

# Telamonioid species of *Cortinarius*, section *Safranopedes* in Norway with emphasis on species in calcareous *Tilia* forests

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## SAMMENDRAG

De telamonioider slørsoppene i seksjon *Safranopedes* (= seksj. *Rubricosi* s. auct.) er presentert, med fokus på våre kalklindeskogsarter. I alt 15 arter tilhørende denne gruppen er nå kjent fra Norge. De aller fleste av artene her må betraktes som lite kjent nasjonalt og internasjonalt, enten oversett eller feilbestemt. Artene kan fordeles på fire grupper i Norge; (i) mer eller mindre habitat-spesifikke kalklindeskogsarter (*Cortinarius elaphinicolor*, *C. epipurris*, *C. milvinicolor*, *C. parhonestus*), (ii) små arter i rike hassel-eik-lindeskoger (*C. russulaespermus*, *C. subexitiosus*, *C. subscotoides*), (iii) små arter hovedsakelig i barskog eller med bjørk (*C.*

*annae-maritae*, *C. comptulus*, *C. nigrocuspis-datus*, *C. aff. pauperculus*, *C. subobtusus*) (iv) svært små taksa knyttet mest til *Salix* spp., inkludert arktisk-alpine populasjoner (*C. paululus*, *C. pauperculus*, *C. scotoides*).

Kalklindeskogen huser kjernegruppen av seksjon *Safranopedes*-artene; middelstore arter med fiolett KOH-reaksjon i kjøtt og ofte tilspisset-rotlig forlenget, safrangult flekket stilk og kjøtt (nederst). Denne kjernen inkluderer dådyrslørsopp *C. epipurris* (= *C. pseudosafranopes*), som ser ut til å ikke være sjelden i Europa, og tre tilsynelatende vidt utbredte men overalt sjeldne arter, bare kjent fra noen få forekomster utenfor Norge: Oliven rådyrslørsopp *C. milvinicolor* skilles på sin olivengråbrune farge som ung, rådyrslørsopp *C. parhonestus* på mer livlig brune farger og liten rådyrslørsopp *C. elaphinicolor* kan karakteriseres som en mellomting mellom de to førstnevnte. En presentasjon og nomenklatur-diskusjon av typearten i seksjonen; *C. safranopes*, er inkludert her, selv om denne arten så langt ikke med sikkerhet er påvist i Norge.

## ABSTRACT

The *Cortinarius* (telamonioid) species of sect. *Safranopedes* (= sect. *Rubricosi* s. auct.) in Norway are presented, with emphasis on our calcareous *Tilia* forest species. Altogether 15 species from the section are now known from Norway. Most of these species must be regarded as so far little known, overlooked or misidentified. The species can be sorted in four groups in Norway; (i) more or less habi-

tat-specific calcareous *Tilia* forest species (*Cortinarius elaphinicolor*, *C. epipurrus*, *C. milvinicolor*, *C. parhonestus*), (ii) small species in rich *Corylus-Quercus-Tilia* forests (*C. russulaespermus*, *C. subexitiosus*, *C. subscotooides*), (iii) small species mainly in conifer forests or with *Betula* (*C. annae-maritae*, *C. comptulus*, *C. nigroscupidatus*, *C. aff. pauperculus*, *C. subobtusus*) (iv) very small taxa associated mainly with *Salix* spp., including arctic-alpine populations (*C. paululus*, *C. pauperculus*, *C. scotooides*).

The calcareous *Tilia* forests taxa include the core group of sect. *Safranopedes*; medium-sized taxa with violet KOH-reaction in context and often radicate, saffron yellow spotted stipe and context. This core group includes *C. epipurrus* (= *C. pseudosafranopes*) which seems not uncommon in Europe, and three apparently widespread but rare species, only known from a few localities outside SE Norway: *C. milvinicolor* is distinguished on its initially olivaceous grey brown colours, *C. parhonestus* on more vivid fulvous colours and *C. elaphinicolor* being more or less intermediate. A presentation and nomenclatural discussion on the type species of the section, *C. safranopes* is included, although this species is so far not confirmed from Norway.

## INTRODUCTION

Formerly, we have in Agarica presented some of the complex and species-rich groups of *Cortinarius* species that are typical for calcareous *Tilia* forests in Norway; the phlegmacioid “*C. parvus*-group” of section *Calochroi* (Brandrud et al. 2018a) and the *C. puellaris* group of small, telamonioid species (Brandrud et al. 2015; cfr. also Brandrud et al. 2016a). In the present paper we treat another difficult group of telamonioid species, belonging to the sect. *Safranopedes*. Some of these species can be co-occurring in the *Tilia* forests and can be very difficult to differentiate morpho-

logically. Some have apparently an overlapping morphological variation and must be regarded as only little differentiated, semi-cryptic species. Moreover, the often very dry conditions in the calcareous *Tilia* forests causes the small/medium-large telamonias to easily dry out, and then they become hardly recognizable.

During our monitoring programme for calcareous *Tilia* forest fungi (Brandrud et al. 2016b, 2022), we have also struggled with the naming of some of the *Safranopedes* taxa. Initially, we used the collective working name *C. pseudosafranopes* for most of them. After intensive DNA-barcoding, and with the recent, extensive type study in *Telamonina* (Liimatainen et al. 2020) at hand, we can now apply a more stable and consistent naming and circumscriptions of the taxa in this group.

The major aim of this paper is to present the species that is typical for the threatened calcareous *Tilia*-forests in Norway. This can be regarded as the core group of sect. *Safranopedes*, with some characteristic features, such as a conical pileus, a radicate stipe with contrasting cartilagineous cortex and soft central context (with a lilac KOH reaction), stipe with often vivid saffron yellow spots in middle/lower part, and rather small, broadly ellipsoid, strongly verrucose spores. These core species are from time to time confused with taxa in the *Hinnulei* group, such as *C. hinnuleus* Fr. and *C. semiodoratus* Rob. Henry. These lack, however, the lilac KOH reaction, and lack the saffron spots. Normally these also has more pronounced veil girdles at stipe and more vivid fulvous, distantly set lamellae.

Apart from the *Tilia*-forest core group, we have also included in the paper a presentation of the other Norwegian species of sect. *Safranopedes*. These are often small and anonymous, and it is not always obvious that they belong to the present section. Altogether,

16 *Safranopedes* species are presented and commented here.

#### MATERIAL AND METHODS

Spores and other microscopic features were studied and measured with a 100× oil immersion lens (achromatic Zeiss and Leitz equipments), with mounts in 2% KOH. From each basidiocarp, a random selection of ten to twenty mature spores obtained from cortina remnants/stipe surface were measured excluding apiculus and ornamentation. The pileipellis and lamellae tissue were studied in 2% KOH. The collections made by the authors are deposited or will be deposited in the herbarium of the University of Oslo (O), or as

otherwise cited. Abbreviations of collectors' names are as follows: TEB; Tor Erik Brandrud, EB; Egil Bendiksen, BD; Balint Dima.

For the DNA extraction and PCR reactions mainly the Phire® Plant Direct PCR Kit (Thermo Scientific, USA) was used following the recommendations of the manufacturer, but also other DNA extraction kits were applied (see Brandrud et al. 2018b).

The ITS region of the nrDNA was amplified with the primer pairs ITS1F/ITS4 or ITS1F/ITS4B (White et al. 1990, Gardes & Bruns 1993). Majority of the amplicons were sequenced at LGC Genomics (Berlin, Germany) with the same primers used in PCR reactions. The electropherograms were

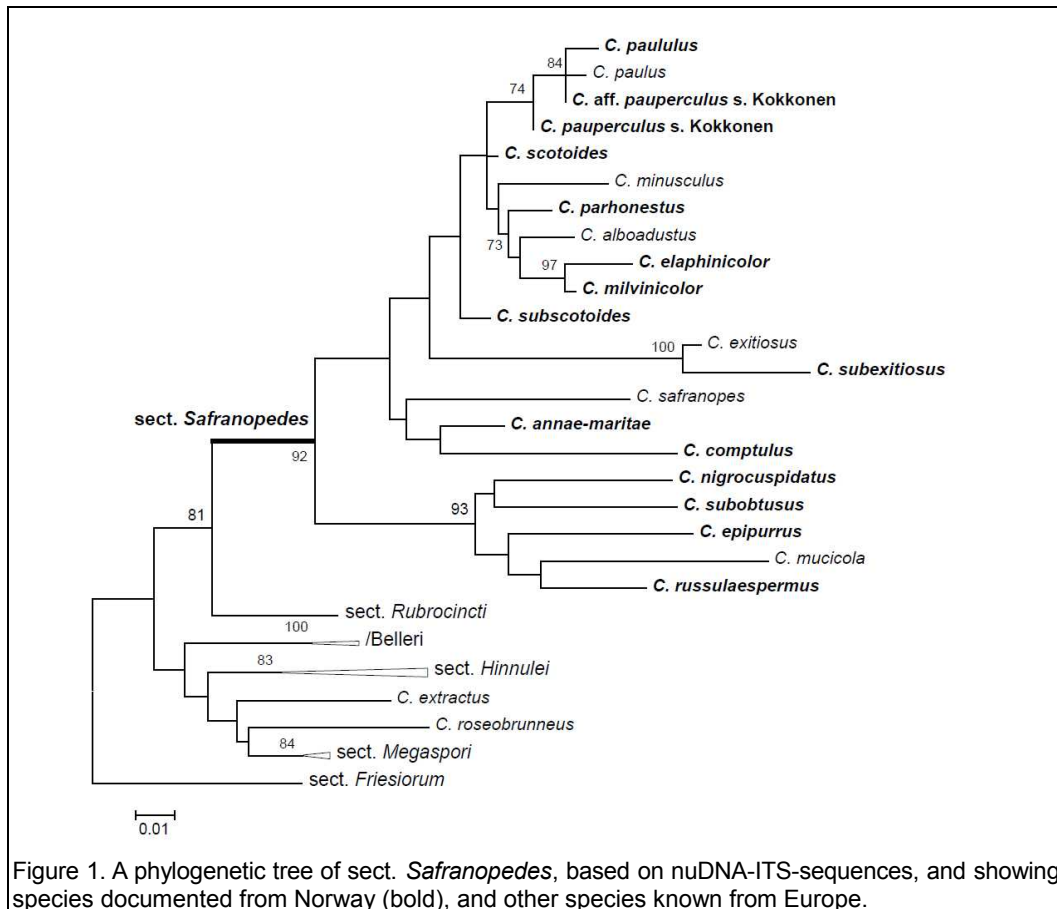


Figure 1. A phylogenetic tree of sect. *Safranopedes*, based on nuDNA-ITS-sequences, and showing species documented from Norway (bold), and other species known from Europe.

checked, assembled and edited with the CodonCodeAligner package (CodonCode Corporation, Centerville, MA, U.S.A).

Some sequences were produced at the University of Oslo and University of Copenhagen, using similar methods. Some were generated in collaboration with the Norwegian Barcode of Life Network (NorBOL) as part of BOLD. For BOLD methods, see Ratnasingham & Hebert (2007, 2013).

Multiple sequence alignment was done by MAFFT online v7 (<http://mafft.cbrc.jp/alignment/server>). Manual adjustment of the alignment was done in SeaView 4 (Gouy et al. 2010). Maximum Likelihood (ML) phylogenetic reconstruction was performed in PhyML v. 3.1 (Guindon et al. 2010) using the non-parametric, Shimodaira-Hasegawa version of the approximate likelihood ratio test (SH-aLRT) (Anisimova et al. 2011) with the following settings: GTR+I+G model of evolution, gamma distribution of 10 rate categories and tree topology search as SPR. The resulting phylogenetic tree (Figure 1) was edited in MEGA 7 (Kumar et al. 2016).

## RESULTS AND DISCUSSION

Section *Safranopedes* in a wide sense, as here circumscribed in Figure 1, includes more than 20 species in Europe, of which so far 15 taxa are sequence-verified from Norway. These are all presented here (plus the sectional type species *C. safranopes*). Based on morphology, Norwegian habitat-preferences and distribution, four subgroups can be distinguished:

- (i) The “core” *Safranopedes* species, mainly in calcareous *Tilia* forests (medium-sized taxa with saffron tinges on stipe and in bulb context and more or less violet KOH reaction in context)
- (ii) Species mainly in rich (but not calcareous) *Corylus-Quercus-Tilia* forests (small taxa, some may have saffron tinges)

- (iii) Other lowland, mainly boreal, conifer-*Betula* associated species (small, red brown–fulvous species with stipe discolouring claybrown-ochre brown from base, mainly with small broadly ellipsoid-subglobose spores)
- (iv) Tiny, mainly *Salix* associated species, often in riparian sites, and including arctic-alpine populations (the *C. pauperculus* complex; with red brown–umber brown pileus and fibrillose-girdled, rather thick veil remnants; spores ellipsoid)

According to our nrDNA ITS phylogeny, most of the here presented taxa of the sect. *Safranopedes* are well supported, separated from sister species with a clear barcoding gap. The exception from this is the mainly *Salix*-associated *C. pauperculus*-*C. scotoides*-*C. paululus* complex, where each taxon is distinguished by only a few differences in the ITS region. Kokkonen (2020) studied this complex in more detail and chose to split it into four taxa (*C. pauperculus*, *C. scotoides*, *C. paululus* and *C. paulus*, the latter not found in Norway). We have followed this splitting here, but a deeper multigene phylogenetic study, combined with more morphology and habitat data are needed for a final sorting of this complex, which includes more taxa.

The circumscription of many of the phylogeny-based species is quite recent, and the habitat range and morphological differentiation of these species are at present little known. Concerning our *Tilia*- forests species, we still struggle to distinguish morphologically *C. parhonestus* from *C. elaphinicolor*, and these sometimes also from *C. milvinicolor* or *C. epipurrus*. With present knowledge, at least the two former could be regarded as semi-cryptic species (with overlapping character variation). However, with more knowledge and repeated collecting, we think these species will be possible to recognize, but only in

young and well-developed stages. In our *Tilia* monitoring programme, the specimens may be in suboptimal conditions, e.g. frequently dried out, and then an ITS barcoding will be needed for a certain identification. In former *Tilia*-forest monitoring reports, this complex was referred to with the working name *C. pseudosafranopes* (Brandrud et al. 2016b). According to type studies, *C. pseudo-safranopes* is, however, a synonym of *C. epipurrus* (Liimatainen et al. 2020).

Most of the small, anonymous taxa outside the calcareous *Tilia* forests, we have so far identified mainly with the aid of ITS barcoding. But with closer, morphological studies in the future, also many of these taxa could appear to be morphologically well-distinguishable species. For instance, the *Corylus-Quercus-Tilia* associate *C. russula-epermus*, should be possible to distinguish from related species on its strongly verrucose spores (see taxonomic part below).

The name *Safranopedes* was first introduced by Bidaud et al. (1997) for a series (“série”) within the section *Hinnulei*. The *Safranopedes* at that time included what here is referred to as the “core group” around *C. safranopes* (*C. rubricosus* s. Moëgne-Loccoz & Reumaux, *C. conicus* s. Brandrud et al.). This core group is characterized by medium sized species with an often vivid saffron-yellow spotted, radicate stipe and bulb context, a violet-dark violet reaction in context when adding a drop of KOH (or other strong alkaline solutions), and small, broadly ellipsoid, strongly verrucose spores, resembling those of e.g., *C. hinnuleus*. The same, narrow circumscription, we see in Niskanen et al. (2008, 2012), where *Safranopedes* was raised to sectional rank.

More recently, the phylogenetic analysis of Liimatainen et al. (2020), and the one performed here (Figure 1) have shown that this core group of *Safranopedes* appears entangled within a larger clade also including

a number of small or even tiny telamonioid species, without a violet KOH reaction. These often rather anonymous species are characterized by red brown–fulvous–ochre brown pileus colours, and a stipe that turns clay brown to ochraceous brown from basis. However, only rarely a vivid saffron-yellow tinge on stipe and in context can be seen. Most, but not all of these species have small, broadly ellipsoid(-subglobose) spores. Most species also possess some encrusted, brown pigments in the epicutis hyphae of the pileipellis.

*Safranopedes* Liimat., Kytöv. & Niskanen in this wide sense was emended to a wider section by Liimatainen et al. (2020, but see also Liimatainen & Niskanen in Hyde et al. 2019). The naming was furthermore changed to sect. *Rubricosi* Moëgne-Loccoz & Reumaux in Liimatainen et al. (2020). The section *Rubricosi* was introduced already by Moëgne-Loccoz and Reumaux (1990) to cover large-medium sized telamonias with vivid red brown–chestnut brown pileus colours and more or less brown–grey brown discolouring stipes (including subsect. *Subferruginei* Moëgne-Loccoz & Reumaux), without any saffron yellow tinges nor violet KOH reaction. However, they neotypified the Friesian *C. rubricosus* in a direction not intended, by selecting a type collection, which on later ITS barcoding appeared to be identical with the type sequence of *C. safranopes*. Thus, *C. rubricosus* automatically became the type of sect. *Safranopedes*, which then change name to sect. *Rubricosi*. However, since the neotype of *C. rubricosus*, selected by Moëgne-Loccoz and Reumaux (1990) in our opinion is in serious contradiction with the protologue of *Agaricus irregularis* var. *rubricosus* (Fries 1818; see also *C. rubricosus* (Fr.) Fries 1838), we have rejected this neotypification, and thus kept the name *C. safranopes* and the original name of the section; *Safranopedes* (see also taxonomic part under *C. safranopes*).

### Taxonomic part

#### **The “core” *Safranopedes* species (in Norway mainly in calcareous *Tilia* forests)**

In the SE Norwegian calcareous *Tilia* forests four middle sized species of sect. *Safranopedes* can be found. Sometimes two or three of them are co-occurring, making identification difficult. Perhaps the most invariable characteristics of these species as a group are that the context becomes violet when KOH is added, and that the central, soft context in the base of the stipe is pale ochre yellow to saffron. Often also there is saffron spots/discolouring in lower/central part of stipe.

The species in this “core group” of sect. *Safranopedes* all have a more or less southern distribution in Europe, apparently ranging from Mediterranean *Quercus ilex* forests to the boreonemoral mixed *Quercus-Corylus-Tilia* forests of S Scandinavia. All of these are remarkably little known and little depicted. *Cortinarius epipurrus* seems to be rather frequent in European *Quercus-Carpinus-Fagus* forests. The other three, more rare ones are per date known from more e-DNA soil samples than from sequence-verified basidiocarp collections. This indicate that these are overlooked/rarely collected, but may possibly also indicate that these are widely distributed in soils, but are very rarely fruiting.

***Cortinarius safranopes*** Rob. Henry (*C. rubricosus* (Fr.) Fr. sensu Bidaud et al.; *C. conicus* (Velen.) Rob. Henry s. Brandrud et al.) (Fig. 2) *Cortinarius safranopes* is so far not recorded from Norway, but it is known from a calcareous *Corylus-Quercus* forests in SE Sweden, and since being the type of the section *Safranopedes* it is included here.

Originally Henry (1938) apparently had a very wide concept of *C. safranopes*, probably including also species such as *C. milvinicolor*, with pronounced saffron yellow tinges on stipe. However, when he much later chose a

type for *C. safranopes*, the present one was selected, in the following referred to as *C. safranopes* s. str.

*Cortinarius safranopes* s. str. has usually a radicating to bulbous-radicating stipe, which is initially ochraceous white in upper part, soon discolouring dark clay brown from base, sometimes more ochraceous brown spotted in central part. The dark grey brown discolouration resembles that of sect. *Bovini* species, and vivid saffron tinges are never seen. The pileus is initially campanulate-conical, with ochraceous brown, fulvous to olivaceous grey brown colours. The species soon dries out in its xerothermic habitats, and the pileus then become pale ochraceous brown. The young lamellae have a (olivaceous) grey brown colour, becoming darker brown. When 10% (or 40%) KOH is added, the soft central part of context becomes dark lilac-violet, almost blackish in cortex and on surfaces. The spores (7.5–9 × 5–6 μm) are typical for the *Safranopedes* (and *Hinnulei*) groups; being small, broadly ellipsoid and strongly verrucose (especially in the distal part of the spores). For a more detailed description of *C. safranopes*, see Brandrud et al. (1992–2012; C38 sub nom. *C. conicus*). The more olivaceous grey brown colours, without vividly saffron or fulvous tinges, distinguished this from other species in the group, such as *C. parhonestus* and *C. epipurrus*.

*Cortinarius safranopes* s. str. seems to be widely distributed in thermophilous, calcareous deciduous forests in South Europe (including evergreen *Quercus ilex* woodlands) and Central Europe west to Great Britain (see Kibby & Tortelli 2021, sub nom. *C. rubricosus*). The species seems to be mainly found in *Quercus-Carpinus* sites, but also with *Fagus* (own observations; sequenced samples from e.g., Gargano, SE Italy and French Jura), probably also occurring with *Corylus* and *Tilia*. The many French synonyms for this listed in Liimatainen et al.



Figure 2. *Cortinarius safranopes*. Gargano, Apulia, SE Italy. (leg. F. Bellù, TEB 822-12). Photo TE. Brandrud.

(2020: Table 1 under *C. rubricosus*) indicate that this, together with *C. epipurrus*, must be one of the most frequent *Safranopedes* species in temperate deciduous forests in France.

Moëgne-Loccoz & Reumaux (1990) neotypified the classical Friesian species *C. rubricosus* (Fr.) Fr. on a material matching 100% in ITS with the present species. However, the authors apparently misinterpreted their selected neotype collection; it is clear that they did not regard their selected neotype as belonging to *Safranopedes*, and the KOH reaction in context was not checked. Furthermore, they did not cite the basionym of *Agaricus irregularis* var. *rubricosus* in Fries 1818 (only Fries 1838). This neotype leads to a circumscription of *C. rubricosus* which is in serious contradiction to the short protologue of Fries (1818), and certainly in conflict also with their own concept of sect. *Rubricosi* (Moëgne-Loccoz &

Reumaux 1990). Fries (1818) describes *Agaricus irregularis* var. *rubricosus* as a red brown species (*C. safranopes* is never red brown; see above). Later, Fries (1838: 310) stated that the species was collected in “silvis ... pinetis”, whereas our *C. safranopes* is a southern deciduous forest species. In fact, it is very unlikely that Fries ever saw *C. safranopes* in Femsjö, Småland (where he was situated in his early days). This area does not house the southern calcareous deciduous forest element to which this species belongs, and more specifically, *C. safranopes* is not known from any of the regions of Sweden where Fries lived or visited.

The French neotypification is also in more or less contradiction with prevailing interpretations of the name. For instance, the much cited interpretation of *C. rubricosus* by Lange (1938), shows a slender species in sect. *Brunnei* or sect. *Bovini*. Following more or less

this tradition, *C. rubricosus* has in Norway been applied on a dark red brown-chocolate brown, darkening taxon in sect. *Bovini*, now called *C. subbulliaridoides* Rob. Henry (Brandrud et al. 2016b, 2022).

Conclusively, this French neotypification of *C. rubricosus* is not accepted here, and we keep using the name *C. safranopes* for the present species and *Safranopedes* for the present section, and not sect. *Rubricosi*, as applied e.g., in Liimatainen et al. (2020). This matter has recently been discussed with the *Cortinarius* group in the Dutch Mycological Society, who will not accept this neotypification either, and will apply the name sect./clade *Safranopedes* in their forthcoming 8. Volume of Flora Agaricina Neerlandica (Thomas Kuyper, pers. comm.).

***Cortinarius parhonestus*** Reumaux (Fig. 3a-b)

This species was included in our wide concept of *C. pseudosafranopes* in our calcareous *Tilia*-forest monitoring (Brandrud et al. 2016b). It possesses the “core” *Safranopedes* features; with a firm, cartilagineous, pointed-radicating stipe, at certain stages turning vividly saffron-yellow outside and inside, especially at the middle part, sometimes also at the lower part (especially in the bulb context), which, however, with time turns more greyish-blackish. The veil remnants on the stipe are usually rather thin; can be seen as white patches when young, but rarely with girdles. The stipe context (especially the soft inner part) turn (blackish) lilac with 10% KOH, a reaction typical for a number of the “core” *Safranopedes* species. The pileus and lamellae in young stages possess a vivid ochraceous-fulvous brown colour. The spores are (very) small and broadly ellipsoid;  $6-7.5(-8) \times 5-5.5$   $\mu\text{m}$ , strongly verrucose, sometimes almost cristate.

In the young stages with vivid fulvous brown colours, the species can fairly easily be distinguished from the closely related *C.*

*milvinicolor* and *C. elaphinicolor* (= *C. sordescitipes* s. auct Norw.). These possess darker and more olivaceous brown colours on the pileus and young lamellae. In more mature stages, these taxa could be very difficult to distinguish (they all have the saffron tinges on the stipe). So far, spore measurement studies indicate only subtle differences in spore size of these.

In the calcareous *Tilia* forests, *C. parhonestus* sometimes co-occur with *C. epipurpus*, and these often have been mixed and treated under the name *C. pseudosafranopes* coll. However, the “core” *Safranopedes* features is more weakly developed in *C. epipurpus*; the stipe is usually not radicating, not very cartilagineous, and usually lack vivid saffron tinges (but has more grey ochre to cinnamon tinges). The lamellae are initially more pale ochraceous yellow (almost pale greyish yellow), and all-in-all, this species resembles more the *Hinnulei* group, with species such as *C. hinnuleus* Fr. s. str. and *C. semiodoratus* Rob. Henry. The spores of *C. epipurpus* are also slightly larger than those of *C. parhonestus*.

The species is so far recorded from 13 calcareous *Tilia-Corylus* forests, from outer Oslofjord (Bamble-Porsgrunn) to inner Oslofjord (Asker-Bærum-Oslo) and Ringerike. Most collections are from the coastal limestone ridges in Asker. Most of these samples are verified with ITS sequencing. However, the species is still little known (due to confusion with e.g. *C. milvinicolor* and *C. epipurpus*), and may have a wider distribution, possibly occurring also in other kinds of rich *Tilia* and *Corylus* woodlands in SE Norway.

*Cortinarius parhonestus* is generally very little known. Apart from the Norwegian *Tilia*-forest population, this is sequence-verified only from one collection of basidiocarps in SE Sweden (Liimatainen et al. 2020) and one collection (the type) from France. It was described in Atlas des Cortinaires vol. 20 (Bidaud et al. 2012), based on one collection





Figure 3. Figure 3. *Cortinarius parhonestus*. Above: *Tilia* forest, Elnestangen SV, Asker (TEB 323-19). Below: *Corylus* forest, Kjerrvika, Bamble (TEB 392-18). Photos: B. Dima.

from deciduous forest in the Paris region. These specimens are very dark grey brown discoloured, not very typical. The presently depicted specimens are apparently the first representative ones illustrated (Figure 2a-b).

The fact that this species was not included in the broad treatment of *Safranopedes-Hinnulei* species in Bidaud et al. (1997), may indicate that this is a rare species in Southern-Central European temperate deciduous forests. However, recently available e-DNA sequences show a wider distribution: The species has an ITS match with e-DNA soil samples from Sweden, Estonia and Georgia. Probably it is widespread eastwards within the range of European-Little Asian(-Hyrcanian) *Quercus-Carpinus-Fagus-Tilia* distribution (like the distribution of another of our *Tilia*-forest species, *C. ochrolamellatus* Ballara, Liimat., Brandrud & Mahiques, see Garrido-Benavent et al. 2020). This furthermore seems have a major, relic population in *Tilia-Corylus* and *Corylus-Quercus* woodlands of S Scandinavia, like some phlegmacioid-calochroid species such as *C. osloensis* Brandrud, T.S. Jeppesen & Frøslev, *C. stjernegaardii* Brandrud & Frøslev (Brandrud et al. 2022) and *C. marklundii* Brandrud, Dima, Saar, Schmidt-Stohn & Ballarà (Schmidt-Stohn et al. 2022).

***Cortinarius milvinicolor*** Moëenne-Locc & Reumaux (Fig. 4a-b)

*Cortinarius milvinicolor* has, as its close sisters *C. parhonestus* and *C. elaphinicolor*, probably frequently been involved in the broad concept of *C. safranopes* in many regions.

When young, the species has an olivaceous brown colour on pileus and lamellae. Especially in early phases of drying out, this olivaceous tinge is pronounced, and can be regarded as a basic, diagnostic character. At this stage, this is a rather beautiful and characteristic *Telamonia*. According to some of our collections, this is probably the *Safranopedes* species which may show the most distinct saffron

yellow discoloration of stipe surfaces and stipe context, especially at the middle part, sometimes also at the lower part, and in the medulla of lower part of stipe and bulb context. The usually thin veil remnants on the stipe may also turn somewhat yellowish. The stipe surface and context turn lilac-blackish lilac with 10% KOH, a reaction typical for the core *Safranopedes* species. The spores are (very) small, broadly ellipsoid and strongly verrucose (spores  $6.5\text{--}8 \times 5\text{--}5.5 \mu\text{m}$ ).

With its initially pronounced olive brown colours, the species can fairly easily be distinguished from the closely related *C. parhonestus*. In more mature stages, these taxa could, however, be very difficult to distinguish, and so far, spore measurement studies indicate only subtle differences in spore size of these. *Cortinarius elaphinicolor* (= *C. sordescitipes* s. auct Norw.) is a kind of intermediate, also sometimes co-occurring species, which makes this species complex even more entangling. It seems, however, normally to be possible to distinguish on less pronounced olivaceous colours, more veil remnants and generally smaller basidiocarps.

The species is so far recorded from eight calcareous *Tilia-Corylus*-forests, from outer Oslofjord (Bamble-Porsgrunn) and inner Oslofjord (Asker-Bærum-Oslo), most of which are verified with sequencing. However, the species is still to be regarded as little known (due to confusion with e.g. *C. elaphinicolor* and *C. parhonestus*), and may have a wider distribution, possibly occurring also in other kinds of rich *Tilia*- and *Corylus*-woodlands in SE Norway.

Like *C. parhonestus*, this species is very little known outside SE Norway, probably due mainly to confusion with related taxa. In spite of much sequence screening of *Safranopedes* taxa, e.g. in Liimatainen et al. (2020), outside Norway the species is so far only sequence-verified from basidiocarps from the type of *C. milvinicolor* from France (Bidaud



Figure 4. Figure 4. *Cortinarius milvinicolor*. *Tilia* forests, Elnestangen SV, Asker (Above: TEB 322-19; below: TEB 401-15). Photos: B. Dima.

et al. 1997), from one collection from calcareous *Corylus-Quercus*-woodland of SE Sweden (Liimatainen et al. 2020), and one

from rich, grazed *Quercus* forest in Denmark (Jacob Heilmann-Clausen, pers. comm.). However, from recent soil/root sample e-DNA



Figure 5. Figure 5. *Cortinarius elaphinicolor*. Above: *Tilia* forest Bærum (TEB 215-14). Below: *Fagus* forest, near Bedarieux, France (TEB 921-13). Photos: B. Dima, TE. Brandrud, resp.

deposited in public databases, the species is documented from Estonia, Germany, Russia, Georgia, Turkey and China, showing a distri-

bution even beyond the continuous European-Little Asian *Quercus-Fagus*-forest range.

***Cortinarius elaphinicolor*** Carteret (Fig. 5)  
*Cortinarius elaphinicolor* (= *C. sordescens* Bidaud, Moëgne-Locc. & Reumauxsensu Brandrud et al. 2016) is the third member of the *C. parhonestus*-*C. milvinicolor* clade that occurs in our calcareous *Tilia*-forests. Based on material seen, it is difficult to assess the morphological variation range and overlap with sister species.

According to own material, *C. elaphinicolor* is a *C. milvinicolor* look-a-like, with somewhat less pronounced olive tinges, less saffron-spotted and generally with smaller, more slender basidiocarps, with only very thin veil-remnants on the stipe. When young and well-developed, these features may distinguish it from *C. milvinicolor*, but these two could also be regarded as semi-cryptic species, with overlapping morphological features. The spores are quite similar; (very) small and broadly ellipsoid ( $6.5\text{--}8 \times 4.5\text{--}5.5 \mu\text{m}$ , from own measurements). The original description of *C. elaphinicolor* in Bidaud et al. (2004) does not throw much light on the characteristics of *C. elaphinicolor*, since it is based on an old and rather aberrant material. An affinity to *Safranopedes* is not mentioned at all in the protologue. But the ITS sequence of the type has 100% match with that of our species.

The species has another, very similar sister species, *C. alboadustus*, which is found several places in Denmark, but so far not in Norway. According to Jacob Heilman-Clausen (pers. comm.), the latter has more velum and is more vividly coloured on the pileus than *C. elaphinicolor*.

*Cortinarius elaphinicolor* is so far sequence-verified from eight calcareous *Tilia-Corylus*-forests from inner Oslofjord (Asker-Bærum-Oslo; for further locality details, see Brandrud et al. 2022). Furthermore, the species is verified from a rich (but not calcareous) *Tilia-Quercus*-forest at Froland, Agder, and one calcareous mixed *Corylus*-woodland in Hadeland near Randsfjorden (being the world's

northernmost record). The species may have a wider boreonemoral distribution beyond the calcareous *Tilia*-forests.

In Denmark, the species is sequence-verified from seven collections (Jacob Heilman-Clausen, pers. comm.). Here it occurs in somewhat richer *Fagus* forests, but not strictly calcareous ones. Outside Scandinavia, the species is verified from basidiocarps from two collections from France; the type from Paris region (*Quercus-Castaneus*-forest) and one collection (TEB 919-13) from montane *Fagus*-forest near Bédarieux, Hérault in S France. From recent e-DNA soil/root samples, the species is furthermore verified from Estonia, Italy and Switzerland, indicating a fairly wide distribution, maybe comparable to that of *C. parhonestus*.

***Cortinarius epipurrus*** Chevassut & Rob. Henry (= *C. pseudosafranopes* Moëgne-Locc. & Reumaux) (Fig. 6a-b-c)

*Cortinarius epipurrus* is probably the most widespread and frequent of the taxa of sect. *Safranopedes* in its strict sense. But yet the species is remarkably little known. In Norway it has been treated (together with e.g. *C. parhonestus*) under the name *C. pseudosafranopes* coll. (Brandrud et al. 2016b). However, *C. epipurrus* in fact lack the “core” *Safranopedes* features, or at least they are not distinct. The stipe usually lacks vivid saffron tinges (but has more grey ochre-cinnamon tinges), and is often more or less radicating. The lamellae are initially more pale ochraceous yellow (almost pale greyish yellow), and all-in-all, this species resembles more the *Hinnulei* group, with species such as *C. hinnuleus* s. str. and *C. semiodoratus*. The pileus is fulvous to ochraceous brown. *C. epipurrus* also possesses slightly larger and more ellipsoid spores ( $7\text{--}9 \times 5\text{--}6 \mu\text{m}$ ) than the above treated taxa, and is in fact phylogenetically not belonging to the same (sub)clade as *C. parhonestus*, *C. milvinicolor* and *C. elaphinicolor* (Figure 1).



Figure 6a. *Cortinarius epipurrus*. *Tilia* forests, Nes, Hole (Ringerike; above: TEB 696-11; below: TEB 708-11. Photos: TE. Brandrud.

*Cortinarius epipurrus* has a wider ecology than *C. parhonestus* and *C. milvinicolor* in Norway, occurring also in other (not strictly calcareous) *Tilia-Corylus-Quercus*-forests



Figure 6b. *Cortinarius epipurpus*. *Tilia* forests, Asker (above: TEB 527a-15; below: TEB 505c-15). Photos: B. Dima.

(together with e.g. *Hinnulei* species). In fact, only half of the 15 Norwegian sequence verified collections are from calcareous *Tilia*-forests. In Denmark the species is widespread and apparently not uncommon with *Quercus* and less commonly *Fagus* on somewhat

richer soils (Jacob Heilmann-Clausen, pers. comm.). In the Netherlands the species is not rare in rich (but not calcareous) deciduous forests and was formerly mainly named *C. conicus* (Velen.) Rob. Henry (Nico Dam, Thomas Kuyper, pers. comm; data in prep.

for Flora Agaricina Neerlandica). From England, it is noted “with *Quercus*” (Kibby & Tortelli 2021).

***Species with affinity to rich (but not calcareous) Corylus-Tilia-Quercus forests***

Three species seem to prefer rich, thermophilous (but not calcareous) deciduous forests in Norway, spanning from steep scree forests to flat forest stands, usually on thin soils. These are not found in the well-developed, strictly calcareous *Tilia*-forests.

***Cortinarius russulaespermus* Carteret (Fig. 7)**

This small, anonymous fulvous brown to grey brown fungus is difficult to recognize in the field, but is distinguished on the combination on rather narrow and strongly verrucose spores. The ornaments are often slightly confluent, resembling those of *Russula* spores (hence the name). The strongly ornamented spores recall that of taxa in the *Puellaris* group (*C. puellaris* Brandrud, Bendiksen & Dima, *C. intemptivus* Moënné-Locc. & Reumaux

and others, see Brandrud et al. 2015, 2016b). However, the spores of the *Puellaris* species are normally more broadly ellipsoid, and the ornaments are more spiny (especially in the distal end). The often deeply translucently striate pileus may be another good character.

*Cortinarius russulaespermus* is so far known from five Norwegian localities with *Corylus*, *Quercus* or *Tilia*; spanning from semi-open *Quercus-Corylus* woodland meadow (Røer, Nesodden), rich, low herb *Quercus* forest (Agdestein, Stord), *Tilia-Quercus* forest of scree type (Snipekollen, Kjose, Larvik), and rich *Corylus(-Tilia)* dominated woodland (Vesterøy, Hvaler). The species may be considerably overlooked, but is so far found only within red listed forest types, and so far, the fungus itself is red listed as DD – data deficient on the red list from 2021 (Artsdatabanken 2021). *Cortinarius russulaespermus* was reported as new to Norway in connection with the Nordic Mycological Congress at Stord (Brandrud et al. 2021). Similar *Quercus* habitats are indicated from Great Britain



Figure 7. *Cortinarius russulaespermus*. *Quercus-Tilia* forest, Kjose, Larvik (TEB 386-08). Photo: TE. Brandrud.



(Kibby & Tortelli 2021). In Denmark the species is not infrequent in *Fagus* forests (<https://svampe.databasen.org/taxon/70441>). Based on eDNA this is in fact one of the most common *Cortinarius* species in Denmark (Jacob Heilman-Clausen, pers. comm.).

***Cortinarius subexitosus*** Liimat., Niskanen, Kytöv. & Ammirati (Fig. 8)

This is a medium-sized to small *Safranopedes* species, which in general lack typical *Safranopedes* features (no cartilagineous, radicating and saffron-discolouring stipe). It may resemble a large *C. obtusus* (Fr.) Fr., with fulvous to ochraceous brown, translucently striate pileus. However, the stipe is not undulating, it is initially whitish, and only discolours slightly. The spores are broadly ellipsoid-ovoid,  $7.5\text{--}9.5 \times 5.5\text{--}6 \mu\text{m}$ , with strongly ornamentation (almost echinate) in the distal (apex) part.

The species is so far known only from one locality in Norway; Stokkevannet East, Bam-

ble, where it has been collected and verified with DNA sequencing twice. Here it grows in a warm, steep, south-faced *Tilia-Quercus*-forest, a transition between calcareous *Tilia*-forests and more moderately calcareous *Tilia*-forest on scree soil. The species was published new to Norway in Brandrud et al. (2022) in a report on the monitoring program on calcareous *Tilia*-forests in Norway.

The species was described in Niskanen (2014), from Western North America (Washington) and from North Finland (Tornio), in mixed forests with conifers, *Populus*, *Betula* and *Salix*. Recently, the species is documented also from Québec (Landry et al. 2021). With finds in Norway, Finland and North America, this might well be a widely distributed, but very rare circumboreal species. With our finds in pure deciduous forest in Norway, this seems most likely to be a deciduous tree associate, possibly preferentially with *Tilia cordata* and *Populus* spp. (*Populus* spp. was the only kind of tree in common in the USA-Finland sites).



Figure 8. *Cortinarius subexitosus*. *Quercus-Tilia* forest, Stokkevannet east, Bamble (TEB 282-15). Photo: B. Dima.



Figure 9. *Cortinarius subscotooides*. *Corylus* thickets, Egge, Gran (above: TEB 312-11, below: TEB 48-12). Photos TE. Brandrud.

Since never found in our strict, well-developed, calcareous *Tilia* forests (which are extensively investigated), the species should in Norway probably be searched for mainly in rich (but

not calcareous) *Tilia-Corylus-Quercus* forests (like the ones where *C. russulaespermus* has been found), or in rich forests with *Populus*.

***Cortinarius subscotoides*** Niskanen & Liimat. (Fig. 9a-b)

This is a fairly characteristic species, showing some features of the core *Safranopedes* group, resembling species such as *C. milvinicolor*, with its olivaceous grey colours. However, *C. subscotoides* is a smaller taxon and lacks the saffron yellow discoloration of the stipe seen in the core group.

*Cortinarius subscotoides* is a small, but yet often rather robust (thick-fleshed) species. When young it has a characteristic grey brown colour with an olivaceous brown tinge, according to own material seen and the type depicted in Hyde et al. (2019). The pileus is dark grey brown, the lamellae is initially pale grey brown, and the stipe whitish grey, soon turning grey brown, due to the grey brown colour of context cortex. The stipe may turn somewhat clay brown from the base. The stipe base is sometimes pointed-radicata. The spores are typical of the *Safranopedes* section, being small, broadly ellipsoid and strongly verrucose ( $7\text{--}8 \times 4.8\text{--}5.3 \mu\text{m}$ ). With these features, the species represents a kind of morphological intermediate and “link” between the core group, and the small, anonymous *Safranopedes* such as *C. comptulus* (see below) which do not seem to have much in common with the core group. Morphologically, *C. subscotoides* also apparently resemble *C. aff. pauperculus*, based on available data so far (see below).

*Cortinarius subscotoides* was described quite recently (in Hyde et al. 2019), and this is the first report from Norway. The species is sequence-verified from two sites at Hadeland near Randsfjorden; Råstadbakka (Lunner), and Egge, Brandbu (Gran; Figure 9), both in calcareous *Corylus avellana* woodlands with some *Betula*, possibly also *Populus*. Furthermore, there is one verified find in calcareous *Tilia(-Corylus)*-forest at Tåje, Røyken, Asker. Formerly, it was known only from the type locality in calcareous *Corylus(-Betula-*

*Populus)* woodland of South Finland (Hyde et al. 2019), and recently also verified from one locality under *Quercus rubra* in Québec (Landry et al. 2021). A such wide North American–European distribution is very rarely seen among presumptive southern *Quercus-Corylus-Tilia* associates, and may indicate an unusual long-distance dispersal ability, or more likely that the species have a wider host range, e.g. associated also with boreal *Betula-Populus-Salix* in a circumboreal distribution range.

A close species, *C. minusculus* Liimat. & Niskanen, with more anonymous brown colours and “trivial” ellipsoid spores, was recently described from South Finland in *Corylus-Populus-Betula* woodland (in Hyde et al. 2019). This is now sequence-verified also from boreal Finland (*Salix-Betula* sites) and from subarctic Iceland (with *Salix-Betula*) (Kokkonen 2020), from Estonia (see Liimatainen et al. 2020) and Canada (Landry et al. 2021; from *Betula* spp). This is so far not documented from Norway, but surely occurs also in our regions.

#### **Other lowland *Safranopedes* species (small, non-*Tilia* species):**

According to data available so far, the core *Safranopedes* species (such as *C. epipurrus*, *C. parhonestus*, *C. safranopes* are in their phylogeny entangled with a number of small, partly anonymous taxa, which morphologically seem rather distant (Figure 1). However, most of them share the feature of having small, broadly ellipsoid spores. Three of these seem to be preferentially associated with conifers, which is otherwise a remarkably rare habitat among the *Safranopedes* taxa.

***Cortinarius comptulus*** M.M. Moser (Fig. 10) *Cortinarius comptulus* is a small, rather anonymous red brown to ochre-fulvous species. When young, it seems sometimes to be red brown with faint bluish tinges, or more ochraceous brown without any bluish. It has a

conical-campanulate pileus, initially fine fibrillose to fine scaly, but soon smooth and glossy. The stipe is sometimes pointed-radiculate, and faintly girdled-scaly from white veil. This can, however, rather easily be distinguished from almost all other, small, brown telamonias on the very small, almost subglobose spores, measuring  $6.5\text{--}7.5(-8) \times (5.5\text{--})6\text{--}7 \mu\text{m}$ . The species resembles taxa in the *C. flexipes* group, but differs e.g. on the lack of a pelargonium smell. An initially rather vivid ochraceous yellow colour in context and on surface on bruising may also be distinguishing from the *C. flexipes* group and may indicate the affinity to the “chore” *Safranopedes*.

*Cortinarius comptulus* seems to be associated preferentially with conifers (*Pinus*, *Picea*, *Abies*). In Fennoscandia, the species is found mainly in moderately rich to calcareous, herb-rich to grassy *Picea* and *Pinus*-forests (Brandrud et al. 1990–2012). In Altay (Siberia), *C. comptulus* has been found in a sandy near-shore margin of a large delta, growing under *Pinus* (Brandrud et al. 2019), and sandy habitat with pines has been observed also in Norway (Figure 10). In montane SW Germany and E France, *Abies-Picea*-forests are given as major habitat (Krieglsteiner & Gminder 2010, Bidaud et al. 2010). From Great Britain coniferous forests, especially *Picea* is mentioned (Kibby & Tortelli 2021). In Denmark the species is recorded also mainly from coniferous forests; under *Abies*, *Picea* or *Betula* (<https://svampe.databasen.org/taxon/12368>). The species is, on the other hand, recorded from deciduous forests in The Netherlands (Nico Dam, Thomas Kuypers, pers. comm; data in prep. for Flora Agaricina Neerlandica).

The species is sequence-verified from 6 collections in Norway, and seems widespread and rather frequent. It is furthermore widely distributed in Europe, from temperate-nemoral mixed forests to montane-subalpine conifer forests in Western and Central Europe, and

boreal conifer forests from Scandinavia to Siberia. The species is furthermore sequence-verified also from Canada (Liimatainen et al. 2020, Landry et al. 2021).

***Cortinarius annae-maritae*** Bendiksen & Brandrud (Fig. 11)

*C. annae-maritae* is another small, rather anonymous, red brown to ochre-fulvous, hygrophanous species. It may be faintly violaceous brown tinged as very young. Morphologically it is difficult to distinguish from resembling species, and genetic evidence was needed to describe this as a new species (Brandrud et al. 2015). Barcoding has also revealed that it seems to have a wide ecology and distribution area.

In the protologue (Brandrud et al. 2015), it was emphasized that species superficially resembled the group of *C. decipiens* (Pers.) Zawadzki in a wide sense; having a slender basidiocarp, dark pileus, and silvery pale stem with a violet tinge in the upper part. The rather richly developed veil, with white remnants in a broad margin zone of the cap and white belts on the stem may perhaps remind also of *C. casimiri* (Velen.) Huijsman s. lat. Both the latter with its much larger spores and *C. decipiens* s. lat. with longer spores, contrast, however, *C. annae-maritae* with its small, broadly ellipsoid to almost roundish spores ( $7\text{--}7.5 \times 5\text{--}5.5 \mu\text{m}$ ). The somewhat similar *C. vernus* H. Lindstr. & Melot also has small and roundish spores, but they are much more strongly ornamented. The mentioned resembling species seem to grow under different deciduous trees (*C. casimiri* s. lat. also by conifers), *C. decipiens* possibly on moister soil.

*Cortinarius annae-maritae* is well-supported genetically, and in our phylogenetic tree, it comes out as sister to *C. comptulus*. Since the protologue in 2015, the species has been sequence-verified also from Flanders, Belgium and from Quebec, Canada (see below). None of these collections seems to show any



Figure 10 *Cortinarius comptulus*. Above: Sandy *Pinus* forest, Altai, Russia (TEB 224-18). Below: margin of sandy *Pinus* forest, Jomfruland, Kragerø (TEB 470-22) Photos: TE. Brandrud). Pileus colour and stipe discolouration vary from grey ochre to vivid ochre yellow brown.

bluish tinges, and from the Belgium collections it is noted that the species morphologically resembles very much its sister species *C. comptulus*, e.g. with the same small, broadly ellipsoid spores (measuring  $6.5\text{--}7.5 \times 4.5\text{--}5.5 \mu\text{m}$ ), and a similar pileipellis structure (André de Haan, pers. comm.). At least in the Nordic countries it seems, however, that these sisters can be distinguished on habitat preferences; *C. comptulus* being associated mainly with calcareous pine-spruce and sandy pine forests, whereas *C. annae-maritae* seems mainly associated with *Fagus* or *Betula* (see below).

The protologue was based on the first find from Norway – it was from sandy pine forest with *Pinus sylvestris* and *Betula pubescens* (probably associated with the latter) in the northernmost part of the country; Storeldalen in Alta, Finnmark. It was demonstrated from DNA that the species also had been

found in Denmark, from a mycorrhiza project with *Fagus* as documented mycorrhizal partner (also basidiocarps available). It has later been reported both from Zealand and Jutland, altogether three localities in Denmark, all with *Fagus*

(<https://svampe.databasen.org/taxon/67029>). Recently it has also been found in south-easternmost Norway; Østfold, Hvaler (Øyvind Weholt, pers. comm., confirmed through barcoding, mycorrhizal partner unknown).

From later years the species has also been found and sequence-verified from Québec, Canada – indicating that it is a circumpolar species in the Northern Hemisphere. The Canadian find was from a *Abies balsamea*-*Betula papyrifera* forest (Yves Lamoureux, pers. comm.). It has also recently been sequence-documented from two localities in Flanders, Belgium (André de Haan, Thomas Kuyper, pers. comm.) where it has been



Figure 11. *Cortinarius annae-maritae*. Chertsey, Québec, Canada. Photo: Yves Lamoureux YL 3521.

reported to be “associated with *Pinus*, *Fagus* and *Betula*, possibly with *Salix*” on sandy to sandy clay soils.

Probably *Cortinarius annae-maritae* has been overlooked, and we will learn more about its distribution and ecology in the future. It is, however, too early to conclude whether it is a common species or not.

***Cortinarius nigrocupidatus* Kauffman**

This species, which frequently also have been named *C. flexipes* (Pers.) Fr. var. *inolens* H. Lindstr. is often confused with *C. comptulus*. Their colours, stature and habitats are rather similar, and they both possess broadly ellipsoid-subglobose spores. The spores of *C. nigrocupidatus* are, however, distinctly larger than those of *C. comptulus*. The species is less known than *C. comptulus*, but this seems also to be a preferentially conifer forest species (mainly with *Picea*, including plantations), with a wide, probably circum-boreal distribution, being documented e.g. from Canada (Landry et al. 2021; four collections). *Cortinarius nigrocupidatus* is so far sequence-verified from three sites in Norway; Skardsmoen, Øyer in Gudbrandsdalen, Fosseide in Rindal (Western Norway), and from Grane in Nordland. The species is probably widespread also in Denmark, but so far only one record confirmed by sequencing; from moist *Betula/Alnus* forest (<https://svampe.databasen.org/observations/10209735>).

***Cortinarius subobtusus* Kauffman & A.H. Smith (Fig. 12)**

This is another rather anonymous, small, red brown species, with little knowledge on typical morphological features, range of variation and habitat. The pileus is red brown-fulvous brown, and the stipe turns brownish-clay brown from base. The species has apparently never been depicted in modern literature or on websites. As the name indicates, the species

shows resemblance with the *Obtusi* group (but is not related). All three Norwegian collections were identified to *C. andreae* H. Lindstr. before sequencing, so this must show morphological affinity also to *C. andreae*, characterized e.g. by a vividly fulvous-red brown pileus and a stipe discolouring fulvous brown. The latter, however, is distinguished on more strictly ellipsoid (not broadly ellipsoid) spores, and is phylogenetically distant.

*Cortinarius subobtusus* is in Norway known from Valdres (Mosåni, Vestre Slidre), Notodden (Rossåsen south) and Ringerike (Horn, Lier). The two first were from rich, planted *Picea*-forests of low-herb type, whereas the latter was from a rich low-herb *Picea*-forest with *Corylus*. Probably the species is mainly associated with spruce in Norway.

***Cortinarius* aff. *pauperculus* J. Favre (Fig. 13)**

This is a species belonging to the *C. pauperculus*-*C. scotoides* group treated below but differs from the other members of this group by different habitat preferences. Whereas *C. pauperculus*-*C. scotoides* are apparently mainly arctic-alpine-boreal species, the present one we have sequence-verified only from two rather southern, lowland sites; a sandy pine-forest with *Salix caprea* at Randsfjorden, Jevnaker (Mosmoen, TEB 692-13) and a calcareous *Tilia*-forest in coastal Porsgrunn, Telemark (Åsstranda NR; TEB 332-15). Since the species belongs to a subclade of mainly *Salix* associates, an association with *Salix caprea* should not be ruled out also in the latter case, since *S. caprea* occurs in this otherwise *Tilia-Corylus*(-*Fraxinus*) dominated forest. Also *Betula* spp. could be possible associates. The species morphologically resembles *C. subscotoides*, with rather “cold” olivaceous grey brown colours. and seems to lack saffron discolouring. The species has no match with reference sequences, and we will preliminary apply “*C. pauperculus*2” as a working name for this.



Figure 12. *Cortinarius subobtusus*. *Picea* forest with *Corylus*, Horn, Modum (Ringerike) (TEB 359-08). Photo: TE. Brandrud.

***Tiny, mainly Salix-associated Safranopedes species (incl. arctic-alpine populations)***

A small subclade of *Safranopedes* includes some in Norway mainly arctic-alpine-boreal species, associated preferentially with *Salix*-thickets and dwarf shrubs. This group is incompletely known, and is given a preliminary treatment here. The following taxa are sequence verified from Norway including Svalbard; *C. paululus*, *C. pauperculus* and *C. scotoides*. This subclade is treated in detail in Kokkonen (2020), referred to as the *C. pauperculus* complex. This complex seems extremely diverse, probably a group undergoing very active speciation. When all recently available e-DNA sequences from public databases are considered, no less than seven more OTUs seem to be present in this group (not shown in Figure 1). This high, complex and not fully understood diversity apparently resemble that of the *Salix* associates in the group of *C. parvannulatus* Kühner and *C. pseudofallax* Carteret.

Kokkonen (2020) treated a whole element of Fennoscandian telamonioid *Salix* associates, and it interesting to note that most of these seem to have a wide distribution and climatic range; occurring both in lowland *Salix* habitats along rivers and lakes, and in alpine-arctic environments. *Cortinarius paululus*, *C. pauperculus* and *C. scotoides* apparently show this wide distribution also in Scandinavia, and such a wide climatic range for *Salix* associates among telamonioid *Cortinarius* has been indicated before, based mainly on Norwegian data (Bendiksen et al. 1993).

Generally, the *C. pauperculus-scotoides-paululus* complex seems to possess slightly larger and more ellipsoid (not broadly ellipsoid) spores than elsewhere typical in sect. *Safranopedes*, typically  $8-9 \times 4.5-5.5 \mu\text{m}$ , and up to  $10 \times 6 \mu\text{m}$ . All species are tiny, with red brown-fulvous pileus and a stipe that often turns somewhat clay brown in the base. Sometimes one can, however, see more vivid ochre (-saffron) brown spots/tinges in





Figure 13. *Cortinarius* aff. *pauperculus*. Sandy *Pinus* forest with *Salix caprea*, Mosmoen, Jevnaker (Hadeland) (TEB 692-13). Photo: TE. Brandrud.

the middle or lower part of the stipe (Figure 14). The pileipellis hyphae have strongly encrusted pigments (Kokkonen 2020).

#### *C. paululus* Kokkonen (Fig. 14)

*Cortinarius paululus* is a very small species, in the Norwegian material characterized e.g. on the thicker veil remnants, rendering the pileus fibrillose-fine scaly and the stipe girdled-scaly from white veil (Figure 14). The pileus is initially dark red brown-umber brown-fulvous, and the stipe and context discolour dark clay brown from the base, sometimes with vivid ochre-saffron brown tinges. The spores are also slightly larger and more ellipsoid ( $7.5\text{--}9.5(-10) \times 4.5\text{--}5.5 \mu\text{m}$ ) than typical in *Safranopedes*. According to Kokkonen (2020), this is very close morphologically and phylogenetically to *C. pauperculus* (distinguished by 4 ITS differences). So far, we have only very little data on *C. pauperculus* s. str. and we therefore know little on

the morphological differentiation between these two (See under *C. pauperculus* below).

According to Kokkonen (2020) the preferential habitats of *C. paululus* are *Salix* thickets along shores of lakes and rivers, and in dwarf *Salix* thickets in alpine zone. This corresponds well with the Norwegian finds. Our description and photos are from flooded, sandy *Salix(-Alnus)*-thickets along the river Gudbrandsdalslågen and along river Randselva (downstream lake Randsfjorden) (material ITS-sequence verified). In Denmark, two records from wet *Salix cinerea* shrubs are sequence-verified

<https://svampe.databasen.org/taxon/70157>

It appears also that this in ITS DNA comes very close to *Cortinarius* sp. 1 (OTU3) in Thoen et al. (2019), in a study of mycorrhizal roots of *Bistorta vivipara* at Finse, Ulvik, Hardangervidda. *Cortinarius* sp. 1 was one of the most frequent associates with *Bistorta* in sites adjacent to the glacier at Finse. On



Figure 14. *Cortinarius paululus*. *Salix-Alnus* thickets on flooded river bank; Above: Hvalsmoen, Randselva, Ringerike (TEB 20-22; photo: TE. Brandrud). Below: Einangsøyene, Gudbrandsdalslågen ved Otta, Sel (TEB 142-15). Photo E. Bendiksen). Mark the saffron tinges on stipes on the above collection, and not on the below one.

closer analysis of the sequences of cluster OTU3 from the raw data of Thoen et al. (2019), it appears that these form an unknown and undescribed sister taxon to *C. paululus*. The Finse sequences of *Cortinarius* sp. 1 show that this species complex is not only associated with *Salix* spp. In the alpine zone, it occurs both with *Salix* spp., *Bistorta* and probably also with *Dryas*, another frequent associate of alpine cortinariii. Based on our own finds and the results of Thoen et al. (2019) and Kokkonen (2020), it seems probable that the *C. paululus* complex including *Cortinarius* sp. 1 sensu Thoen is one of the more frequent *Salix-Bistorta* associates in alpine zone as well along riverbanks. Furthermore, this seems to be favoured by disturbances and pioneer vegetation conditions, e.g. in flooded zones or where glaciers retreat. However, there is so far no matches on this *C. paululus* complex from Svalbard (Klaus Høiland pers. comm.) and Kokkonen (2020) had no arctic finds. We have just scratched the surface on the taxonomy of the *C. paululus-C. pauperculus* complex, and both the species delimitations and habitat preferences need further studies.

### **C. pauperculus** J. Favre

*Cortinarius pauperculus* s. str. (as typified by Kokkonen 2020) is so far only verified once from Norway, a collection from moist *Salix* thickets, in an open, grazed, northern boreal/subalpine summer-farm area at Vaset-Brennabu, Vestre Slidre, Valdres. Kokkonen (2020) was only able to verify this species in Finland from one locality in *Salix* thickets along river bank in a northern boreal canyon. The Finnish habitat seems to correspond well with the Norwegian, and it seems to be a rare species in the Nordic countries. As indicated under *C. paululus*, *C. pauperculus* s. str. and *C. paululus* are very closely related in ITS sequences, and apparently hardly possible to distinguish morphologically (Kokkonen 2020).

With present knowledge, these should be regarded as (semi-)cryptic species, as indicated by Kokkonen (2020).

There are 31 collections of *C. pauperculus* s. lat. in the Norwegian national species database Species map (“Artskart”) per December 2022. Some collections from Svalbard have recently been sequenced. These collections turned out to be *C. desertorum* (Velen.) G. Garnier (*C. diasemospermus* Lamoure s. lat.), *C. gossypinus* H. Lindstr., *C. parvannulatus*, *C. pseudofallax* and *C. scotoides* (Høiland et al. in prep.). Likewise, collections of *C. pauperculus* s. lat. from mainland Norway are probably also heterogeneous, and include many misidentifications, since this name has been used in a very wide and not consistent concept throughout the years, and since the species belongs to a (semi-)cryptic complex. A full revision with a sequence-screening of this material is needed.

### **C. scotoides** J. Favre

*C. scotoides* is so far verified from five certain and one uncertain locality on Svalbard. The Svalbard finds will be presented in more detail in Høiland et al. (in prep). It was originally described from the Swiss Alps (Favre 1955), but the species seems to have a wide circum-boreal distribution, including temperate sites. According to phylogenetic tree in Hyde et al. 2019, the species is sequence-verified from Estonia (associated with *Salix caprea* and *Fagus sylvatica*, respectively) and from Canada (associated with *Salix arctica*). Kokkonen (2020) did not find this species in boreal regions of Finland, but could show that original material of *C. pauperculoides*, Moëgne-Loec. ad int. described from old quarry with *Populus nigra* in France was conspecific with identical ITS-DNA. Our concept of *C. scotoides* follows that of Niskanen & Liimatainen in Hyde et al. (2019) and Kokkonen (2020), but no original material of

*C. scotoides* from Favre has so far been sequenced.

Although data from young and well-developed material is scarce, *Cortinarius scotoides* seems to be macromorphologically very close to *C. pauperculus*-*C. paululus*, being a tiny species with red brown (-ochre brown) pileus and a stipe turning vividly ochre brown to clay brown from base. Two sequence-verified Danish collections indicate the species to be more robust and with a less campanulate pileus than *C. paululus*:

<https://svampe.databasen.org/taxon/12602>.

The Svalbard material possess rather abundant veil remnants, often leaving a ring-zone on stipe (Høiland et al. in prep). According to Kokkonen (2020), the spores of original material from the Swiss Alps are indistinguishable from those of *C. pauperculus* and *C. paululus*, but the Svalbard material seems to have slightly wider, more broadly ellipsoid spores (Høiland et al. in prep.). However, with present knowledge, it is not clear how to distinguish this from *C. pauperculus* and *C. paululus*, and barcoding is needed to perform a precise identification among these tiny, mainly *Salix*-associated taxa. According to the national database Species map (“Artskart”) December 2022, there are 10 alpine non-sequenced collections of *C. scotoides* from Norway. These should all be revised with molecular genetic methods.

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