conditions of each country. We encourage all professional and amateur mycologists (Citizen Scientists) to collect at least one sample of *Hygrophorus* during the spring.

Specimens will be registered using the PlutoF GO app and uploaded to the main server as soon as possible after the sampling expeditions to ensure the accuracy of collection timing. Each collector should complete an Excel table recording all the specimen IDs used for this project and submit it to us at the end of spring and autumn.The basidioma samples will be

dried and preserved in labeled paper bags following the specimen collection guidelines provided for PlutoF GO app samplings (https://fun-dive.eu/get-involved/how-to-engage/).

For each specimen, comprehensive documentation through notes and photographs is well received, suggesting the following:

- Young and mature sporocarps in a moist condition, arranged in a well-organized manner suitable for mycological scientific publication;
- The color of both young and mature gills;
- Distinctive characteristics of the species (e.g. smell of fresh specimens);
- Pictures and measurements of spores.

All pictures should be uploaded to the specimen page in the PlutoF GO app, and notes regarding the aforementioned details should be entered in the “Remarks” field of the app.

Hygrophorus genus

Taxonomy

The *Hygrophorus* genus belongs to the order Agaricales and the family Hygrophoraceae (Candusso, 1997; Wang et al., 2023). It was first described by Fries in the early 19th century with the type species *Hygrophorus eburneus* (Bull) Fr. Later, the taxonomic delimitation of the genus *Hygrophorus* has been gradually improving to be more congruent with phylogeny and biology of its members. The taxonomic concept of *Hygrophorus* has varied among mycologists. Some, like Quélet (1888), Hesler & Smith (1963), and Largent (1985), supported a broad definition (*Hygrophorus s.l.*), including related groups like *Hygrocybe* within the genus. Others favored a narrower definition (*Hygrophorus s.s.*). For instance, Kummer (1871) elevated three "tribes" to independent genera: *Camarophyllus*, *Hygrocybe*, and *Limacium*, while Karsten (1879) used the name *Hygrophorus* in place of *Limacium*. In recent years, the narrower concept of the genus *Hygrophorus* (*s.s.*) has gained widespread acceptance (Bessette et al., 2012; Candusso, 1997; Horak, 1990; Wang et al., 2018).

Moreover, the *Hygrophorus* genus represents the hygrophoroid clade, identified as one of the six major lineages within the Agaricales order through a phylogenetic study utilizing six DNA loci (Matheny et al., 2006). From a phylogenetic perspective, *Hygrophorus* is the sole genus within the tribe Hygrophoreae of the family Hygrophoraceae. It is closely related to the tribe Chrysomphalineae, which includes the genera *Aeruginospora*, *Chrysomphalina*, and *Haasiella* (Lodge et al., 2014).

Diversity and morphological characters

Globally, approximately 130 species of *Hygrophorus* were described (Wang et al., 2023). Species of this genus are predominantly distributed across the Holarctic and temperate zones of the Northern Hemisphere. They include diverse ectomycorrhizal fungi that form symbiotic associations with trees, primarily from the families Betulaceae, Fagaceae, and Pinaceae, within various forest ecosystems (Boccardo et al., 2013; Candusso, 1997; Wang et al., 2023).

The genus is distinguished by its characteristic morphological features (Fig. 3). The pileus is typically smooth to viscid in texture and exhibits a wide range of colors. The gills are waxy in appearance, generally adnate or decurrent or slightly so, and the spore mass is consistently white. The hymenophore has slender basidia, and divergent hymenophoral trama (Boccardo et al., 2013; Candusso, 1997; Lodge et al., 2014).

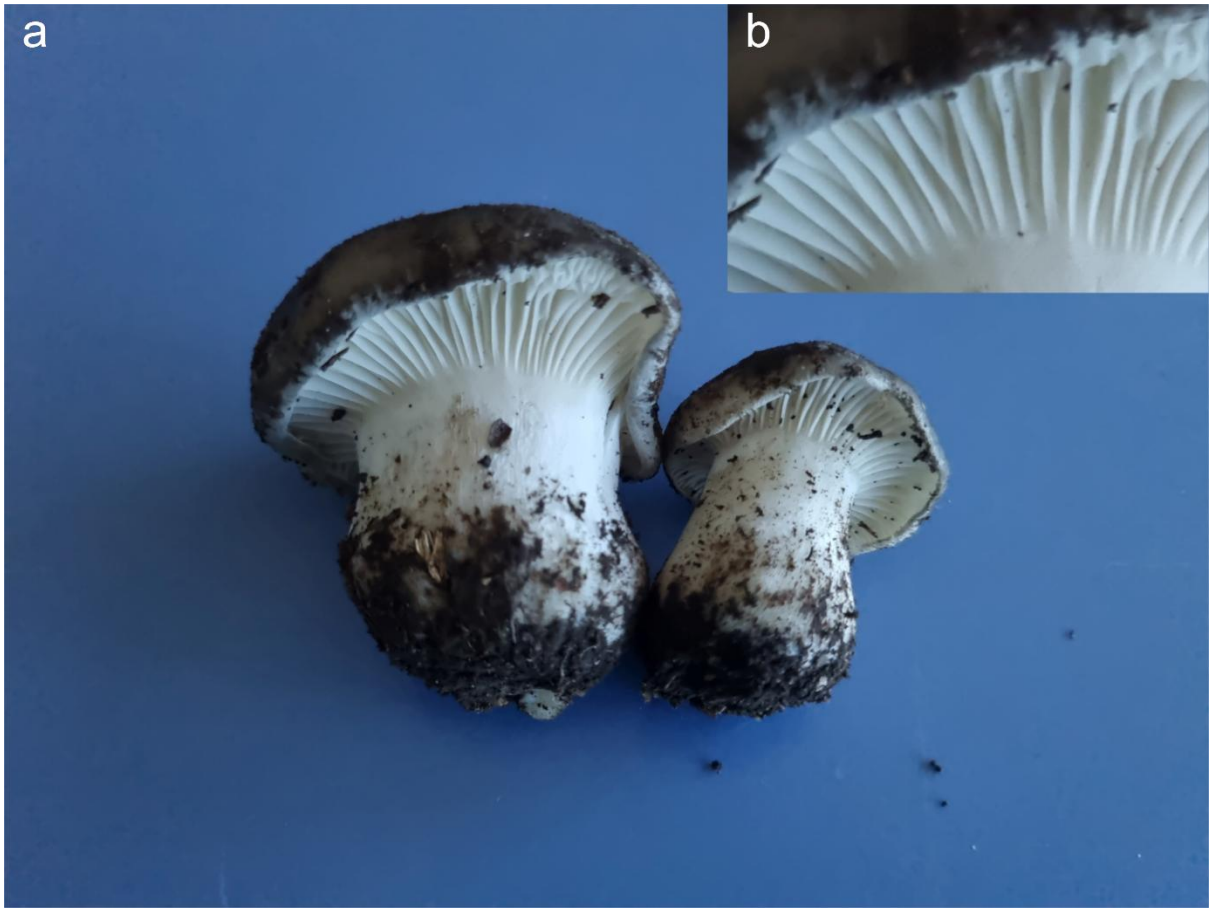


Figure 3 Morphological features of *Hygrophorus* genus. a) Young basidiomata of *Hygrophorus marzuolus* (Fr.) Bres., with numerous soil debris adhering to their surface, highlighting the characteristic viscous texture of the pileus; b) Close-up of the gills, showing their waxy appearance and slight decurrence

The characteristics of the most well-known *Hygrophorus* spp. associated to *Abies* spp**.** stands are presented below:

Hygrophorus marzuolus (Fr.) Bres. (Boccardo et al., 2013; Candusso, 1997)

Figure 4 *Hygrophorus marzuolus* badisiomata found in an *Abies alba* forest from Trentino Alto Adige region in northern Italy. Photo of Marco Floriani.

Pileus: the pileus of *H. marzuolus* (Fig. 1a, 4) measures 3–10 (up to 15) cm in diameter and is initially hemispherical with an inrolled margin, it quickly flattens and eventually becomes depressed at the center, often with an undulating, irregular edge. Its surface is marked by humps and irregularities, partly due to its tendency to grow partially embedded in the soil. The color is predominantly gray, occasionally fading or marked with lighter or whitish spots, and rarely showing ochre-like tinges. Over time, it may darken to lead-gray or nearly black. The cuticle is thin, only partially separable, and its texture varies with humidity, ranging from slightly viscous to dry but never translucent.
Hymenophore: it consists of adnate to subdecurrent gills that are sometimes slightly arched. They are widely spaced, thick, and interspersed with lamellulae. Initially white, they turn gray and eventually blackish starting at the base, with the edges remaining slightly lighter.
Stipe: it measures 5–8 × 2–4 cm and is solid, robust, and short, often appearing cylindrical, curved, or irregular in shape. The upper portion is white and powdery, while the rest is marked by fibrils and striations, becoming ashen gray towards the base.
Flesh: it is abundant, firm, and hygrophanous, with a slightly fibrous texture. It is white, with grayish tones beneath the cap cuticle and along the cap edges. Its odor is faint but can become unpleasant in mature specimens, while the flavor remains sweet and delicate, contributing to its unique characteristics in the wild.

Microscopy: the spore print is white and the spores measure 6.1–7.7 × 4.5–5.7 µm. They are ellipsoidal in shape, smooth, and feature a prominent apiculus. The spores often contain a large central guttule (oil droplet), with some displaying multiple smaller guttules throughout.

Hygrophorus abieticola Krieglst. ex Gröger & Bresinsky (synonymy with *Hygrophorus persicolor* s. auct. plur., non Fr.) (Boccardo et al., 2013; Candusso, 1997)

Figure 5 *Hygrophorus abieticola* badisiomata found in an *Abies alba* forest from Trentino Alto Adige region in northern Italy. Photo of Alessandro Valdagni.

Pileus: the pileus of *H. abieticola* (Fig. 1b, 5) varies from 6 to 12 cm in diameter. It starts as globose when young, then it changes to a convex form before finally flattening out, often with a broad, low umbo at the center. The margin of the cap remains involute even as it matures. The surface of the pileus is notably glutinous or slimy when wet. Over time, as the cap dries, the surface becomes less sticky and develops a dry texture. The cuticle is distinctively strawberry pink when the mushroom is young, giving the species its characteristic appearance. However, as the mushroom ages, this vivid coloration fades unevenly into whitish patches, sometimes showing slight yellowish discoloration, particularly in older specimens. The cuticle can be peeled away up to two-thirds of the way towards the center.
Hymenophore: it is composed of gills that are adnate to shortly decurrent. The gills are relatively thick and not closely spaced, with lamellulae interspersed among them. Their color is whitish, though they may occasionally display purplish-red spots, adding another distinctive feature to the mushroom's appearance.
Stipe: it measures 5–10 x 1–2.5 cm, is cylindrical, regular in shape, and robust in structure. The upper portion is adorned with fine, flocculose (woolly or scaly) textures, contrasting with its overall smooth appearance. Its color is generally whitish, blending harmoniously with the rest of the mushroom.
Flesh: it is fibrous and white, with a tendency to yellow slightly at the base of the stem as the mushroom matures. Its scent is not particularly noteworthy, but its taste is described as slightly bitter.

Microscopy: *H. abieticola* exhibits smooth, ellipsoidal to ovoid spores containing small guttules (oil droplets), measuring approximately 7–9 x 5–6 µm. The basidia are tetrasporic.

Hygrophorus camarophyllus (Alb. & Schwein.) Dumée, Grandjean & Maire (Boccardo et al., 2013; Candusso, 1997)

Figure 6 *Hygrophorus camarophyllus* basidiomata found in an *Abies alba* forest from Trentino Alto Adige region in northern Italy. Photo of Alessandro Valdagni.

Pileus: the pileus of *H. camarophyllus* (Fig. 1c, 6) varies from 5 to 15 cm in diameter, initially campanulate (bell-shaped), it transitions to a convex form and eventually flattens out, often developing an undulating, lobed margin. At its center, it displays a broad, low, obtuse umbo. The cap margin starts involute, gradually opening with age. Its surface is greasy when moist, becoming dry and fibrous over time. The uniform coloration of the cap is striking, ranging from a deep brown-black to almost sooty in appearance.
Hymenophore: the gills are decurrent, arcuate, spaced apart, and have a waxy or greasy texture typical of the genus. Their coloration is a clean white, providing a stark contrast to the darker tones of the cap and stem.
Stipe: it measures 6–8 x 1–2 cm, ranges from cylindrical to club-shaped and is predominantly whitish in color. It is adorned with fine fibrils that match the darker hues of the cap. These fibrils are arranged densely enough to give the stem a sooty appearance, enhancing the fungus overall dark aesthetic.
Flesh: it is firm and whitish, maintaining a solid texture throughout. It has a mild flavor and is almost entirely odorless.
Microscopy: the spore print is white and the spores are smooth and range in shape from ellipsoidal to ovoidal. They measure approximately 7–8.5 µm x 4.5–5.5 µm.

Hygrophorus capreolarius (Kalchbr.) Sacc. (Boccardo et al., 2013; Candusso, 1997)

Figure 7 H*ygrophorus capreolarius* found in an *Abies alba* forest from Trentino Alto Adige region in northern Italy. Photo of Alessandro Valdagni.

Pileus: the pileus of *H. capreolarius* (Fig. 1c, 7) varies from 3 to 8 cm in diameter and ranges from hemispherical-campanulate to flattened, with a broad, obtuse umbo. The margin is long involute, the surface smooth, finely fibrillose, slightly viscous, and colored wine-brown to purplish with darker spots.
Hymenophore: the gills are adnate to subdecurrent, spaced, and the same color as the cap.
Stipe: it measures approximately 3–7 x 1–1.5 cm, cylindrical, tapering at the base, dry, solid at first but later hollow, with longitudinal brownish streaks on a more or less light purplish background, darkening with age and upon handling.
Flesh: it is pinkish cream to grayish, with a mushroom-like odor and a sweet taste.
Microscopy: The spore print is white and the spores are characterized by dimensions of 6–7 x 4–5 µm.

References

Agerer R 2012. Asexual reproduction of *Hygrophorus olivaceoalbus* by intracellular microsclerotia in root cells of Picea abies - A winner of ozone stress?. Mycol Prog 11:425–434. https://doi.org/10.1007/S11557-011-0757-Y

Arista M, Herrera FJ, Talavera S 1997. Biología del pinsapo. Consejería de Medio Ambiente, Junta de Andalucía, Sevilla, Spain.

Arnolds E 1990. Tribus Hygrocybeae (Kühner) Bas & Arnolds, in: Bas C, Kuyper TW, Noordeloos ME, Vellinga EC (Eds.), Flora Agaricina Neerlandica, Critical Monographs on Families of Agarics and Boleti Occurring in the Netherlands. A Balkema Publishers, Rotterdam, Netherlands, pp. 71–115.

Aussenac G 2002. Ecology and ecophysiology of circum-Mediterranean firs in the context of climate change. Ann For Sci 59:823–832. https://doi.org/10.1051/forest:2002080

Awad L, Fady B, Khater C, Roig A, Cheddadi R 2014. Genetic Structure and Diversity of the Endangered Fir Tree of Lebanon (*Abies cilicica* Carr.): Implications for Conservation. PLoS One 9:e90086. https://doi.org/10.1371/JOURNAL.PONE.0090086

Bessette AE, Roody W, Sturgeon W, Bessette AR 2012. Waxcap mushrooms of eastern North America.

Bingham J 2023. *Hygrophorus marzuolus* new to Britain. Field Mycology 24:41–42.

Boccardo, Traverso M, Vizzini A, Zotti M 2013. Funghi d'Italia, 6th ed. Zanichelli, Bologna, Italy.

Candusso 1997. *Hygrophorus* s.l., Fungi Europaei. Edizioni Candusso, Varese, Italy,

Dämmrich F, Lotz-Winter H, Schmidt M, Pätzold W, Otto P, Schmitt JA, Scholler M, Schurig B, Winterhoff W, Gminder A, Hardtke HJ, Hirsch G, Karasch P, Luderitz M, Schmidt-Stohn G, Siepe K, Täglich U, Wöldecke K 2016. Rote Liste der Großpilze und vorläufige Gesamtartenliste der Ständer- und Schlauchpilze (Basidiomycota und Ascomycota) Deutschlands mit Ausnahme der Flechten und der phytoparasitischen Kleinpilze.

Dämon W, Krisai-Greilhuber I 2017. Die Pilze Österreichs. Verzeichnis und Rote Liste 2016.

Dimou DM, Zervakis GI, Polemis E 2008. Mycodiversity studies in selected ecosystems of Greece: 4. Macrofungi from *Abies cephalonica* forests and from other intermixed tree species (Oxya Mt., central Greece). Mycotaxon 104, 39–42. (complete checklist available under http://www.mycotaxon.com//resources/weblists.html, 52 pp.).

Eckenwalder JE 2009. Conifers of the world: the complete reference. Timber Press, Portland, Oregon, USA.

Farjon A, 2010. A Handbook of the World's Conifers (2 vols.). Brill., Berlin, Germany.

Fraiture A, Otto P 2015. Distribution, ecology and status of 51 macromycetes in Europe - Results of the ECCF Mapping Programme. Botanic Garden Meise, Bruxelles, Belgium.

Hesler L, Smith A 1963. North American species of *Hygrophorus*. Univ Tennessee Press, Knoxville, Tennessee, USA.

Horak E 1990. Monograph of the New Zealand Hygrophoraceae (Agaricales). N Z J Bot 28:255–309. https://doi.org/10.1080/0028825X.1990.10412313

Huang HY, Zhang WH, Huang T, Gabriel M, Liu, TZ, Tang, LP 2021. *Hygrophorus russula* complex (Hygrophoraceae, Agaricales) in China. Mycol Prog 20:1115–1134. https://link.springer.com/article/10.1007/s11557-021-01715-7

Hygrophorus marzuolus (Fr.) Bres. in GBIF Secretariat (2023). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2025-02-05

Karadelev M, Tofilovska S, Rusevska K 2024. 2021 NATIONAL RED LIST OF FUNGI:FOCUSING ON CRITICALLY ENDANGERED SPECIES. Contributions, Section of Natural, Mathematical and Biotechnical Sciences 42. https://doi.org/10.20903/MASA/NMBSCI.2021.42.9

Kasom G, Milickovic 2006. Protected macrofungi in Montenegro. Natura Montenegria, Podgorica 9:19–203.

Kaya Z, Raynal DJ 2001. Biodiversity and conservation of Turkish forests. Biol Conserv 97:131–141. https://doi.org/10.1016/S0006-3207(00)00069-0

Konstantinidis G 2014. Mushrooms: the Mushroom Collector's Photo Guide (2nd ed). Published by the author, Grevena, 559 pp. [In Greek].

Lodge DJ, Padamsee M, Matheny PB, Aime MC, Cantrell SA, Boertmann D, Kovalenko A, Vizzini A, Dentinger BTM, Kirk PM, Ainsworth AM, Moncalvo JM, Vilgalys R, Larsson E, Lücking R, Griffith GW, Smith ME, Norvell LL, Desjardin DE, Redhead SA, Ovrebo CL, Lickey EB, Ercole E, Hughes KW, Courtecuisse R, Young A, Binder M, Minnis AM, Lindner DL, Ortiz-Santana B, Haight J, Læssøe T, Baroni TJ, Geml J, Hattori T 2014. Molecular phylogeny, morphology, pigment chemistry and ecology in Hygrophoraceae (Agaricales). Fungal Divers 64:1–99. https://link.springer.com/article/10.1007/s13225-013-0259-0.

Marino ED 2008. The ectomycorrhizal community structure in beech coppices of different age. University of Padova, Padova, Italy.

Matheny PB, Curtis JM, Hofstetter V, Aime MC, Moncalvo J-M, Ge ZW, Yang ZL, Slot JC, Ammirati JF, Baroni TJ, Bougher NL, Hughes KW, Lodge DJ, Kerrigan RW, Seidl MT, Aanen DK, DeNitis M, Daniele GM, Desjardin DE, Kropp BR, Norvell LL, Parker A, Vellinga EC, Vilgalys R, Hibbett DS 2006. Major clades of Agaricales: a multilocus phylogenetic overview. Mycologia 98, 982–995. https://doi.org/10.1080/15572536.2006.11832627

Onofri S, 2005. Checklist of Italian fungi- Basidiomycetes. O.P.T.I.M.A., Italy.

Schuck HJ, Weisgerber H, Schütt P 2008. Lexikon der Nadelbäume. Nikol, Hamburg, Germany.

Tedersoo L, May TW, Smith ME 2009. Ectomycorrhizal lifestyle in fungi: global diversity, distribution, and evolution of phylogenetic lineages. Mycorrhiza 2009 20(4):217–263. https://doi.org/10.1007/S00572-009-0274-X

The Global Fungal Red List Initiative, 2025. https://redlist.info/iucn/species_view/181113/ (accessed 28/01/2025).

The Gymnosperm Database. https://www.conifers.org/ (accessed 25/01/2025).

Tinner W, Colombaroli D, Heiri O, Henne PD, Steinacher M, Untenecker J, Vescovi E, Allen JRM, Carraro G, Conedera M, Joos F, Lotter AF, Luterbacher J, Samartin S, Valsecchi V 2013. The past ecology of *Abies alba* provides new perspectives on future responses of silver fir forests to global warming. Ecol Monogr 83:419–439. https://doi.org/10.1890/12-2231.1

Wang CQ, Zhang M, Li TH, Liang XS, Shen YH 2018. Additions to tribe Chromosereae (Basidiomycota, Hygrophoraceae) from China, including *Sinohygrocybe* gen. nov. and a first report of *Gloioxanthomyces nitidus*. MycoKeys 38:59-76. https://doi.org/10.3897/MYCOKEYS.38.25427

Wang CQ, Zhang M, He XL, Liu JW, Wei TZ, Liu TZ, Wang K, Adamčík S, Deng WQ 2023. Species diversity of *Hygrophorus* in China and a phylogenetic study of the genus. Mycosphere, 14:1742-1834. https://doi.org/10.5943/mycosphere/14/1/21

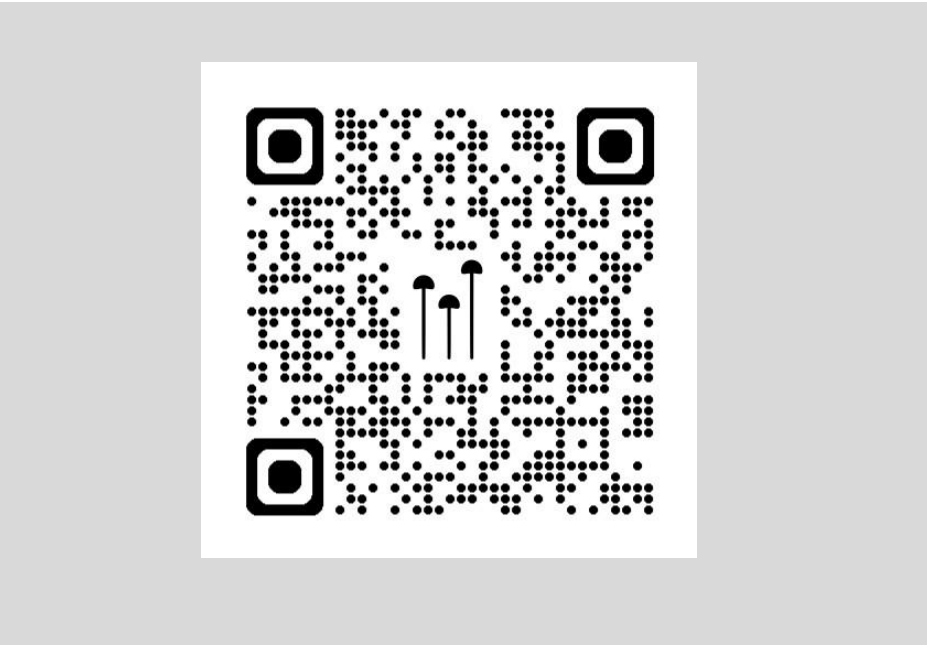
Zervakis G, Dimou D, Balis C 1998. A check-list of the Greek macrofungi including hosts and biogeographic distribution: I. Basidiomycotina. Mycotaxon 66:273–336.

Text by: Simone Graziosi

Edited by: Alessandra Zambonelli, Alfredo Vizzini, Andrea Rinaldi, Julia Pawlowska

Version 1.1, published online, 21.07.2025

For more information on FunDive, please visit https://fun-dive.eu/get-involved/



This research was funded by Biodiversa+, the European Biodiversity Partnership, in the context of the “FunDive: Monitoring and mapping fungal diversity for nature conservation“ project under the 2022–2023 BioDivMon joint call. It was co-funded by the European Commission (grant agreement No. 2128-00020A - Biodiversa2022-640) and the following national funding agencies: Research Foundation Flanders (Belgium), Technology Agency of the Czech Republic (Czechia), Innovation Fund Denmark (Denmark), Estonian Research Council (Estonia), Republic of Estonia - Ministry of Climate (Estonia), Academy of Finland (Finland), Agence National de la Recherche (France), German Research Foundation (Germany), Bundesministerium für Bildung und Forschung (Germany), General Secretariat for Research and Innovation (Greece), National Research, Development and Innovation Office (Hungary), Ministero dell'Università e della Ricerca (Italy), Netherlands Organisation for Scientific Research (the Netherlands), Research Council of Norway (Norway), National Science Centre (Poland), Fundação para a Ciência e a Tecnologia (Portugal), Agencia Estatal de Investigación (Spain), and Swiss National Science Foundation (Switzerland).