Join *Geastrum* 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/

Geastrum

is one of the target genera for the 2024 FunDive projects aimed at supporting assessments of gasteromycetes for the European IUCN Red List

***Geastrum* – earthstars** – have the appearance of small puffballs but differ in having an outer tissue that splits up in a starlike pattern (Fig. 1). When fully expanded, some earthstars can reach a diameter of 10–12 cm, but most are smaller, measuring up to 1–5 cm in diameter. The spores are contained in a small, rounded structure in the centre of the basidioma, called the endoperidial body. When the spores are ripe, they constitute a dry and powdery mass, just like a puffball. The wall of the endoperidial body acts as a bellow's mechanism and when compressed by wind, raindrops, or trampling, the spores are released and dispersed through a small pore at the top of the endoperidal body. The surrounding outer tissue with its more or less acute rays is called the exoperidum.

Fig. 1. Representatives of *Geastrum* genus (from the left): *G. coronatum*, *G. schmidelii*, *G. melanocephalum* (photo Jörgen Jeppson).

Habitats for *Geastrum* species are quite diverse and include grazed calcareous grasslands, sand steppe vegetation, sand dunes, old-growth coniferous forests, and rich deciduous woodlands. Some species are typically recorded in urban areas.

37 species are known from Europe. Most of them are rare and appear in habitats that are rare and in decline in many European regions and thus are red-listed in many countries.

The genus is easy to recognise by its star-shaped fruitbodies, and most species are readily identified already in the field. Thirty-seven European species are briefly presented and illustrated in this booklet. The species are grouped according to readily visible morphological features. This grouping does not fully represent their phylogenetic placement.

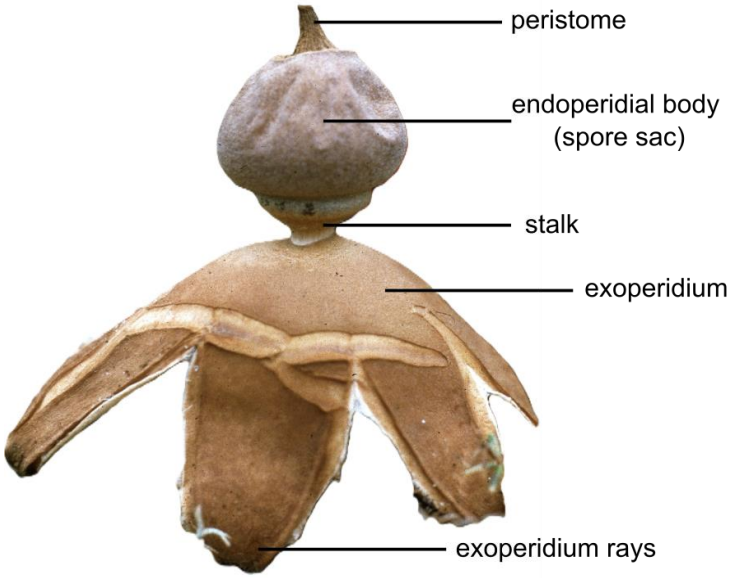
By reporting your findings, you will add to the knowledge of this species group and your records will be important contributions to nature conservation.

Morphological terminology and visualisation of features important for *Geastrum* species identification

Gasteromycetes (literally "stomach fungi") is a group of fungi producing spores inside of the basidioma. The group is polyphyletic, meaning that some species are not closely related to each other, even if they are morphologically similar.

Basidioma (also called basidiocarp or basidiome) is the sporocarp (also known as fruitbody) of a basidiomycete (fungus producing spores on basidia), the multicellular structure where the spores are borne.

Basidioma of Geastrum



Exoperidium - the outer peridium when the peridium has two layers. If the outer peridium opens when wet and closes when dry, it is described as **hygrometric.** In **non-hygrometric** species the rays remain in a permanently expanded state. In most species of earthstars the exoperidium splits into rays as the fungus matures. In one species, *G. michelianum*, the exoperidium forms a **collar-like structure** around the bottom of the endoperidial body.

exoperidium rays **collar-like structure**

involute

revolute

Endoperidial body (spore sac) - the inner peridium when the peridium has two layers. In some species this endoperidial body can be **sessile**, in other species borne on a **stalk (pedicel)**. Its surface can be **smooth** or **asperate (rough).**

endoperidial body

sessile

stalked

asperate

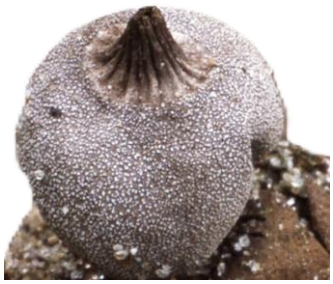
smooth

Peristome – a complex pore at the top of the endoperidial body where the spores are released. It can be **delimited**, **undelimited**, and either **sulcate** or **fimbriate-silky**.

peristome

delimited

undelimited



sulcate

fimbriate - silky

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1. Non-hygrometric species with fimbriate – silky peristome

Geastrum benitoi

A small earthstar (1-2 cm) with a stalked endoperidial body with a smooth surface. The area around the pore (peristome) is silky, fimbriate (not sulcate) and delimited by a low circular wall (Fig. 1). The fruitbodies are reminiscent of *G. granulosum* or *G. marginatum* but differ in the fact that the exoperidial rays in *G. benitoi* may bend upwards and partly enclose the endoperidial body. This is a single event and is not triggered by air humidity. It is to date only found in central Spain. It was described by J.C. Zamora in 2015 but had previously been recorded as *G. arenarium*, which has proven to be a separate, non-European species. All records must be verified by DNA-sequencing.

Reference barcoding sequence: GenBank KP687494 (holotype).

Fig. 1. *Geastrum benitoi* (photo Jörgen Jeppson).

Geastrum britannicum

A medium-sized earthstar with 5 - 7 raised exoperidial rays. The lower part of the rays is attached to a cup-shaped structure immersed in the soil. It recalls *G. fornicatum* but is distinguished by a delimited peristome, an endoperidial body with a mealy surface and the exoperidium splitting in 5 rays or more (Fig. 2). It was originally described from urban parks and gardens in the United Kingdom but has recently also been recorded from Slovakia. It should be looked for in suitable habitats in southern and central Europe.

Reference barcoding sequence: GenBank EU784243 (holotype).

Fig. 2. *Geastrum britannicum* (photo Radovan Bednár; source: https://uk.inaturalist.org/photos/335726150; CC-BY-NC).

Geastrum coronatum* and *G. pseudolimbatum

Two medium-sized to large earthstars with similar traits: a fimbriate-silky peristome and a stalked endoperidial body. The main morphological difference is in the peristomal area, where *G. coronatum* (Fig. 3) has a non- or only slightly delimited peristome whereas *G. pseudolimbatum* (Fig. 4) has a delimited peristome. The former is a species of rich deciduous woodland (sometimes also under conifers), gardens and urban parks, with a wide European distribution whereas *P. pseudolimbatum* is a thermophilous species of open grazed grassland and light forests in warm and dry regions. Both species seem to be somewhat nitrophilous.

Reference barcoding sequence for *G. coronatum:* GenBank KC581965 and for *G. pseudolimbatum:* GenBank KC581973.

Fig. 3. *Geastrum coronatum* (photo Jörgen Jeppson).

Fig. 4. *Geastrum pseudolimbatum* (photo Péter Finy; source: https://www.inaturalist.org/photos/349304941; CC-BY-NC).

Geastrum fimbriatum

A usually ochraceous – pale brownish species with its endoperidial body attached to the exoperidium without or with a very short stalk, i. e more or less sessile (Fig. 5). It is a fairly abundant species in woodland on calcareous ground all over Europe.

Somewhat similar species are the rare *G. saccatum* and *G. lageniforme* but they both have a delimited peristome.

Fig. 5. *Geastrum fimbriatum* (photo Jörgen Jeppson).

Geastrum fornicatum

A fairly large, brown – dark brown species with 4-5 raised exoperidial rays. The lower part of the rays is attached to a cup-like structure immersed in the soil (Fig. 6). It is a characteristic species of rich deciduous woodland in the southern and central parts of Europe. In northern Europe it is rare and declining. It has a newly described look-alike, *G. britannicum*, which has a delimited peristome as opposed to *G. fornicatum*.

Reference barcoding sequence: GenBank KC582012.

Fig. 6. *Geastrum fornicatum* (photo Mikael Jeppson).

Geastrum granulosum* and *G. marginatum

These are two small species with rare occurrences in dry and open calcareous grassland habitats. They were formerly both known as *G. minimum*, but morphological studies combined with DNA-sequencing have shown that we have to deal with two separate species and none of them can with certainty be linked to the American *G. minimum.* They both have a small and stalked endoperidial body and a distinctly delimited peristome. One of the more obvious features to tell them apart is the colour of the stalk in young and newly expanded fruitbodies: light-coloured in *G. granulosum* (Fig. 7), dark coloured in *G. marginatum* (Fig. 8). The former has a wide European distribution occurring all the way up in the alpine vegetation whereas the distribution and frequency of *G. marginatum* is less known. Recently a look-alike species, *G. dolomiticum*, has been described from Hungary (reference barcoding sequence for *G. dolomiticum*: GenBank MT569463). *Geastrum benitoi*, only known from the Iberian peninsula may also be superficially similar.

Reference barcoding sequence for *G. granulosum*: GenBank KF988401 and for *G. marginatum:* GenBank KP687506.

Fig. 7. *Geastrum granulosum* (photo Mikael Jeppson).

Fig. 8. *Geastrum marginatum* (photo Mikael Jeppson).

Geastrum lageniforme

A small- to medium-sized earthstar with ochraceous to light brownish colours and a stalk-less (sessile) endoperidial body. The overall look is similar to *G. saccatum* from which it can be distinguished by the more brownish, smooth, not felted and sometimes radially striated surface of the exterior side of the exoperidium (Fig. 9). It is a rare thermophilous species recorded from rich deciduous woodland and light steppe woodland in southern and Central Europe.

Reference barcoding sequence: GenBank KC581966.

Fig. 9. *Geastrum lageniforme*, left - from above, right - from below (photo Mikael Jeppson).

Geastrum michelianum

A large, brown species with a non-stalked or very shortly stalked endoperidial body. The area around the opening (the peristome) at the top of the endoperidial body is usually somewhat delimited. The fleshy layer of the exoperidium regularly forms a collar at the bottom of and partially encircling the endoperidial body (Fig. 10).

Geastrum michelianum is found in rich deciduous and coniferous forests as well as in gardens and urban parks in large parts of Europe. It is a widely distributed species, potentially one of the more common earthstars. In Europe it was formerly known as *G. triplex*, but recent studies based on DNA-sequencing have revealed that *G. triplex* s. str. is a non-European species, restricted to south-eastern Asia.

Reference barcoding sequence: GenBank KC581978 and KF988398.

Fig. 10. *Geastrum michelianum* (photo Mikael Jeppson).

Geastrum quadrifidum

A small pale brown – yellowish brown species with 4 (rarely 5) raised exoperidial rays attached to a basal cup, much like in *G. fornicatum* and *G. britannicum. Geastrum quadrifidum* can be distinguished by its smaller size and the presence of a distinctly delimited peristome (Fig. 11). It is found mainly in coniferous and deciduous continuity woodlands. In some parts of Europe, it is considered declining due to modern forestry methods.

Reference barcoding sequence: GenBank KC581959.

Fig. 11. *Geastrum quadrifidum* (photo Mikael Jeppson).

Geastrum rufescens

A medium-sized to large earthstar with pink or reddish brown colors and a shortly stalked endoperidial body (Fig. 12). It is widely distributed in European woodlands.

Reference barcoding sequence: GenBank KC582010 and KF988424.

Fig. 12. *Geastrum rufescens* (photo Jörgen Jeppson).

Geastrum saccatum

A small – medium-sized earthstar (1-4 cm) with ochraceous – light brownish colours and a stalk-less (sessile) endoperidial body (Fig. 13). The overall look is similar to *G. lageniforme* from which it can be distinguished by the felty, yellowish - ochraceous – chamois-like surface of the exterior side of the exoperidium. It is a rare thermophilous species recorded from calcareous dry grasslands, rich deciduous woodland and light steppe forests, reaching north to the Uppsala area in Sweden. It may recall the more common *G. fimbriatum* in stature and colour but is easily distinguished by its delimited peristome and felty exterior. Phylogenetic data indicate that several cryptic taxa may be involved in the current species concept.

Reference barcoding sequence: GenBank KC581968 and KF988430.

Fig. 13. *Geastrum saccatum* (photo Jörgen Jeppson).

2. Hygrometric species with fimbriate-silky peristome

Geastrum corollinum

A small – middle-sized species with a delimited peristome (Fig. 14). It is a rare thermophilous species characteristic of dry meadows and rich deciduous forests, particularly on calcareous soil. It has a wide distribution in Europe. In dry, steppic regions of Central Europe and Spain it can be confused with the much smaller *G. hungaricum*.

Reference barcoding sequence: GenBank KC581972.

Fig. 14. *Geastrum corollinum* (photo Jörgen Jeppson).

Geastrum floriforme

A small – middle-sized species with an undelimited peristome (Fig. 15). It is widely distributed in Europe, occurring in dry grassland, light deciduous woodland, and gardens. It can be confused with *G. corollinum.*

Reference barcoding sequence: GenBank KC581984.

Fig. 15. *Geastrum floriforme* (photo Mikael Jeppson).

Geastrum hansagiense

It is a little-known earthstar that was recently described from Hungary. It is similar to *G. floriforme* but differs in having slightly larger fruitbodies. It has so far been recorded only from its type locality where it grew in a nitrogen-rich grassland. It should be looked for in central Europe.

Reference barcoding sequence: GenBank MN582753 (holotype).

Geastrum hungaricum

A very small earthstar (2-8 mm) with a sessile (not stalked) endoperidial body with a smooth and sometimes slightly mealy surface. The area around the pore (peristome) is silky, fimbriate (not sulcate) and delimited by a low circular wall, much like in *G. quadrifidum*. The exoperidial rays are strongly hygrometric and enclose the endoperidial body in dry weather (Fig. 16). It grows in grazed steppic grasslands on calcareous, often sandy soils and has to date been reported from the Czech Republic, Germany, Hungary, Poland, Russia, Slovakia and Spain. It is very rare and is considered endangered due to human exploitation or overgrowth of its habitats.

Reference barcoding sequences: GenBank KC581963 and KP687501.

Fig. 16. *Geastrum hungaricum* (photo Jörgen Jeppson).

3. Non-hygrometric species with a distinctly sulcate peristome

Geastrum berkeleyi

A middle-sized to large earthstar with reddish brown – brown colors, a stalked endoperidial body with a rough, sandpaper-like surface (Fig. 17). It is closely related to *G. pseudostriatum* but forms much larger and more robust fruitbodies and grows in shaded – semi-shaded situations in rich deciduous woodland as well as in coniferous forests. It is rare all over Europe.

Reference barcoding sequence: GenBank KC581985.

Fig. 17. *Geastrum berkeleyi* (photo Mikael Jeppson).

Geastrum elegans

A small species with ochraceous to pale brown colors. It has a stalkless (sessile) endoperidial body (Fig. 18). The peristome is undelimited. It could be confused for *G. fimbriatum*, were it not for its smaller size and its distinctly sulcate peristome. It is a widely distributed but rare species usually growing on grazed calcareous grasslands.

Fig. 18. *Geastrum elegans* (photo Mikael Jeppson).

Geastrum meridionale

A middle-sized earthstar recalling *G. pectinatum* in morphology. It has a distinctly stalked endoperidial body and a conically protruding sulcate peristome (Fig. 19). It differs from *G. pectinatum* in having a more densely plicate peristome (22-52 folds vs 11-35 in *G. pectinatum*) and somewhat thinner capillitial hyphae (6-9 µm vs 9-13 µm). It is a Mediterranean species described from the Madrid area in Central Spain, where it seems to have a stronghold. It has also been on record from Portugal, Mallorca and the Canary Islands. It should be searched for in the Mediterranean area.

Reference barcoding sequence: GenBank KF988412 (holotype).

Fig. 19. *Geastrum meridionale* (photo Juan Carlos Zamora; source: https://spain.inaturalist.org/observations/80538452; CC-BY-NC).

Geastrum parvistriatum

A small-sized earthstar with a thin whitish-bluish white farinaceous (mealy) cover on the stalked endoperidial body (Fig. 20). It is similar to *G. striatum* but differs in having a more rounded endoperidial body and a smooth (not sharply edged) wall at its base. It has thus far only been recorded In Spain, growing in urban parks and plantations. It should be looked for in other parts of Europe.

Reference barcoding sequence: GenBank JN943160 (holotype).

Fig. 20. *Geastrum parvistriatum* (photo Mikael Jeppson).

Geastrum pectinatum

A medium-sized species with a stalked endoperidial body with a radially sulcate lower side, encircling the stalk (Fig. 21). In Europe it is one of the more common earthstars, widely distributed, occurring in rich deciduous woodlands as well as in old-growth coniferous forests, where it can often be found growing on needle beds or on abandoned ant hills. A rare, similar species is the newly described *G. meridionale* that so far has only been observed in Spain and Portugal.

Reference barcoding sequence: GenBank KC581962 and KF988413.

Fig. 21. *Geastrum pectinatum* (photo Mikael Jeppson).

Geastrum pseudostriatum

A small - medium-sized earthstar with a stalked endoperidial body with a rough, sandpaper-like surface. The exoperidium is non-hygrometric but the rays may sometimes bend upwards in weathered specimens (Fig. 22). It was described from Hungary in the early 20th century and has since been recorded also in dry calcareous grassland in Denmark, Germany and southernmost Sweden. *Geastrum pseudostriatum* was previously considered a synonym of *G. berkeleyi* but molecular data have shown that they belong to two separate taxa. *Geastrum berkeleyi* has larger basidiomata and grows in woodlands whereas *G. pseudostriatum* is a generally smaller species found in sun-exposed habitats.

Reference barcoding sequence: GenBank KC581997 (holotype).

Fig. 22. *Geastrum pseudostriatum* (photo Jörgen Jeppson).

Geastrum schmidelii

A small species with dominating greyish or brown colours, a distinctly stalked endoperidial body, and a conically protruding, sulcate peristome (Fig. 23). It is fairly common in dry and open calcareous grazed grasslands or on sandy fields and sand dunes with low and patchy vegetation. It is distributed in large parts of Europe but is missing in arctic-alpine regions. In the Mediterranean area *G. senoretiae* is a potential risk of confusion.

In places where it is found, several other species of earthstars could be expected and should be searched for. A very rare look-alike in the same habitats is *Geastrum pseudostriatum* which can be distinguished by the rough, sand-paper-like outer wall of the endoperidial body (smooth in *G. schmidelii*). Yet another similar and rare species is *G. campestre*, also having a rough endoperidial surface but in which the exoperidial rays are hygrometric.

Reference barcoding sequences: GenBank KC582007 and KF988435.

Fig. 23. *Geastrum schmidelii* (photo Jörgen Jeppson).

Geastrum senoretiae

A small-sized earthstar with a shortly stalked endoperidial body. The finely sulcate peristome is indistinctly delimited (Fig. 24). It has been recorded from dry Mediterranean woodlands on sandy soil, to date only recorded in Spain and in France (Corse) but should be looked for elsewhere in Mediterranean regions.

Reference barcoding sequence: GenBank KF988459 (holotype).

Fig. 24. *Geastrum senoretiae* (photo Mikael Jeppson).

Geastrum striatum

A small to middle-sized species with a thin whitish – bluish white farinaceous (mealy) cover on the endoperidium. The endoperidial body is stalked, often somewhat flattened, beret-like, and has a circular, sharply edged wall at its base, encircling the stalk (Fig. 25). It is a fairly abundant species in rich deciduous woodlands and in gardens and has a wide European distribution. It has a smaller look-alike, *G. parvistriatum*, hitherto only known from gardens and urban plantations in central Spain.

Reference barcoding sequences: GenBank KC581961 and JN943164.

Fig. 25. *Geastrum striatum* (photo Mikael Jeppson).

Geastrum xerophilum

A small species with sessile or only shortly stalked endoperidial body and an undelimited sulcate peristome (Fig. 26). The exoperidial rays bend upwards and often break at their tips, but are not truly hygrometric. It was recently detected in European steppe habitats and appears to be strongly xerothermophilous. Records to date are from Spain, Hungary and Bulgaria.

Reference barcoding sequences: GenBank MG987624 and KC581975.

Fig. 26. *Geastrum xerophilum* (photo Jesús Manuel Martínez-Calderas; source: https://www.inaturalist.org/observations/178651342; CC-BY-NC).

4. Hygrometric species with a sulcate peristome

Geastrum campestre

A small – middle-sized earthstar with a stalked endoperidial body with a rough, sandpaper-like surface. The exoperidial rays are hygrometric (Fig. 27). It is a widely distributed, thermophilous species in dry, grazed grassland, sand steppe and sometimes in wastelands surrounding old farms. It fruits in the autumn but dry fruitbodies are very persistent and can be seen almost all year round. *Geastrum pouzarii* is a similar species but it fruits in the spring. It was described from the Czech republic and has its only records in calcareous and exposed rupiculous steppe habitats of Central Europe.

Reference barcoding sequence: GenBank KC582001.

Fig. 27. *Geastrum campestre* (photo Jörgen Jeppson).

Geastrum kotlabae

A small species with a sessile (not-stalked) endoperidial body with a rough, sandpaper-like surface that soon becomes more or less smooth. The exoperidial rays are strongly hygrometric and cover the whole endoperidium when dry (Fig. 28). A similar species is *G. campestre*. It forms larger fruitbodies and the endoperidial body is stalked. *Geastrum kotlabae* is a very rare species confined to more or less steppic habitats. In Europe it has been on record mainly from the east-central parts and from the Iberian peninsula.

Reference barcoding sequence: GenBank KC582004.

Fig. 28. *Geastrum kotlabae* (photo Jörgen Jeppson).

Geastrum pouzarii

A small - medium-sized earthstar with a rough, sandpaper-like surface of the endoperidial body (Fig. 29). A similar species is *G. pseudostriatum*, with non-hygrometric exoperidium. A distinguishing feature of *G. pouzarii* is the outer surface of the exoperidium. When young it is covered with sand and soil particles but as opposed to the two look-alike species, the mycelial layer soon detaches to expose a whitish, radially striate surface. *Geastrum pouzarii* is a very rare species. It was described from Czechia where it is regularly seen in rupicolous steppe habitats on basic soil. An additional finding is that from a dry steppic mountain grassland in Switzerland. Identifications need to be verified with DNA-sequencing.

Reference barcoding sequence: GenBank KC582003.

Fig. 29. *Geastrum pouzarii* (photo Mikael Jeppson).

5. Some more earthstars that split in rays, but do not match the above categories

Geastrum melanocephalum

Geastrum melanocephalum forms large basidiomata. It deviates from other earthstars by its lack of endoperidium at maturity (Fig. 30). Ínstead the whole spore mass is exposed to wind and weathering. It grows in rich deciduous woodlands and gardens, often amongst garden refuse, and seems to be nitrophilous and thermophilous. It is widely distributed in Europe.

Reference barcoding sequences: GenBank KC581980 and KF988395.

Fig. 30. *Geastrum melanocephalum* (photo Jörgen Jeppson).

Geastrum morganii

Geastrum morganii is a potentially introduced thermophilous species with rare occurrences in humid coastal forests along the Atlantic and Mediterranean coasts. It is characterized by a strongly sulcate, almost folded, conically protruding peristome (Fig. 31).

Reference barcoding sequence: GenBank KC581971.

Fig. 31. *Geastrum morganii* (photo Jörgen Jeppson).

Geastrum nigrum

Geastrum nigrum is a little-known earthstar occurring in agricultural areas (on bushy road banks and verges) in east-central Germany. It was originally described as belonging to the puffball genus *Disciseda* but DNA-data clearly show that it is nested in *Geastrum*. It has, however, not been observed recently and new records are eagerly anticipated to add information about its morphology and ecology. All records must be verified by DNA-sequencing.

Reference barcoding sequence: GenBank MG282096 (holotype).

Geastrum smardae

It forms medium-sized to large fruitbody with silky-fimbriate peristome and a convex and arched exoperidium under which the exterior part detaches (Fig. 32). It has been found in anthropogenic situations all over Europe, but the occurrences are typically ephemeral and disappear after one or two seasons. Its main distribution is in N. America, and it might have been introduced to Europe.

Reference barcoding sequence: GenBank KC581976.

Fig. 32. *Geastrum smardae* (photo Mikael Jeppson).

6. Rounded, truffle-like earthstars that do not split in rays at maturity - “earthstars without a star”

Geastrum flexuosum

It is a semi hypogeous member of the earthstar genus. It forms rounded fruitbodies that split irregularly (not star-like) at maturity. It recalls a truffle and has an inky smell to attract small mammals for its dispersal. It was detected and described from a deciduous woodland habitat developing in the remnants of a garden belonging to a small farmhouse, since long abandoned. It was first found in the 1970-ies, and the same occurrence was monitored for more than 30 years. Since 2006 no more fruitbodies have been observed and it has not been found elsewhere in Sweden, nor in the world. The type material has been sequenced and barcoded. It must currently be suspected of being extinct. All records must be verified by DNA-sequencing.

Reference barcoding sequence: GenBank KC581970 (topotype).

Fig. 33. *Geastrum flexuosum* (photo Mikael Jeppson).

Geastrum federeri

This newly (2024) described species forms small (up to 2.6 cm), rounded fruitbodies that do not split in stellate rays at maturity. It is so far only known from its type locality in southern Spain where it occurred among plant debris under *Quercus suber* and *Q. canariensis* on siliceous soil. Together with *G. flexuosum, G. nadalii* and some extra-European *Geastrum* species, it forms enclosed fruitbodies reminding of truffles and do not have the typical star-shape of a mature earthstar. All records must be verified by DNA-sequencing.

Reference barcoding sequence: GenBank PP575904 (holotype).

Geastrum nadalii

This is a newly (2024) described species that forms small (up to 3.2 cm) rounded pale brownish fruitbodies that do not split in stellate rays at maturity. It is known from Spain (type locality), Bulgaria, France and Italy. It has been found in calcareous habitats under e.g. *Quercus ilex, Q. pinaster, Robinia pseudacacia* and *Juniperus thurifera*. Together with *G. flexuosum, G. federeri* and some extra-European *Geastrum* species, it forms enclosed fruitbodies reminding of truffles and do not have the typical star-shape of a mature earthstar. All records must be verified by DNA-sequencing.

Reference barcoding sequence: GenBank PP575901 (holotype).

7. *Geastrum*-like fungi belonging to other genera

***Astraeus* spp.**

The genus *Astraeus* is represented by four species in Europe. Although morphologically reminiscent of earthstars (Fig. 33), they are related to the boletes and classified in the Boletales.

Reference barcoding sequences for *A. hygrometricus:* GenBank HG000287 (neotype), for *A. macedonicus* (nom.inval.)*:* GenBank MK491320 (holotype), for *A. pteridis:* GenBank HG000288, and for *A. telleriae:* GenBank HG000286 (paratype).

Fig. 34. *Astraeus hygrometricus* (photo Jean-Marie Frenoux; source: https://www.inaturalist.org/observations/103306078; CC-BY-NC)

Myriostoma coliforme

This species is closely related to the earthstars in *Geastrum* but is characterized by many (3 or more) small circular openings on top of the endoperidial body. It is also provided with numerous stalks uniting the endoperidial body and the exoperidium (Fig. 34). There seems to be only one species of *Myriostoma* in Europe. It has a wide distribution but, being strongly thermophilous, it is restricted to warm and dry woodland sites in southern and central Europe. In northern Europe it is extremely rare and in need of conservation actions.

Reference barcoding sequence: GenBank KC582020 and KY096682.

Fig. 35. *Myriostoma coliforme* (photo Mikael Jeppson).

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