Join *Paxillus* sampling campaign!

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:

- find a representative of a target species from project list: https://fun-dive.eu/get-involved/current-projects/
- make a photo and record your specimen in PlutofGO app https://plutof.ut.ee/go following our instructions https://fun-dive.eu/get-involved/how-to-engage/
- send it to your national point of contact https://fun-dive.eu/get-involved/fundive-national-points-of-contact/
- your specimen will be processed and identified based on molecular information
- you can follow your fungus on FunDive records: https://fun-dive.eu/dataportal/.

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

Paxillus Fr.

is one of the target genera for the 2025 FunDive projects aimed at resolving species distribution and host range in Europe

Members of the genus ***Paxillus*** are ectomycorrhizal fungi living in symbiosis with trees from various genera - some only with alders (*Alnus* spp.), but others with different deciduous trees and conifers. These fungi are among the minority in the order Boletales due to their lamellate hymenophore. The genus is easy to recognise due to the involute rimmed edge of the cap, easily removable gills and flesh that stains brownish-red when bruised. The most common species, *P. involutus*, is also known as the brown roll-rim. The caps can reach 30 cm in diameter, but mostly measure 5–15 cm. *Paxillus* basidiomata produce olive to dark reddish-brown spore-deposit that should be observed when fresh, since in all species it dries to a somewhat similar shade of brown.

Fig. 1. Representatives of *Paxillus* (from the left): *P. adelphus* (photo by Anne-Liia Maido), *P. involutus* (photo by Kadri Põldmaa), *P. olivellus* (photo by Vello Liiv).

Habitats for *Paxillus* species are quite diverse and include old-growth forests, thickets with alders, deciduous woodlands with high grass, parks with mowed grass, margins of fields, rivers, ditches etc. Some habitats are hard to access, such as thickets and soft terrains near waterbodies.

Recent studies revealed the two species traditionally recognised in the genus in Europe - *P. involutus and P. rubicundulus (= P. filamentosus)*, to represent species complexes. Currently three species are distinguished in the '*P. rubicundulus*' group associated with alders: *P. adelphus*, *P. olivellus*, and *P. rubicundulus,* with only a few sequence supported records available for *P. rubicundulus.* The four species in the '*P. involutus*' group, which are forming mycorrhizae with trees from other genera are rather difficult to distinguish based solely on morphology.

The habitat and gross morphology of basidiomata can be used for identification of *Paxillus* species in the field. That process, however, has to be supported using microscopy and/or sequencing to reach the final identification. Seven species occurring in Europe are briefly characterised and illustrated in this booklet. The descriptions are based on original descriptions and field observation made in Estonia from where also all the photos originate.

How to collect and record data on *Paxillus* specimens*?*

There are no definitive characters that would enable to unequivocally identify *Paxillus* basidiomata at species level. Therefore, all findings (except for those outlined under *P. involutus*) need to be collected and dried as well as the collection data, main characteristics and photos recorded using PlutoF GO or equivalent biodiversity recording app. The general procedures for doing that are outlined at the FunDive webpage: https://fun dive.eu/en/get-involved/how-to-engage/.

You are welcome to add species level identification or a guess on its identity at the taxon field in PlutoF GO but the genus name is sufficient for processing the collections and their records in the database. However, it is obligatory to indicate the potential host tree taxon/taxa in each record. This can be done by

-choosing the name of the tree species/genus at the *'Interacting taxon'* field in case the basidioma(ta) was/were collected in a monodominant forest or in other habitat inhabited by a single EcM tree species.

- In case of a mixed stand of EcM trees, list all nearby tree species at sight, distinguishing the ones closest to the basidiomata at the '*Interaction remarks'* field in PlutoF GO.

If the basidiomata were not found on the ground, indicate that by picking the best choice at the *'Substrate type*' field or insert as free text at the '*Substrate remarks'* field.

Characterize the habitat type on the '*Habitat description'* field, a photo of the site would be beneficial as well.

In case of using another application, record the same info using constant data fields to facilitate sorting data upon later import to PlutoF.

By reporting your findings, you will add to the knowledge on morphological variation as well as geographic and host range of species belonging to *Paxillus* which will be used to improve identification methods in this genus.

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1. Species associated with *Alnus*

Paxillus adelphus J.-P. Chaumeton, Gryta, Jargeat & P.-A. Moreau 2016

UNITE: SH0990266.10FU
Reference sequence KU163512, from type: TL127-0003, France.

Basidiomata solitary or in groups, with two or more basidiomata sometimes merged. **Cap** olivaceous and convex when young; reddish-brown, cracked or scaly and flattened when old; surface usually rimmed (up to ⅔ of the cap surface area), with irregular red dots, and sticky when wet; 4-14 cm in diam, margin pale yellow to light pinkish- or orange-grey. Cap margin can be strongly involute in young basidiomata but flattened and undulose when older. **Stipe** short and strong, up to 4.5 cm high and 1.8 cm wide; surface slightly wrinkled, bright yellow, becoming dark reddish-purple at the base that can extend up to 2 cm under the ground. Mycelium at the base of the stipe white to pinkish. **Gills** decurrent, thick when young, crowded and forked with anastomoses; creamish-beige to light lemon with greenish or orange tinge, brownish-olive and with a blunt edge when old. The fresh **spore-deposit** ocher-red to chocolate-brown, without greenish tinge.

Ecology: forms ectomycorrhiza with alders, records from various countries show association with different *Alnus* species (*A. incana, A. cordata, A. glutinosa, A. orientalis*). Mostly found in thickets near waterbodies but has also been reported from tree nurseries.

Identifications based on morphology have to be verified by DNA-sequencing.

a. young basidioma (TUF140013)

b. young basidioma from underside (TUF140168)

c. cap of an old basidioma (TUF140064)

d, e. cap and lamellae of a mature basidioma (TUF140135)

f. (TUF140159)

Fig. 2. Examples of variation in colour, pattern and shape *Paxillus adelphus* basidiomata (photos by Anne-Liia Maido).

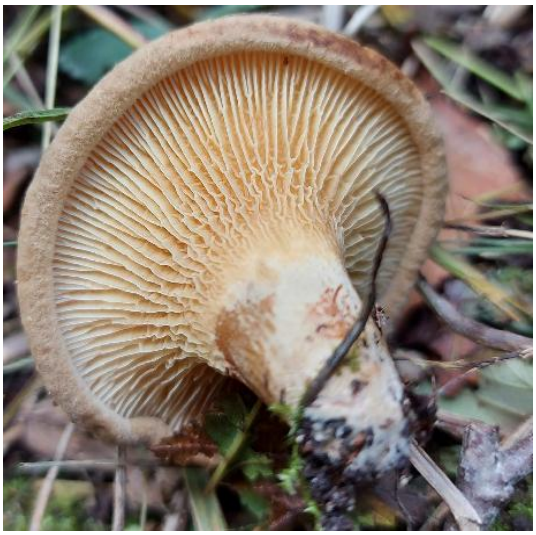
Paxillus olivellus P.-A. Moreau, J.-P. Chaumeton, Gryta & Jargeat 2016

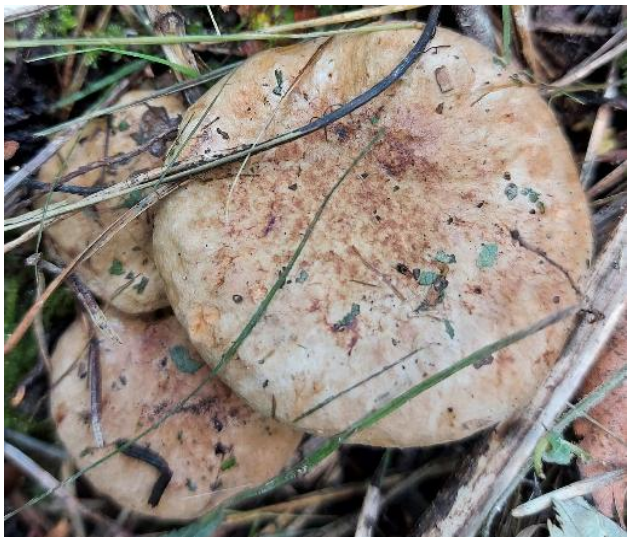
UNITE: SH0990265.10FU
Reference sequence KU163479, from the holotype: TL127-0004, France.

Basidiomata singly or in groups. light or dark olive when young, flesh in the cap and upper part of the stipe first whitish, turning light lemon-yellow, pale grey at the base; **Cap** up to 12 cm in diam, surface slightly felty when young, flat or umbonate; depressed in the middle and margin slightly hairy when old; surface layer sticky, slightly jelly-like, easily removable, olive or ash-grey. Reddish scales observed in the centre when dry or aging. Margin until maturation slightly involute, first hairy then almost smooth, 3-4 mm thick. **Stipe** slender, up to 4.5 cm high and 1.2 cm wide, sometimes narrowing at the base; pale yellow, turning reddish to dark purplish-brown in time. Stipe surface covered with white fibres, rarely scaly. Mycelium at the base of the stipe pale yellow, turning pinkish in time. **Gills** crowded, decurrent and whitish to butter-yellow with a pale lemon-yellow margin and rusty shade in older basidiomata; anastomoses rare or unclear.

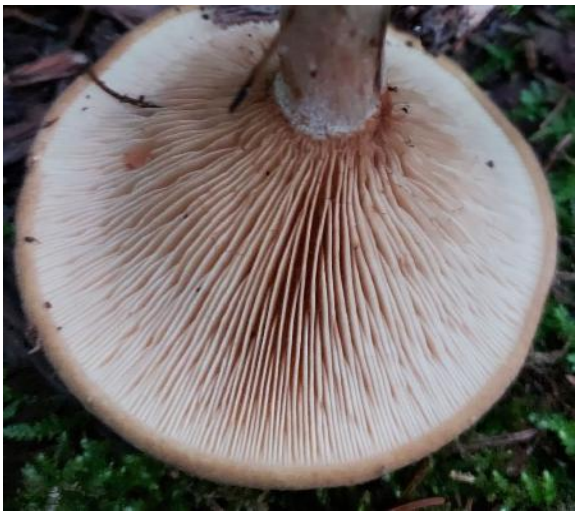
Ecology: moist areas with alders, has been recorded with *Alnus glutinosa* and *A. incana*.

Two morphotypes can be distinguished in this species: one with slender stipe and pale gills, cap olive and with red scales in the middle; another with thicker and shorter stipe, basidiomata aggregated, gills dark yellow and scales reaching up to half of the cap diameter.





a, b. young basidioma (TUF140144)



c. mature basidioma (TUF140136)

d. old basidiomata (TUF140146).

E. TUF118607

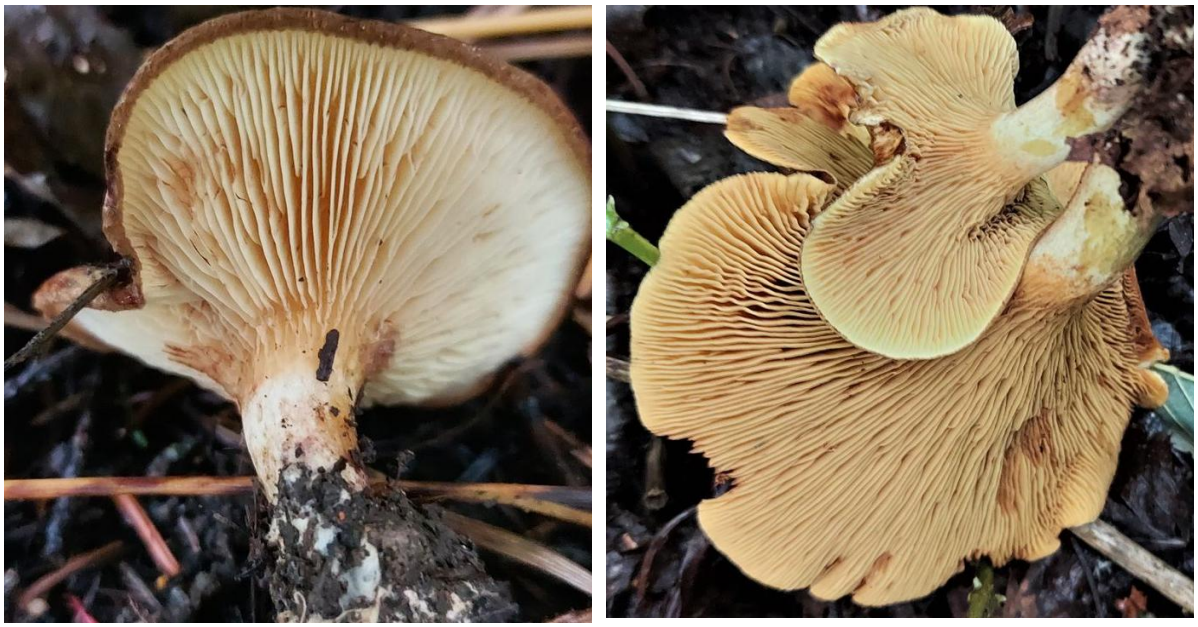
Fig. 3. *Paxillus olivellus* basidiomata of different age (a-d by Anne-Liia Maido, e. by Vello Liiv).

***Paxillus rubicundulus* P.D. Orton**

UNITE: SH1370023.10FU
Reference sequence: KU163502, from holotype: K(M)190474, England.

Cap 4 cm in diam, deeply depressed in the centre; surface with or without scales; margin inrolled, copper-coloured and reddish in the middle or brownish-yellow to olive-brown. **Stipe** 3 cm high, 0.5 cm in diam, deeply narrowing, light yellow with blushing red spots; mycelium at the base of the stipe ochraceous-yellow, lacking pinkish tones. **Gills** dark creamish-yellow to beige.

Ecology: on humid soil, associated with alders (*Alnus* spp.). Apparently uncommon, according to sequence data in UNITE altogether 16 occurrences in Estonia, Finland, France and UK, in association with *A. glutinosa* and *A. incana*.



a. Young basidioma with pale yellow gills (TUF140133)

b. Mature basidioma with creamish-yellow gills (TUF140131)

Fig. 4. Basidiomata of *P. rubicundulus* (photos by Anne-Liia Maido).

2. Species associated with trees from various genera

Paxillus ammoniavirescens Contu & Dessi 1999

UNITE: SH1370031.10FU
Reference sequence: JN661718, from holotype: IB1997_0980, Italy, Sardinia

Basidiomata aggregated, fleshy. **Cap** 3-13 cm in diam, convex or slightly funnel-shaped when young; surface pale-brownish yellow or with a golden tinge, velvety; margin deeply involute when young to flat when old, rimmed, smooth and leathery but slimy when wet. Surface with or without dark red spots, can be cracked. **Stipe** up to 6.5 cm high and 2.5 cm wide, cylindrical or narrowing at the base; concolorous with the cap or reddish; surface smooth or wrinkled. **Gills** golden orange or yellowish-brown, decurrent, crowded and easily removable. Spore-deposit yellow- to olive-brown.

Ecology: on fertile soil, in open landscape, parks, churchyards etc; growing under *Tilia*, *Populus* and *Salix* spp. Sometimes up to 120 basidiomata close to each other on the lawn, usually 10 to 15 together.

This species has two morphotypes: 1) fleshy basidiomata with wine-red brownish cap and a small stout leg; 2) basidiomata with slender stipe, gills and flesh light beige, cap evenly orange-coloured, stipe dark and basidiomata often aggregated. The latter morphotype was found in a dark and hard to access roadside thicket. The ecology, morphology and genetics of this species is highly variable.

a. morphotype with fleshy stipe and orange-brown gills (TUF140075)

b. morphotype with slender stipe and pale gills (TUF140498)

Fig. 5. Two morphotypes of *Paxillus ammoniavirescens*

Paxillus cuprinus Jargeat, Gryta, J.-P. Chaumeton & Vizzini 2014

UNITE SH0990268.10FU
Reference sequence: KF261379, from holotype: TL127-0002, France

Basidiomata singly or in groups; strong when young, often two or more merged. **Cap** up to 25 cm in diam, usually 4-13 cm; ⅓ or almost half of the cap rimmed, with a light zone between the rimmed margin and the cap centre; greyish-brown with olive tinge when young, ochraceous-brown or clay-red, rarely with wine-red shade, when old. Young basidiomata convex or flat, covered with a fine felty-velvety layer. In dry weather and older specimens, cap surface leathery and often scaly, cracked; sticky with rain. Cap margin felty and inrolled, can be completely flat in older basidiomata. **Stipe** mostly stout, sometimes slender and narrowing; Up to 6.8 but mostly 2-5 cm high and 0.7-1.6 cm wide; whitish to pale pink, with reddish marble pattern on the base of the stipe. **Gills** crowded and irregular, wavy with blunt edges, decurrent and easily removable, anastomosing towards the stipe; pale yellow to rusty brown. Spore print ocher with red tinge or chocolate brown, turning olivaceous in time.

Ecology: in open landscapes such as lawns, roadsides, glades but also near waterbodies and in thickets, among tall grass in birch stands, attached to a treetrunk base or on mossy stumps in mixed forests. Mycorrhizal hosts belong to *Alnus*, *Betula*, *Castanea*, *Corylus*.

a, d Cap with scales on the surface, involute edge and crowded gills (TUF140108).

b, e. orange basidioma with bright yellow flesh (TUF140032).

c, f. Cap with clay-red surface, rimmed edge and crowded gills (TUF140044).

Fig 6. Basidiomata of *Paxillus cuprinus* (images by Anne-Liia Maido)

Paxillus involutus (Batsch) Fr. 1838

UNITE: SH0990270.10FU
Reference sequence KF261368, from epitype: TL127-0001, France

Basidiomata mostly aggregated, funnel-shaped, often with a mound when old, yellowish-white, soft but tough, smell strong and fruity. **Cap** up to 15 cm wide, convex when young; margin deeply involute; surface greyish to rusty-brown, with orange shade when older, velvety but sticky when wet; up to half of the cap rimmed, uniform in colour or with red spots. **Stipe** up to 8 cm high and 2 cm wide, narrowing or widening at the base or evenly thick; covered with white felty layer when young, turning reddish brown with age, lacking a yellow line in the upper part. **Gills** crowded, deeply decurrent, pale or rusty yellow, slightly anastomosed or not, easily removable. Fresh spore-deposit ochraceous-brown with reddish tinge.

Ecology: on acidic soil, in parks, yards, wasteland and roadsides, especially in places with anthropogenic influence, more rare in natural habitats, mostly in shade. Mycorrhizal host trees belong to various genera (*Abies*, *Betula*, *Fagus*, *Picea*, *Quercus*). Common across Europe.

a. TUF140036, b. TUF13156, C. TUF140152, d. TUF140053, e. TUF140492 (photos by Anne-Liia Maido)

Fig. 7 *Paxillus involutus* basidiomata in different stages of development.

Paxillus obscurisporus C. Hahn 1999

UNITE: SH2067406.09FU
Reference sequence: HQ207700; Type: M, Hahn, 21 Sept. 1998, Germany

Basidiomata aggregated, often in large numbers, fleshy. **Cap** up to 23 cm wide, pale with wine-red spots; margin up to 1.5 cm wide, involute in young and old basidiomata, margin conspicuously felty and inrolled, slightly rimmed or not. **Stipe** short and thick, base reddish with a yellowish line in the upper part. Spore-deposit reddish-brown (darkest in the genus).

Ecology: on fertile soil in open landscapes, parks, yards etc. Host trees belong to the genera *Betula*, *Quercus* and *Tilia*.

Fig. 8. *Paxillus obscurisporus* (photo by Vello Liiv)

Additional information and identification keys:

Dessi, P. & Contu, M. (1998). *Paxillus ammoniavirescens* sp. nov. with notes on the genus *Paxillus* (*Boletales*) in Sardinia. *Micologia e Vegetazione Mediterranea*. Vol 13 (2), pp. 121-130.

Henrici, A. (2004). A Key to *Paxillus* s.l. in Europe. *Field Mycology*. Vol 5 (3), pp. 87-88. https://doi.org/10.1016/S1468-1641(10)60560-9

Henrici, A., & Kibby, G. (2014). *Paxillus* – An End to Confusion? *Field Mycology*. Vol 15 (4), pp. 121–127. https://doi.org/10.1016/j.fldmyc.2014.09.007

Jargeat, P., Chaumeton, J-P., Navaud, O., Vizzini, A., Gryta, H. (2014). The *Paxillus involutus* (Boletales, Paxillaceae) complex in Europe: Genetic diversity and morphological description of the new species *Paxillus cuprinus*, typification of *P. involutus s.s*., and synthesis of species boundaries. *Fungal Biology*. Vol 118 (1), pp. 12-31. https://doi.org/10.1016/j.funbio.2013.10.008

Jargeat, P., Moreau, P., Gryta, H., Chaumeton, J., & Gardes, M. (2016). *Paxillus rubicundulus* (Boletales, Paxillaceae) and two new alder-specific ectomycorrhizal species, *Paxillus olivellus* and *Paxillus adelphus*, from Europe and North Africa. *Fungal Biology*. Vol 120 (5), pp. 711–728. https://doi.org/10.1016/j.funbio.2016.02.008

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

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