Join our “truffle-like Russulaceae” 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/

FunDive

Truffle-like Russulaceae

are some of the target species for the 2024 FunDive projects aimed at mapping the biodiversity of fungi in Europe

Truffulales

Truffulales Project: Help us unravel the evolution of truffle-like Russulaceae!

What are 'truffle-like' Russulaceae?
Whereas most Russulaceae mushrooms (*Russula*, *Lactarius* and *Lactifluus* species) form regular mushrooms, others show an abbarant morphology. Rather, they form enclosed fruitbodies, which can be either with or without a stipe. These species are called truffle-like or sequestrate. Some grow completely hypogeous, others are partially or fully epigeous.

They are easily recognized by their enclosed shape, compressed and contorted white to cream-colored gills, and typically ornamented, amyloid spores. In case of milkcap-truffles, the fruiting bodies release a milky substance when cut. Some species are especially interesting, as they show both co-occuring 'regular' and truffle-like morphologies.

Why are these species interesting for FunDive?
Almost 30 species of these truffle-like milkcaps or russulas have been described in Europe, but their distribution is poorly known due to their hidden lifestyle. They are possibly very rare, but more knowledge is needed to assess their ecology and Red List status.

Part of the Truffulales Project is to investigate the genomes of these species, to understand how this morphology has arisen several times in the evolutionary history of this family. To do so, we need fresh fruiting bodies of any truffle-like *Russula* or *Lactarius* species. We are especially interested in the clade of *Russula messapica* and *Russula meridionalis*. The latter species is always sequestrate, whereas the former forms both regular (var. *messapica*) and truffle-like morphologies (var. *messapicoides*).

Where can you find these species?
Most European species of truffle-like Russulaceae occur in the Mediterranean region, whilst a few can be found in temperate and alpine habitats. For example, the wishlist species occur mostly in Italy and Spain, where *Russula meridionalis* occurs under *Quercus rotundifolia*, and *Russula messapica* can be found under *Quercus coccifera* and *Q. ilex*, from Spring to Autumn. They both show a yellow-ochre pileus, that reacts red in contact with KOH in *R. messapica*.

Figure 1: Truffle-like Russulaceae wishlist; a) *Russula meridionalis*, b) *R. messapica* var. *messapicoides*, c) *R. messapica* var. *messapica*, d) *R. messapica* var. *messapicoides*, illustrating the red discoloration of the pileus with KOH.

How can you help?

If you find fresh, living fruitbodies of any truffle-like *Russula* or *Lactarius* species: please contact us as soon as possible with location details. All metadata of the observation should be added to PlutoF. Alternatively, if you have access to a freezer, you can collect the fruitbodies minimizing the disturbance and damage of the fruitbodies, transfer them to the freezer (preferably in a cooling box and as fast as possible) and store them at -20°C awaiting further instructions from us regarding transport of the samples.

If you have knowledge of any previous locations of truffle-like species, please contact us as well, so we can look for them.

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

IDENTIFICATION KEY TO EUROPEAN SPECIES OF SEQUESTRATE RUSSULACEAE (from Vidal et al. (2019))

1. Hymenophore producing milk or with laticifera. Hymenophoral trama homoiomerous, lacking nests of sphaerocytes . . . . . *Lactarius* 2

1. Hymenophore not producing milk, lacking laticifera. Hymenophoral trama heteromerous, with nests of sphaerocytes, especially in tramal anastomoses . . . . . *Russula* 8

2. Spores echinate. 3

2. Spores reticulate 6

3. Basidia 3–4-spored. — Spores 9.5–13(–15) × 8–10(–11) µm, subglobose to broadly ellipsoid; warts 1–1.5 µm high, isolated. Basidiomata 1–4 cm, subglobose to tuberiform, with a residual stipe, pale yellow with reddish brown maculae. Hymenophore loculate, pale yellow to pale brown. Latex scant, colourless to white, changing to yellow. In subalpine conifer woods (*Abies, Picea*). Temperate (Alps to Rhodopes) . . . . . *L. borzianus*

3. Basidia 1-spored 4

4. Spores weakly amyloid. — Spores (11.5–)12–14.5(–15) × (10–)11–13 µm, subglobose to broadly ellipsoid; warts 0.5–2 µm high, isolated. Basidiomata 1–3.5 cm, subglobose to tuberiform, maize yellow to reddish brown. Hymenophore loculate, ochraceous to reddish brown. Latex scant and hyaline, changing to citrine yellow in young specimens, white, abundant, and almost immutable in old basidiomata. In montane woods of *Carpinus, Corylus, Fagus, Quercus, Tilia*. Temperate to submediterranean (British Isles to Southern Europe) . . . . . *L. stephensii*

4. Spores strongly amyloid 5

5. Spores subglobose to broadly ellipsoid. — Spores 13–15 × 11–13 µm; warts 1–2 µm high, isolated or tooth-like fused. Basidiomata 1–4 cm, subglobose to tuberiform, at first pale orange then reddish brown to violet brown. Hymenophore loculate, deeply coloured, reddish yellow to orange red. Latex white. Under *Populus*. Temperate to Mediterranean (Belgium to Bulgaria) . . . . . *L. populicola*

5. Spores broadly ellipsoid to ellipsoid. — Spores 14–18.5 × 12–15 µm; warts 1–2 µm high, cylindrical, isolated or forming short ridges. Hymenium completely embebbed in a dark orange substance. Basidiomata 1–2 cm, subglobose to tuberiform, orange to reddish brown or violet brown. Hymenophore loculate, deeply coloured, dull red to dull violet. Latex watery, scant. In montane conifer woods (*Abies, Pinus*) or under

broadleaved trees (*Corylus, Quercus*). Temperate (Germany, Italy, Spain) . . . . . *L. soehneri*

6. Basidia 2–4-spored. — Spores 8.5–12.5(–13.5) × 7–9.5(–10.5) µm, subglobose to ellipsoid; reticulum 0.5–1 µm high, incomplete. Basidiomata 2–5 cm, obpyriform to tuberiform, pale orange to reddish brown, with minute depressions. Hymenophore loculate, yellowish white to orange-white. Latex scant, white, immutable. Taste sweetish, later astringent. In montane conifer woods (*Cedrus, Pinus*). Submediterranean (France, Morocco, Spain) . . . . . *L. josserandii*

6. Basidia 1-spored 7

7. Reticulum 1–2 µm high, complete. — Spores 10–13 × 7–9 µm, ovoid to ellipsoid. Basidiomata 1–2.5 cm, subglobose to tuberiform, whitish to pale yellowish, pileus membranous, partially evanescent, indistinctly scrobiculate or with some scattered minute openings. Hymenophore loculate, whitish to pale cream or pinkish. Latex not observed. Under *Cistus* and *Halimium*. Mediterranean (Central Spain) . . . . . *L. giennensis*

7. Reticulum 0.5–1 µm high, incomplete. — Spores 8.5–11 × 6.5–8 µm, ovoid. Basidiomata 0.5–2.5 cm, globose to tuberiform, whitish to brownish buff, pileus membranous, partially evanescent, distinctly scrobiculate, with abundant large openings. Hymenophore loculate, whitish to cream or faintly ochraceous pink. Latex white. Under *Cistus*. Mediterranean (Cyprus) . . . . . *L. subgiennensis*

8. Basidiomata stipitate, pseudoangiocarpic. Spores heterotropic. Amyloid suprahilar plage present. 9

8. Basidiomata sessile, angiocarpic. Spores orthotropic. Amyloid suprahilar plage absent 16

9. Spores verrucose to echinate. Warts isolated or connected by low ridges 10

9. Spores subreticulated 14

10. Macrocystidia 45–70 µm long 11

10. Macrocystidia 70–130 µm long 13

11. Spores subglobose to ovoid. — Spores 7–9 × 5.5–7.5 µm; warts 0.25–0.75 µm high, some forming short ridges or connected by short lines. Pileus 2–7 cm, orange white to pale orange, with brownish orange and dark brown maculae; margin open, alveolate to sublamellate. Hymenophore loculate, orange-white to pale orange. Stipe-columella 1–4 × 0.7–2.5 cm, with brownish orange dots. Common in coastal sand dunes, under *Pinus*. Mediterranean (Southern Portugal and Spain). . . . . *R. ammophila*

11. Spores globose to broadly ellipsoid. 12

12. Warts interconnected with low ridges. — Spores 9.5–12.5 × 8.5–10.5 µm; warts 1.2–2 µm high, in groups of 2–4. Pileus 1.4–2.8 cm, pure white, belatedly maculated of pale yellow; margin closed or laterally open, sublamellate. Hymenophore loculate, pale yellow to yellow. Stipe-columella 1–2 × 0.2–0.4 cm. In montane broadleaved woods (*Carpinus, Corylus, Fagus, Quercus*) or conifer woods (*Abies*). Temperate (Eastern to Southern Europe) . . . . . *R. candidissima*

12. Warts isolated. — Spores 8.5–11(–12.5) × 7–9(–11) µm; warts 0.5 –1.5 µm high. Pileus 0.5 – 3.5 cm, white to yellowish white, with yellowish orange maculae; margin closed or laterally open, alveolate. Hymenophore loculate, pale orange. Stipe-columella 0.6–1.5 × 0.15–0.4 cm. In montane broadleaved woods (*Carpinus, Corylus*). Temperate (Eastern to Southern Europe) . . . . . *R. candida*

13. Warts 0.6–1(–1.5) µm high. — Spores (8–)10–15(–17) × (7–)9–14(–15) µm, subglobose to broadly ellipsoid. Pileus 2.3–5 cm, yellowish to yellowish buff, with dark brown maculae; margin open, lamellate. Hymenophore sublamellate-daedaleoid, cream to ochre-orange. Stipe-columella 1.6–4.2 x 0.7–1.8 cm. Under broadleaved trees (*Castanea, Quercus*). Mediterranean (Greece and Italy) . . . *R. mediterraneensis*

13. Warts (0.7–)1.5–2.5(–3) µm high. — Spores (9–)10.5–15.5(–18) × (8–)10–15(–17) µm, globose to subglobose, some ellipsoid when immature. Pileus 1.2–3.8 cm, pale yellow to pale orange with dark brown maculae; margin open, sublamellate. Hymenophore loculate, pale yellow to titian red. Stipe-columella 0.8–2.5 × 0.3–1 cm. In montane conifer woods (*Abies, Picea*). Temperate to submediterranean (Southern Poland, Greece and Italy) . . . . . *R. mattiroloana*

14. Reticulum 0.5 µm high. — Spores (9–)10–11.5(–15) × (7.5–)9.5–10.5(–14) µm, subglobose; reticulum made of crests and warts. Pileus 2–6 cm, white with cream to pale umber maculae; margin radially alveolate when mature, but not open. Hymenophore loculate, cream-ochre. Stipe-columella 0.5–3.5 × 0.5–1.7(–3) cm. In sclerophyllous woods of *Quercus*. Mediterranean (Israel) . . . . . *R. galileensis*

14. Reticulum 0.7–1.5 µm high 15

15. Macrocystidia present. — Spores 7–11 × 6–9.5 µm, glo- bose to broadly ellipsoid; reticulum made of crests and isolate warts. Pileus 3–8.5 cm, pinkish white to purplish brown; margin open, lamellate. Hymenophore loculate to sublamellate, pale orange. Stipe-columella 1.5–4 × 0.8–2.5 cm. Odour intense, vinaceous. In littoral sand dunes, under *Pinus*. Mediterranean (Atlantic coast of Southern Spain) . . . . . *R. vinaceodora*

15. Macrocystidia absent. — Spores 8–10 × 7.5–9.5 µm, globose to subglobose; reticulum made of isolate warts and ridges. Pileus 0.5–2 cm, rounded or bi-trilobate, areolate, papillose, pale yellow to orange-yellow, intense red in contact with KOH; margin laterally open, alveolate to sublamellate. Hymenophore loculate to sublamellate, pale yellow to pale orange. Stipe-columella 0.3–0.7 × 0.15–0.2 cm,

concolourous with pileus. In littoral sclerophyllous woods of *Quercus ilex*. Mediterranean (Greece to Spain) . . . . . *R. messapica var. messapicoides*

16. Spores reticulated 17

16. Spores echinate or verrucose 18

17. Macrocystidia absent. — Spores 8–11×7–10 µm, globose to subglobose; reticulum 0.4–0.6 µm high, made of isolated warts and ridges. Basidiomata 1–2 cm, subglobose to lobate or irregular, smooth, pale cream to ochraceous, drying dark reddish brown, intense red in contact with KOH. Hymenophore loculate, pale cream to ochraceous. In continental sclerophyllous woods of *Quercus rotundifolia*. Mediterranean (Central Spain) . . . . . *R. meridionalis*

17. Macrocystidia present but scarce. — Spores 7–9.5(–10.5) × 7–9(–10), globose; reticulum 0.5 µm high, complete to incomplete, made of low ridges and warts. Basidiomata 2–7 cm, turbinate, firmly rooted into the substrate, often cracked, cream-white to ochraceous cream, with ochraceous to brownish stains. Hymenophore loculate, ochraceous yellow to ochraceous orange, vinaceous in $FeSO_4$. In montane woods of *Pinus*. Mediterranean (Cyprus) . . . . . *R. hobartiae*

18. Pileipellis a trichoepithelium or an oedotrichoderm 19

18. Pileipellis a trichoderm. 20

19. Pileipellis a trichoepithelium. — Spores 9.5–12.5 × 8.5–11 µm, globose to subglobose; warts dense 0.5–1 µm high, isolated. Basidiomata 1–3 cm, globose to irregular, whitish. Hymenophore loculate, yellow, orange yellow to ochre. Under broadleaved trees (*Carpinus, Betula, Quercus*). Temperate (Central Europe) . . . . . *R. neuhoffii*

19. Pileipellis an oedotrichoderm. — Spores (6.5–)7.5–9.5(–11.5) × (6–)7–9(–11) µm, globose to subglobose; warts up to 0.3 µm high, some connected with low ridges. Basidiomata 0.5–2 cm, globose to subglobose, pruinose, whitish, with brownish red maculae. Hymenophore loculate, whitish at first, finally brownish red. Under *Cistus*. Mediterranean (Central Spain) . . . . . *R. andaluciana*

20. Basidia 1-spored 21

20. Basidia 2–4-spored 22

21. Macrocystidia present. — Spores 13–15(–15.5) × 12.5–14.5(–15) µm, globose to subglobose, weakly amyloid, yellow; warts dense, 1.5–3 µm high, isolated. Macrocystidia numerous, 30–70 × 8–16 µm, clavate. Basidiomata 1–2 cm, subglobose to tuberiform, finely tomentose, pale orange with brown maculae. Hymenophore

loculate, pale orange. Temperate (Germany) . . . . . *R. bavarica*

21. Macrocystidia absent. — Spores (9–)10–13 µm, spherical, weakly amyloid, intense pink at maturity; warts 0.4–1.4(–1.6) µm high, isolated. Basidia clavate to lageniform-urticiform, sometimes 2-spored. Basidiomata 1.5–5.5 cm, subglobose to tuberiform, finely tomentose to papillate-squamulose, pale orange to greyish orange with wine red and olivaceous maculae when rubbing. Old specimens nude. Hymenophore loculate, pink to purplish red at maturity. Under *Pinus* and *Quercus*. Mediterranean to submediterranean (Bulgaria, France and Spain). . . . . *R. monospora*

22. Warts 0.5–1 µm high. — Spores 9–11(–13) µm, globose to subglobose; warts isolated, some forming short ridges or even an incomplete reticulum. Basidiomata 0.5–3.5 cm, subglobose to turbinate, with a residual stipe, pruinose, pure white, with pale orange to reddish brown maculae. Old specimens nude, completely alveolate. Hymenophore loculate, yellowish white to yellowish orange or deep orange. In sclerophyllous woods of *Quercus*. Mediterranean (France and Spain). . . . . *R. vidalii*

22. Warts 0.8–3 µm high 23

23. Basidia 2-spored. Macrocystidia present. — Spores (8–)9.5–12.5(–14) µm, globose; warts variable in length, 1–3 µm high, isolated. Macrocystidia (25–)30–50 × (5–)7–12(–16) µm, cylindrical to cylindro-clavate, thick walled. Basidiomata 1–3 cm, subglobose, smooth, greyish orange to pale brown, maculated of reddish brown. Hymenophore loculate, brown to reddish brown. In montane conifer woods (*Abies, Picea, Pinus*) or broadleaved woods (*Carpinus, Castanea, Corylus, Fagus, Quercus*). Temperate to submediterranean (British Isles to Southern Europe) . . . . . *R. cerea*

23. Basidia 1–4-spored. Macrocystidia absent 24

24. Spores globose. — Spores (9–)10–12(–13) µm; warts variable in length, 1–2.5 µm high, isolated. Basidiomata 1– 3 cm, subglobose to tuberiform, caespitose, pubescent, greyish to pale orange or orange, maculated of dark brown and producing aromatic exudations. Hymenophore loculate, orange-white to greyish orange or brownish orange. In montane broadleaved woods (*Fagus, Quercus*). Temperate (Southern Europe) . . . . . *R. pila*

24. Spores subglobose to ovoid. — Spores (8.5–)9.5–11(–12.5) × (8–)8.5–10(–10.5) µm; warts of regular length, 0.8–1.6(–3) µm high, isolated. Basidiomata 0.6–2.2 cm, subglobose to tuberiform, finely tomentose, pastel yellow to pale orange, maculated of brown. Hymenophore loculate, pale yellow, pale orange to brown. In woods of *Castanea, Pinus* and *Quercus*. Mediterranean (Greece to Spain) . . . . . *R. mistiformis*

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Additional information & references

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