

Recent records of telamonioid species of *Cortinarius* (Agaricales: Cortinariaceae) in New Brunswick, Canada

DAVID MALLOCH^{1,*}, ALFREDO JUSTO¹, and JOSEPH F. AMMIRATI²

¹Department of Natural History, New Brunswick Museum, 277 Douglas Avenue, Saint John, New Brunswick E2K 1E5 Canada

²Department of Biology and Burke Museum, University of Washington, P.O. Box 351800, Seattle, Washington 98195-1800 USA

*Corresponding author: dmalloch@xplornet.com

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Abstract

Eight species of *Cortinarius* (webcaps) subgenus *Telamonia* and two other telamonioid *Cortinarius* species are reported from New Brunswick, Canada. Internal transcribed spacer sequences of these were used to build a phylogenetic tree confirming species identifications and relationships to relevant material, especially types and other Canadian collections. Descriptions and photographs of fresh material and microscopic features are provided. Habitat details, particularly potential mycorrhizal partners and dominant bryophytes, were recorded for each collection and compared with published records. Seven species, *Cortinarius caninoides*, *Cortinarius cicindela*, *Cortinarius fulvescens*, *Cortinarius harvardensis*, *Cortinarius plumulosus*, *Cortinarius pseudobiformis*, and *Cortinarius valgus* are new distribution records for New Brunswick, and *C. plumulosus* is apparently a first record for North America. Because these species have rarely been reported, they have yet to be given common names.

Key words: Fungi; Agaricales; mushroom; *Cortinarius*; *Telamonia*; New Brunswick; Bay of Fundy; Canada; new distribution record

Introduction

The mushroom-forming genus *Cortinarius* (Basidiomycota: Agaricomycetes: Agaricales: Cortinariaceae) is considered to be one of the largest of all fungal genera, as it is estimated to include several thousand species (Bhunjun *et al.* 2022). In the past, many authors have expressed doubts about the taxonomic uniformity of *Cortinarius* and have treated parts of this group as separate genera. Some of these segregates, such as *Dermocybe* and *Phlegmacium*, attained a limited level of acceptance by mycologists, but never came into wide usage.

Recent studies using genomic analyses have led to a reconsideration of how we view *Cortinarius*. The family Cortinariaceae, long thought to contain several genera, was shown by Matheny *et al.* (2015) to contain only *Cortinarius*, with other genera, such as *Crepidotus*, *Gymnopilus*, *Inocybe*, distributed in several other families. However, using multi-locus genomic data, Liimatainen *et al.* (2022) presented a phylogenetic analysis dividing *Cortinarius* into 10 genera: *Cortinarius*, *Phlegmacium*, *Thaxterogaster*, *Calonarius*, *Aureonarius*, *Cystinarius*, *Volvanarius*,

Hygronarius, *Mystinarius*, and *Austrocortinarius*, all included in the Cortinariaceae. Species of seven of these genera (*Cortinarius*, *Phlegmacium*, *Thaxterogaster*, *Calonarius*, *Aureonarius*, *Cystinarius*, and *Hygronarius*) have been shown to occur in Quebec (Landry *et al.* 2021) and probably occur throughout North America.

In spite of its relatively small size, the province of New Brunswick is ecologically diverse and contains a variety of habitats favourable to Cortinariaceae. It is within the Atlantic Maritime Ecozone and contains seven ecoregions (McAlpine and Smith 2010). Of the seven genera of Cortinariaceae reported from Quebec, only members of *Calonarius* and *Hygronarius* have yet to be reported in New Brunswick.

As part of an ongoing effort to catalogue the fungi of New Brunswick, species of Cortinariaceae are currently being collected and studied. One of the taxonomically most difficult groups within the genus *Cortinarius* is the subgenus *Telamonia* and the superficially similar taxa referred to as “telamonioid”. Traditionally these have been characterized as having basidiomata with dry pilei and stipes and generally

lacking brightly coloured lamellae. Here we report on eight species of *Cortinarius* subgenus *Telamonia* and two additional telamonioid species. We have included descriptions, illustrations, and habitat information for these species, based on genetically verified voucher specimens.

Methods

All collections were made in New Brunswick. They were photographed in the field and later scanned on a flatbed scanner. Notes were taken on the fresh material and spore prints were made by placing pieces of basidiomata over glass microscope slides. Colours were recorded from a cellphone using a handbook with the HSV/HSB (Hue, Saturation, Value or Hue, Saturation, Brightness) colour system, an alternative representation of the RGB (Red, Green, Blue) model commonly used in computer graphics (Malloch 2021). The basidiomata were then dried in a food drier for 24 h at 60°C. All collections were deposited in the herbarium of the New Brunswick Museum (NBM).

Microscopic studies

Microscopic features of sections of the pileipellis and lamellae were examined in Windex window cleaner (S.C. Johnson & Son, Racine, Wisconsin, USA) and in 3% KOH. Basidia and other hymenial structures were examined in 3% KOH after presoaking and clearing in aqueous Congo Red.

Basidiospores from spore prints were suspended in a drop of Melzer's solution on a microscope slide and examined with a 100× objective using bright field illumination. When spore prints were not available (e.g., *Cortinarius evernius* (Fr.) Fr., Silky Webcap), basidiospores deposited on the universal veil were examined.

The slides were scanned along parallel transect lines and basidiospores lying in profile were photographed. The photographs were viewed using an open-source image editor (Gnu Image Manipulation Program, v. 2.10, <https://www.gimp.org>). Basidiospores lying in profile were rotated so that the apiculus was at the left and oriented to approximately 225°. Rotated basidiospores were then cut from the photograph and placed side by side on a new and separate image. The aligned basidiospores were measured using ImageJ (National Institutes of Health, Bethesda, Maryland, USA) and the results transformed using a spreadsheet. Measurements are expressed as the full size range and aspect ratio (Q) of the sample followed by the mean and SD of length, width, and Q. Sample size is shown in square brackets.

Molecular studies

DNA was extracted from dried herbarium specimens following standard procedures for mushroom-

forming fungi. The fungal barcode, nrITS region (nrITS1-5.8S-nrITS2), was targeted for amplification, using the primer pair ITS1F-ITS4 (White *et al.* 1990; Gardes and Bruns 1993). DNA extraction, polymerase chain reaction (PCR), and sequencing were carried out at ALVALAB (Oviedo, Spain).

Raw chromatogram data were edited and assembled using ChromasPro (Technelysium DNA Sequencing Software, South Brisbane, Australia). A total of 11 new sequences were generated in our study. We assembled a molecular dataset that includes all type specimens of the species studied here and representatives of those species from Eurasia and North America (if available). The final dataset consisted of 38 nrITS sequences, including two species of *Cortinarius* subgenus *Dermocybe* (*Cortinarius neosanguineus* Ammirati, Liimat. & Niskanen and *Cortinarius sierraensis* (Ammirati) Ammirati, Niskanen & Liimat.) that were used as outgroup taxa.

Sequences were aligned using MAFFT version 7 (Katoh *et al.* 2019) with the strategy FFT-NS-i. The alignment was inspected and manually corrected in AliView (Larsson 2014). We ran a maximum likelihood analysis using RAxML 8.2.10 under a GTRGAMMAI model as recommended (Stamatakis 2014), with 100 rapid bootstrap replicates. The analysis was run using resources at the CIPRES Science Gateway (Miller *et al.* 2010). A phylogenetic tree was visualized in FigTree v. 1.4.4 (University of Edinburgh, Edinburgh, United Kingdom), then exported as an SVG file and edited in Adobe Illustrator (Adobe, San Jose, California, USA) for final presentation.

Results

The best tree from the maximum likelihood analysis of the sequences we studied is presented in Figure 1. The internal transcribed spacer (ITS) sequences of the New Brunswick collections grouped in all cases with their respective type collections and/or reference sequences from North America and Eurasia. The species-level clades recovered in the analyses get full bootstrap support (100%), with the exception of *Cortinarius tortuosus* (Fr.) Fr. (99%) and *Cortinarius gentilis* (Fr.) Fr. (Conifer Webcap; 98%). This is consistent with previous phylogenies of these two species (Landry *et al.* 2021; Liimatainen *et al.* 2022).

Annotated Checklist

Cortinarius subgenus *Telamonia*, section *Bicolores*

Cortinarius plumulosus Rob. Henry (Figures 2a, 3a)

Pileus conic-turbinate at first, not seen when fully expanded, with a large rounded umbo, glabrous, light orange brown (HSV30:20–30:90) but probably hygrophanous and faded, slightly paler at the margin, dry, 43 mm in diameter. *Stipe* equal, dry, pale violet

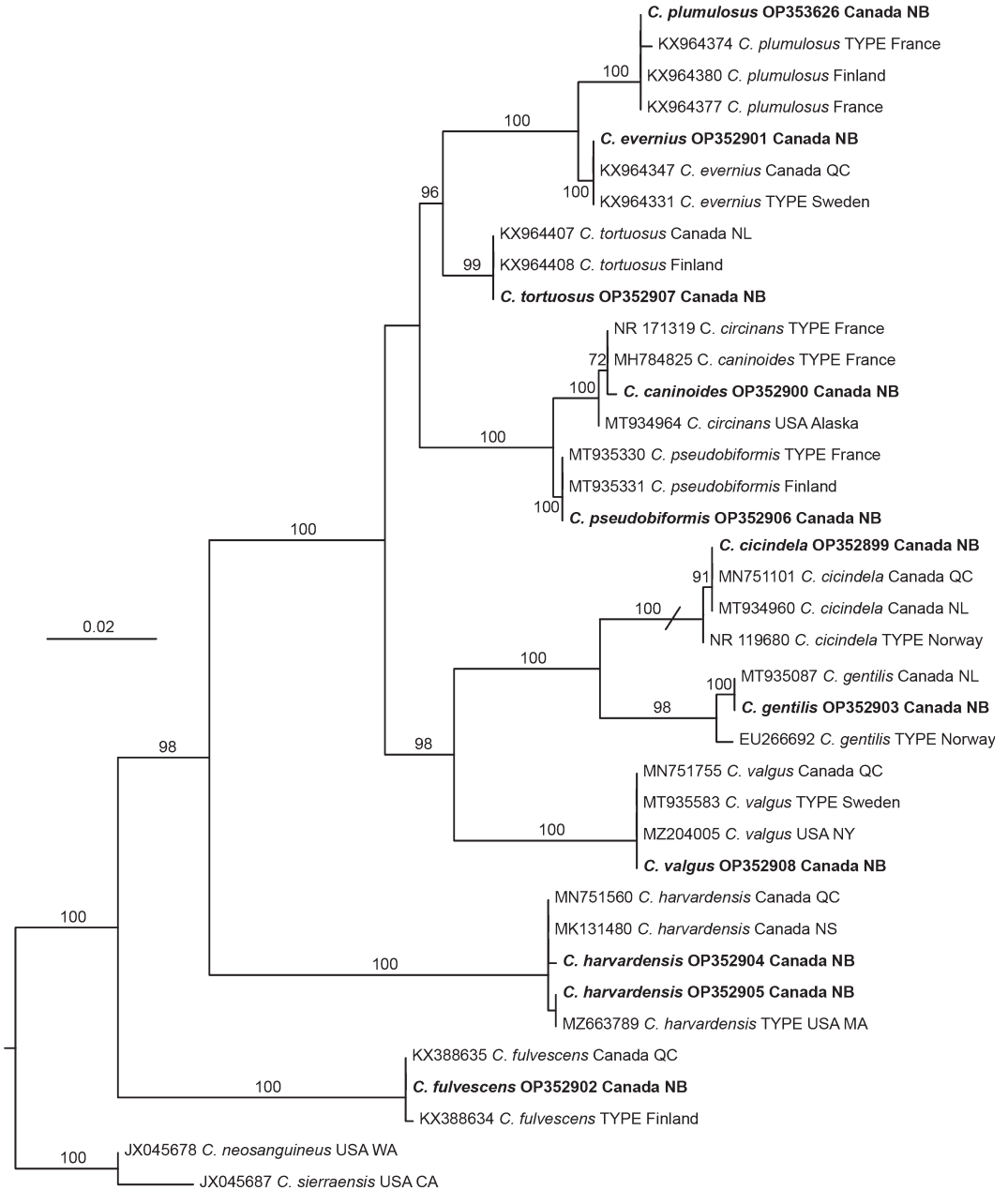


FIGURE 1. Best tree from maximum likelihood analysis of the nrITS sequences of *Cortinarius*. Bootstrap values $\geq 70\%$ are shown on or below the branches. The symbol / indicates that the branch length has been reduced to facilitate graphic representation. All sequences of New Brunswick specimens were newly generated for this study and are shown in bold. The scale bar represents number of nucleotide substitutions per site.

(HSV250:30–40:90), with universal veil present as a white annular band and irregular streaks below the annular zone, 75×13 mm. *Lamellae* dark brown (HSV20:70–80:30), subclose, adnexed, white at the

margin. *Cortina* not seen, probably white. *Flesh* faded in the pileus but possibly concolorous with the surface tissues, pale violet (HSV250:30–40:90) in the stipe, lacking a distinctive odour and taste.



FIGURE 2. Basidiomata. a. *Cortinarius plumulosus*. b. Silky Webcap (*Cortinarius evernius*). c. *Cortinarius cicindela*. d. Conifer Webcap (*Cortinarius gentilis*). e. *Cortinarius caninoides*. f. *Cortinarius pseudobiformis*. Scale bar = 10 mm. Photos: D. Malloch.

Basidiospores bright orange brown (HSV25:70:80–90) in spore print, elliptical to obovate in profile, infrequently ovate, coarsely roughened, weakly dextrinoid, $8.2\text{--}9.7 \times 4.8\text{--}5.8 \mu\text{m}$, $Q = 1.53\text{--}1.93$ (mean [60]: $9.1 \pm 0.4 \times 5.2 \pm 0.2 \mu\text{m}$, $Q = 1.75 \pm 0.09$). *Cheilocystidia* forming a partly sterile margin, barely distinguishable from immature basidia, narrowly clavate to almost cylindrical, with a basal clamp connection. *Basidia* clavate, four-spored, with a basal clamp connection. *Lamellar trama* parallel, brown, with clamp connections at the septa, only rarely encrusted. *Pileipellis* duplex, a cutis of hyaline hyphae over a hypoderm of brown hyphae that are rather short and almost

brick-like. *Clamp connections* present on most septa.

Specimens examined—CANADA, New Brunswick: Charlotte Co., Little Lepreau, 45.135°N , 66.492°W , 5 October 2020, D. Malloch 05-10-20/03 (NBM-F-009374), GenBank no. OP353626 (ITS); 24 September 2021, D. Malloch 24-09-21/01 (NBM-F-009378; not sequenced or included in the description above although similar macro- and micro-morphologically).

Closely related to *Cortinarius evernius* (Liimatainen *et al.* 2020) but with narrower basidiospores. Both of the New Brunswick collections had rather robust basidiomata with turbinate pilei and relatively thick stipes, in contrast to the more slender

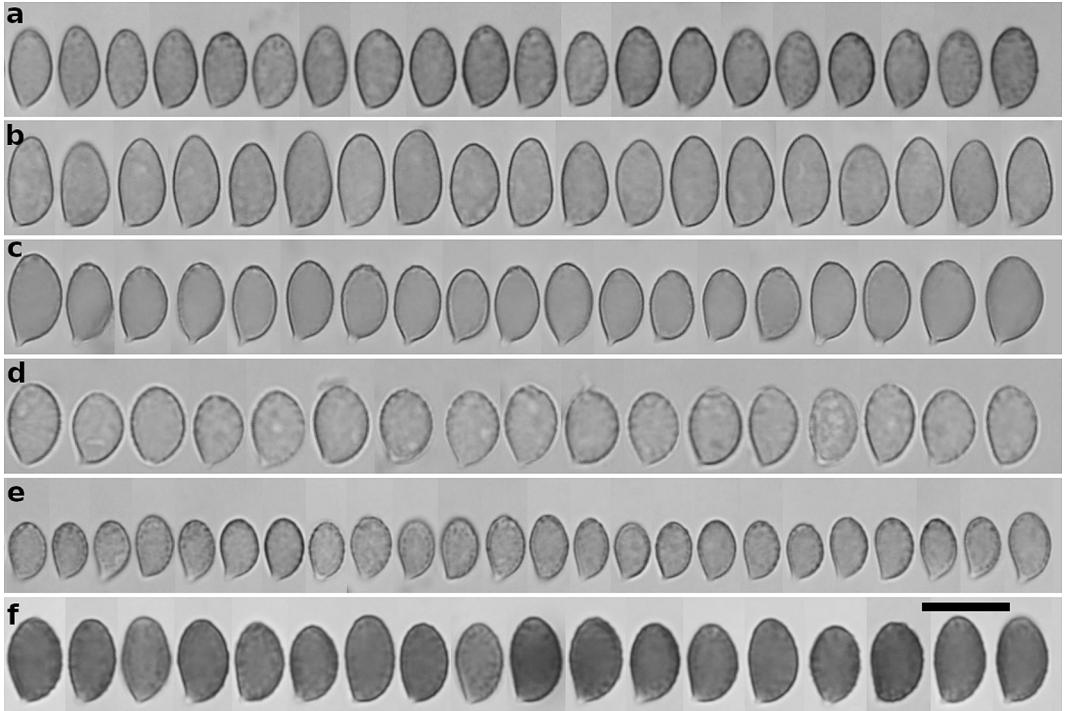


FIGURE 3. Basidiospores. a. *Cortinarius plumulosus*. b. Silky Webcap (*Cortinarius evernius*). c. *Cortinarius cicindela*. d. Conifer Webcap (*Cortinarius gentilis*). e. *Cortinarius caninoides*. f. *Cortinarius pseudobiformis*. Scale bar = 10 μ m. Photos: D. Malloch.

basidiomata of *C. evernius*. *Cortinarius cagei* Melot is similar but differs in its association with hardwood trees, such as species of beech (*Fagus* L.), linden (*Tilia* L.), and hazel (*Corylus* L.; Brandrud *et al.* 1998). In common with most other members of the section *Bicolores*, all of these species have hygrophanous pilei, brown lamellae, and firm tapered stipes with blue flesh. Landry *et al.* (2021) reported a collection as *C. cf. cagei* that is very similar to ours and might be conspecific. Aside from that possibility, *C. plumulosus* seems to be unreported in North America.

Collections of this species have not been reported frequently in the literature. The type specimen was collected in the Vosges Mountains of France in a forest of European Silver Fir (*Abies alba* Miller). Our collection was in a dense patch of moss (*Rhytidiadelphus* (Limpr.) Warnst. sp.) in an area of a lawn shaded by two large Balsam Fir (*Abies balsamea* (L.) Miller) trees.

***Cortinarius evernius* (Fr.) Fr.** (Silky Webcap; Figures 2b, 3b)

Pileus conic-turbinate at first, expanding to more broadly so at maturity, with a low but prominent broad umbo, dry, fibrillose at first with the universal veil, shiny, medium grey brown (HSV35:30:50–60), hygrophanous, 18–23 mm in diameter. *Stipe* equal to

very narrowly clavate, often tapered at the base, very finely streaked or banded with universal veil material, pale yellow (HSV55:05:100) in the upper $\frac{2}{3}$, white to very pale violet (HSV250:03:100) below, dry, 55–93 \times 5–8 mm. *Lamellae* chocolate brown (HSV35:80:40–50), white toward the edge but not really marginate, subclose, adnexed. *Veil* difficult to interpret. The universal veil on the pileus margin appears to be pale yellow and contrasts with the violet cortina. However, the bands on the stipe are yellow while the veil near the stipe base appears to be violet. *Flesh* in the pileus is a dilute brown below the pileipellis but is otherwise nearly white; in the stipe it is mostly white but has definite but very pale shades of violet near the middle, with a nondescript mushroom odour, slightly sweet but otherwise without a distinctive taste.

Basidiospores not forming a spore print, ovate to elliptical in profile, rarely obovate, with walls moderately roughened, 9.0–10.8 \times 5.0–5.8 μ m, Q = 1.63–1.95 (mean [38]: 9.9 \pm 0.5 \times 5.5 \pm 0.2 μ m, Q = 1.81 \pm 0.09). *Basidia* four-spored, clamped at the basal septum. *Cheilocystidia* forming a sterile margin, clavate, clamped at the basal septum. *Lamellar trama* parallel, light brown, obscurely encrusted with fine granules. *Pileipellis* duplex, with a compact hyaline cutis

23–39 µm thick composed of narrow hyphae 1.4–2.5 µm in diameter, with a well-developed orange-brown hypoderm of broad encrusted hyphae.

Specimen examined—CANADA, New Brunswick, Charlotte Co., New River Beach Provincial Park, 45.125°N, 66.525°W, 23 September 2018, *D. Malloch 23-09-18/03* (NBM-F-009368), GenBank no. OP352901 (ITS).

Cortinarius tortuosus (Fr.) Fr. is superficially similar in having a brown hygrophanous pileus and brown lamellae. Although the stipe apex may have some violaceous colours, the flesh of the stipe, as in *C. evernius*, is never strongly violaceous.

Cortinarius evernius is commonly reported to be associated with conifers. There are other collections of this species in the herbarium of the New Brunswick Museum, but these have not been confirmed genetically. Brandrud *et al.* (1990) stated that it is usually thought to associate with conifers in northern or mountain habitats, often with *Sphagnum* L., but that it has also been collected in subalpine birch forests. In Quebec, it has been found on wet soils in coniferous forests, often with *Sphagnum* (Landry et Labbé 2022). Our collection was gregarious to clustered in a carpet of Red-stemmed Feathermoss (*Pleurozium schreberi* (Brid.) Mitt.) and other mosses in a well-drained site, associated with Balsam Fir. No *Sphagnum* was present.

Cortinarius subgenus *Telamonia*, section *Brunnei*

Cortinarius cicindela Kytöv., Niskanen & Liimat.
(Figures 2c, 3c)

Pileus not seen when young, broadly conical and then irregularly buckled in age, with a prominent umbo, finely striate at the margin, dry, glabrous, dark brown (HSV10:80:30–40), dark brown to black in exsiccates, hygrophanous, 21–33 mm in diameter. *Stipe* equal, light silvery grey (HSV20:00–10:100), soon darkening to brown (HSV20:70:40–50), dry, glabrous, 60–80 × 3–5 mm. *Lamellae* very pale orange brown (HSV15:50:60), adnexed, subclose, not marginate. *Flesh* concolorous with the surface tissues, lacking a distinctive odour and taste.

Basidiospores reddish brown in spore print, mostly elliptical in profile, varying obscurely between ovate and obovate, coarsely roughened (especially at the apex), darkening slightly in Melzer's Solution, 7.4–10.8 × 4.2–6.4 µm, Q = 1.47–1.88 (mean [42]: 8.5 ± 0.7 × 5.3 ± 0.4 µm, Q = 1.61 ± 0.08). *Pileipellis* duplex, with a thin and compact cutis of pale narrow encrusted hyphae and a thick dark brown hypoderm of short broad strongly encrusted hyphae. *Lamellar trama* parallel, with hyphae clamped and strongly encrusted externally.

Specimen examined—CANADA, New Brunswick,

Northumberland Co., Kennedy Lakes Protected Natural Area, 46.792164°N, 66.478584°W, 4 July 2019, *D. Malloch 04-07-19/08* (NBM-F-009031), GenBank no. OP352899 (ITS).

A typical member of section *Brunnei*, characterized by dark brown hygrophanous pilei, dark brown lamellae, and basidiomata that become blackened when dried. All are associated with coniferous trees. Niskanen *et al.* (2009) studied section *Brunnei* extensively and provided a key to the species. Identification in the group is difficult, requiring precise determination of basidiospore size and shape. *Cortinarius cicindela*, one of the smaller members of the section, is very similar to *Cortinarius carabus* Kytöv., Niskanen & Liimat. and can be distinguished from it mainly by its slightly longer and less markedly obovate basidiospores and by its habitat, *C. carabus* growing mainly in sandy forests of pine (*Pinus* L.) and *C. cicindela* growing in more mesic forests of spruce (*Picea* A. Dietrich) and fir (*Abies* Miller). However, Niskanen *et al.* (2009) reported one sequence matching that of *C. carabus* from roots of Western Hemlock (*Tsuga heterophylla* (Rafinesque) Sargent) in British Columbia, which suggests the species is not restricted to *Pinus* spp. Both species were reported from Quebec by Landry *et al.* (2021).

In their original description of *C. cicindela*, Niskanen *et al.* (2009) reported that, in northern Europe, it can occur in *Sphagnum* bogs and other wet places with spruce and pine species, but also in mesic or dry forests with these trees. It was reported by Landry et Labbé (2022) from Radisson, northern Quebec, in mesic to humid soil among *Sphagnum*. Our collection was gregarious on *Sphagnum* in a wet forest dominated by Red Spruce (*Picea rubens* Sargent), Balsam Fir, and Paper Birch (*Betula papyrifera* Marshall).

Cortinarius gentilis (Fr.) Fr. (Conifer Webcap;
Figures 2d, 3d)

Pileus conic-convex at first, expanding to broadly convex, with a low umbo, moist, glabrous except for some marginal pubescence, light brown to brown (HSV05–20:70:50–70), with marginal pubescence pale yellow to light yellow (HSV40:20–30:100), 13–37 mm in diameter. *Stipe* equal, yellowish white to pale yellow (HSV40:05–10:100), reddish brown (HSV380:70:30–40) where bruised, glabrous to fibrillose with yellow veil material, 40–70 × 3–7 mm. *Lamellae* light brown (HSV15:50:60) at first, more yellow when viewed on edge, darkening at maturity, adnexed to sinuate. *Universal veil* yellowish white (HSV40:05:100). *Flesh* concolorous with the surface tissues, concolorous with the bruising colour in the interior of the stipe, with a raphanoid odour, fairly tasteless.

Basidiospores orange brown (HSV35:50–60:90) in spore print, elliptical to obovate in profile, infre-

quently ovate, roughened with small spine-like warts, unchanging in Melzer's solution, darkening in KOH, $7.8\text{--}9.7 \times 5.6\text{--}6.6 \mu\text{m}$, $Q = 1.34\text{--}1.60$ (mean [49]: $8.7 \pm 0.4 \times 6.0 \pm 0.2 \mu\text{m}$, $Q = 1.45 \pm 0.07$). *Basidia* clavate, four-spored, with a basal clamp connection. *Hymenial cystidia* lacking. *Pileipellis* duplex, composed of a compact cutis of pale encrusted hyphae, with a brown hypoderm of short and broad encrusted hyphae. *Lamellar trama* parallel, of narrow brown finely encrusted hyphae.

Specimens examined—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.491°W, 24 September 2003, *D. Malloch 24-09-03/04* (NBM-F-00454), GenBank no. OP352903 (ITS); Little Lepreau, 45.135°N, 66.475°W, 24 September 2003, *D. Malloch 24-09-03/02* (NBM-F-000452; not sequenced but morphologically similar).

Cortinarius gentilis was traditionally placed in *Cortinarius* subgenus *Leproclybe* among other bright orange-brown species (e.g., Hansen and Knudsen 1992); however, ITS sequences show it to be a member of subgenus *Telamonia*, sect. *Brunnei* (Høiland and Holst-Jensen 2000). Although its association with coniferous trees and the overall stature of its basidiomata are consistent with the *Brunnei*, the colour of the basidiomata and the bright yellow veil remnants on the stipe are less so. There are several collections of *C. gentilis* in NBM, including others from New Brunswick and one (NBM-F-0311) from Newfoundland and Labrador. Two records, possibly representing separate species, have been reported for Quebec by Landry *et al.* (2021). Their collection YL3407, as photographed, is very similar in appearance to those made in New Brunswick.

This well-known species was stated by Niskanen *et al.* (2009) to occur in dry to mesic coniferous forests with pine and spruce in northern Europe. Landry *et al.* (2022) give the habitat as soil under conifers and cite two sequenced collections from Chibougamau and Jamesie, both northerly localities in Quebec. The collection presented here was gregarious in litter among sparse Red-stemmed Feathermoss, associated with Balsam Fir and Red Spruce.

***Cortinarius* subgenus *Telamonia*, section *Firmiores*
Cortinarius caninoides Rob. Henry (Figures 2e, 3e)**

Pileus conical at first, expanding to broadly convex at maturity, with a low rounded umbo, dry to moist, glabrous, dull orange (HSV25:60:70–80) on the umbo, light brown (HSV15:30:50–60) elsewhere, hygrophanous, darkening in 3% KOH but without colour changes, 32–63 mm in diameter. *Stipe* clavate, with a bulbous base, dry, with a white sheath-like universal veil extending from the base to the annular zone, very pale brownish white above the annular

zone, 72–100 × 8–10 mm. *Lamellae* light orange brown (HSV30:30–40:80), close, adnate to adnexed, not marginate. *Universal veil* abundant, white. *Flesh* concolorous with the surface tissues in the pileus but fading to white as it dries, pale dull orange yellow (HSV30:10–20:80) in the stipe except for the violaceous apex, darkening in 3% KOH but without colour changes, with a nondescript odour and taste.

Basidiospores orange brown in spore print, obovate in profile, usually with a pronounced suprahilar depression, coarsely roughened, $6.1\text{--}7.5 \times 3.8\text{--}4.7 \mu\text{m}$, $Q = 1.48\text{--}1.71$ (mean [53]: $6.7 \pm 0.3 \times 4.2 \pm 0.2 \mu\text{m}$, $Q = 1.58 \pm 0.05$). *Hymenial cystidia* lacking. *Basidia* four-spored, with a basal clamp connection. *Pileipellis* a series of three distinct layers: (1) a thin hyaline cutis of narrow hyphae that may be slightly gelatinous, (2) a thicker hyaline zone of shorter and broader cells, and (3) a compact layer of brown narrow hyphae with conspicuous pigment encrustations. *Pileus trama* parallel, of loosely arranged and nearly colourless hyphae.

Specimen examined—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.491°W, 24 September 2020, *D. Malloch 24-09-20/02* (NBM-F-009370), GenBank no. OP352900 (ITS).

A medium-sized brown hygrophanous species characterized by its white sock-like peronate universal veil extending up almost to the apex of the stipe, light orange-brown lamellae and bulbous stipe. The blue colour of the flesh near the apex of the stipe is obscure and was only noticed in the photograph. The basidiomata in the photograph of *C. caninoides* in Landry *et al.* (2021), with their orange-brown basidiomata, seem dissimilar to ours.

Cortinarius caninoides and *C. circinans* were originally described validly in the same publication. Landry *et al.* (2021) pointed out that the types of these two names had ITS sequences similar enough that they could be considered conspecific, and, following Art. 11.5 of The International Code of Nomenclature for algae, fungi, and plants (Turland *et al.* 2018), they chose to recognize *C. caninoides* as their preferred name for this species, citing *C. circinans* as a synonym.

Robert Henry's original description (Kühner and Romagnesi 1953) lists the habitat as soil under pine and birch (*Betula* L.). Landry *et al.* (2021) reported three sequenced collections from Quebec and gave the habitat as being under conifers, possibly with Jack Pine (*Pinus banksiana* Lambert). Landry *et al.* (2022) reported what appear to be the same collections on soil under conifers and plantations of Jack Pine with poplars (*Populus* sp.). Our material was gregarious to clustered among Red-stemmed Feathermoss, associated with Heart-leaved Birch (*Betula cordifolia* Regel) and Balsam Fir.

***Cortinarius pseudobiformis* Bidaud & Carteret**

(Figures 2f, 3f)

Pileus convex when young and remaining so at maturity, with a low broad umbo, dry, silky-shiny, glabrous or with a very sparse covering of white universal veil material, dark reddish brown (HSV00:20:50), hygrophanous, with fading beginning in a ring surrounding the umbo, 38–40 mm in diameter, unchanging in KOH. *Stipe* tapering up gradually from an only very slightly enlarged base, thickly covered with the white silky universal veil, mostly white but with a very dilute violaceous colour at the apex, dry, 70 × 13 mm. *Lamellae* orange brown (HSV25:40:50–60), close, adnate to adnexed, finely eroded at the margin, not marginate. *Universal veil and cortina* white. *Flesh* concolorous with the surface tissues in the areas of the pileus surrounding the broad umbo but only in the uppermost 1 mm on the umbo, violaceous (HSV280:30–40:60–70) in the upper 20 mm of the stipe but with this colour soon fading to greyish when exposed to air, light brown (HSV25:40:60–70) in the stipe cortex, dull whitish in the umbo and lower part of the stipe, with a pronounced but nondescript mushroom odour and taste, unchanging in KOH.

Basidiospores weak reddish brown in spore print, elliptical to obovate in profile, rarely ovate, with a tapering apex, usually with a suprahilar flattening, coarsely roughened, strongly dextrinoid, 8.3–10.7 × 5.1–6.1 μm, Q = 1.42–1.82 (mean [53]: 9.5 ± 0.5 × 5.8 ± 0.2 μm, Q = 1.63 ± 0.09). *Basidia* clavate, four-spored, with a basal clamp connection, occasionally filled with a yellow-brown substance. *Cheilocystidia* not well defined, appearing as narrow clavate cells arising from the terminal ends of the lamellar trama. *Pileipellis* duplex, a cutis of narrow hyaline hyphae above a subpellis of short brown encrusted cells. *Clamp connections* present on most septa.

Specimen examined—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.490°W, 17 June 2021, *D. Malloch 17-06-21/01* (NBM-F-009373), GenBank no. OP352906 (ITS).

Cortinarius pseudobiformis has a dark brown hygrophanous pileus, a nearly cylindrical stipe covered by a thick white universal veil, orange-brown lamellae, and violaceous flesh in the upper part of the stipe. Unlike other species in this report, it has markedly dextrinoid basidiospores. Landry *et al.* (2021) reported and illustrated this species from Quebec. The basidiomata in their photograph resemble our material except for the slightly bulbous base of the stipe. Although Landry *et al.* (2021) described the lamellae of their collection as brownish violet at first, we did not observe any violaceous colours in ours, perhaps because they were more mature.

This species is not commonly reported and habitat data are limited. Landry *et al.* (2022) report it on acid soil under fir trees among mosses near a bog. Landry *et al.* (2021) state it is found under Balsam Fir, poplar (“trembles”), and birch. Their illustrations show the habitat to be well drained and with Red-stemmed Feathermoss and *Dicranum* Hedw. Our collection was solitary in a well-drained area at the base of a mature Balsam Fir among numerous seedlings of that species, associated with Balsam Fir and a few individuals of Heart-leaved Birch. Its appearance in mid-June is much earlier than the Quebec collections.

Cortinarius* subgenus *Telamonia*, section *Tortuosi***Cortinarius tortuosus* (Fr.) Fr.** (Figures 4a, 5a)

Pileus conic-turbinate at first, broadly convex at maturity, with a rounded to subacute umbo, dry, glabrous, chocolate brown (HSV25:80:30–40), strongly hygrophanous, 26–38 mm in diameter. *Stipe* equal or slightly swollen at the base, with a slightly flocculose annular zone in some but with this lacking in others, white with an appressed universal veil layer over a very pale straw-coloured ground colour, dry, 45–65 × 4–5 mm. *Lamellae* medium brown (HSV20:70:50–60), subclose, adnexed, not marginate. *Cortina* white, sparse, not visible on mature basidiomata. *Flesh* concolorous with the surface tissues in the pileus, pale yellow orange (HSV40:20:98) in the stipe, lacking a distinctive odour and taste.

Basidiospores orange brown in spore print, elliptical to ovate in profile, infrequently obovate, coarsely roughened, 8.0–11.5 × 5.0–6.1 μm, Q = 1.54–1.92 (mean [70]: 9.3 ± 0.5 × 5.4 ± 0.2 μm, Q = 1.71 ± 0.08). *Basidia* four-spored, clavate. *Hymenial cystidia* lacking. *Pileipellis* duplex, a cutis of narrow brown encrusted hyphae overlying a thicker layer of broad hyphae. *Clamp connections* produced at nearly all septa.

Specimen examined—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.488°W, 27 September 2020, *D. Malloch 27-09-20/02* (NBM-F-009375), GenBank no. OP352907 (ITS).

Some earlier authors, e.g., Brandrud *et al.* (1998), included *C. tortuosus* in the section *Bicolores* along with the superficially similar *C. evernius*, but more recent molecular results (Liimatainen *et al.* 2022) suggest placement in a separate section. Although the stipe of *C. tortuosus* may be lightly violaceous at its apex (Brandrud *et al.* 1990), it is never as markedly violaceous throughout its length, inside and out, as that of fresh basidiomata of *C. evernius*.

The neotype was growing among *Sphagnum* in a spruce forest (probably Norway Spruce [*Picea abies* (L.) H. Karsten]) in Sweden. Liimatainen *et al.* (2017)



FIGURE 4. Basidiomata. a. *Cortinarius tortuosus*. b. *Cortinarius valgus*. c. *Cortinarius harvardensis*. d. *Cortinarius fulvescens*. Scale bar = 10 mm. Photos: D. Malloch.

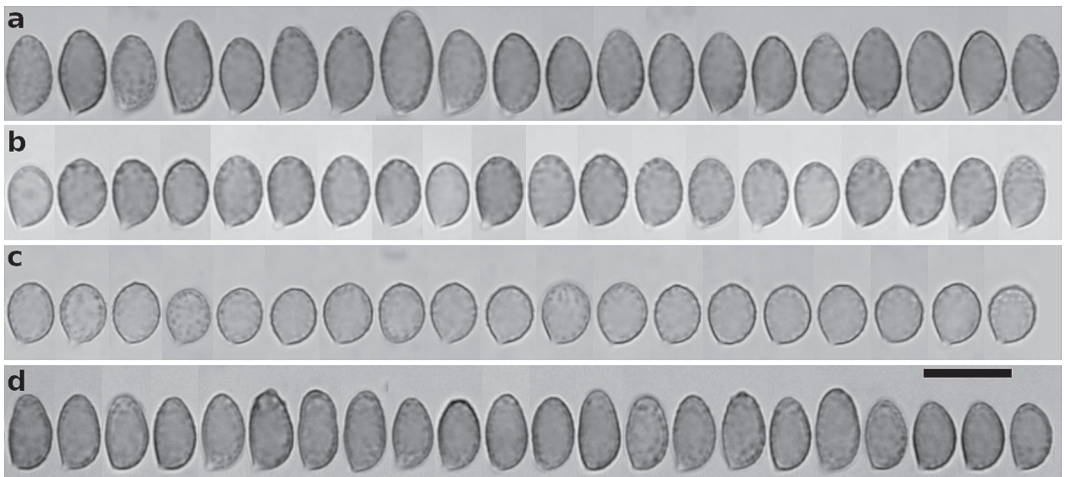


FIGURE 5. Basidiospores. a. *Cortinarius tortuosus*. b. *Cortinarius valgus*. c. *Cortinarius harvardensis*. d. *Cortinarius fulvescens*. Scale bar = 10 μ m. Photos: D. Malloch.

stated that *C. tortuosus* has a very narrow ecological niche, growing in wet and acidic soils with conifers. Soop (2021) reported that, in Sweden, it is fairly common in moist spruce forests, often in *Sphagnum*. Landry et Labbé (2022) report it in Quebec on poorly drained soil in coniferous forests, usually in

Sphagnum. Our collection was not in *Sphagnum* but was clustered among Red-stemmed Feathermoss, associated with Heart-leaved Birch and Balsam Fir. There are other collections of this species in the herbarium of the NBM, but these have not been confirmed genetically.

Cortinarius* subgenus *Telamonia*, section *Valgi***Cortinarius valgus* Fr. (Figures 4b, 5b)**

Pileus conic-convex at first, expanding to more broadly so at maturity, with a low rounded umbo, dry, glabrous except for the minutely white-fibrillose margin, dark orange brown (HSV25:50:50) when young and fully hydrated, strongly hygrophanous and soon fading and revealing some orange shades on the umbo, 21–43 mm in diameter. *Stipe* equal down to the distinctly bulbous base, slightly white fibrillose with veil material but otherwise glabrous, with a weakly defined annular zone when young, mostly pale straw coloured with some darker regions below, very obscurely violaceous at the apex, dry, 40–60 × 4–8 mm. *Lamellae* light brown (HSV30:30–40:70), subclose, adnexed, not marginate. *Cortina* not seen. The universal veil as seen on the stipe and pileus margin is sparse but appears to be white. *Flesh* pale greyish white, lacking a distinctive odour and taste.

Basidiospores orange brown in spore print, broadly elliptical to slightly ovate in profile, less frequently slightly obovate, coarsely roughened, slightly dextrinoid, 6.9–9.7 × 4.9–6.7 μm, Q = 1.30–1.65 (mean [40]: 7.9 ± 0.6 × 5.4 ± 0.4 μm, Q = 1.45 ± 0.06). *Hymenial cystidia* lacking. *Basidia* clavate, four-spored, with a basal clamp connection. *Pileipellis* a thin cutis of narrow brown encrusted hyphae, not clearly duplex and with hypoderm poorly defined. *Clamp connections* present throughout.

Specimen examined—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.488°W, 27 September 2020, *D. Malloch 27-09-20/04* (NBM-F-009377), GenBank no. OP352908 (ITS).

This collection is difficult to characterize. Landry *et al.* (2021) reported *C. valgus* from Quebec and stated that their collection's ITS sequence was identical to that of the neotype, as is ours. They describe their basidiomata as having some slightly olivaceous colours, the pileus with an uneven margin, and the lamellae slightly violaceous when young.

We did not observe any violaceous colour in our collection. *Cortinarius rheubarbarinus* Rob. Henry, a later synonym with ITS sequence identical to that of *C. valgus* (Liimatainen *et al.* 2020), was illustrated by Brandrud *et al.* (1992, 1994). Although their collections resemble ours, they were described as growing in dry calcareous soil in association with beech, hornbeam (*Carpinus* L.), and oak (*Quercus* L.). It is possible that these collections have not been sequenced.

According to Soop (2021), *C. valgus* grows in both acidic and richer forests of spruce. Landry *et al.* (2022) report two collections from Quebec as growing on soil in young plantations of spruce and pine. The New Brunswick material was clustered in a relatively moist rocky site among *Sphagnum* sp. and

Red-stemmed Feathermoss, associated with Heart-leaved Birch and Balsam Fir.

Cortinarius* subgenus *Camphorati*, section *Anomali***Cortinarius harvardensis* L. Nagy, Dima & Ammirati (Figures 4c, 5c)**

Pileus conical when young, expanding to more broadly so at maturity, with a low rounded umbo or without an umbo, dry to moist, glabrous, light orange brown (HSV30-40:30:70–100) and dull grey (HSV15:05:70) toward the margin when young, later maintaining the colour on the umbo but otherwise dull orange grey (HSV25:05:90; photos show violaceous colours in the cap not recorded in the description), possibly hygrophanous, 16–41 mm in diameter. *Stipe* equal down to the swollen base, without a distinct bulb, slightly white fibrillose with veil material but otherwise glabrous, with a moderately well-defined annular zone when young, mostly white, very obscurely violaceous at the apex, dry, 36–78 × 3–8 mm. *Lamellae* light brown (HSV30:30:60–80) to dull violaceous grey (HSV310:10–15:70), subclose to close, adnexed, not marginate. *Cortina* possibly white. *Flesh* dark bluish grey (HSV280:10:50) to dull reddish grey (HSV00:10:60) in the pileus, violaceous grey (HSV270:20–30:50) in the centre of the upper stipe, concolourous with the surface tissues in the cortex of the stipe, paler grey in the rest of the stipe context, concolourous with the surface tissue in the stipe cortex, lacking a distinctive odour and taste.

Basidiospores reddish brown in spore print, broadly elliptical to slightly obovate in profile, less frequently slightly ovate, finely echinulate-roughened, 6.6–9.9 × 5.3–6.6 μm, Q = 1.22–1.49 (mean [80, of two collections]: 7.5 ± 0.5 × 5.8 ± 0.2 μm, Q = 1.28 ± 0.05). *Basidia* clavate, four-spored, with a basal clamp connection. *Hymenial cystidia* lacking. *Lamellar trama* parallel, with a few adhering colourless crystals but not encrusted with pigment material. *Pileipellis* duplex, a cutis of hyphae one or two cells deep overlying a compact subpellis of short broad hyphae, with cuticular hyphae containing a yellowish cytoplasmic pigment. *Clamp connections* on nearly all hyphae.

Specimens examined—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.490°W, 27 September 2020, *D. Malloch 27-09-20/02* (NBM-F-009369), GenBank no. OP352904 (ITS); Little Lepreau, 45.135°N, 66.487°W, 27 September 2020, *D. Malloch 27-09-20/05* (NBM-F-009376), GenBank no. OP352908 (ITS).

Reported from Massachusetts (holotype), Nova Scotia, and Quebec by Dima *et al.* (2021). It is characterized by its orange-brown to bluish-grey pileus, its white stipe with flesh in upper part blue, and lamellae

that are blue at first. The subglobose basidiospores are also characteristic.

The type was reported to be associated with pine and oak (Dima *et al.* 2021). Landry et Labbé (2022) list three Quebec specimens confirmed by sequences. No species of oak were recorded from any of the Quebec localities. All of the photos of Quebec material, except one made on a scanner, show well-drained habitats with Red-stemmed Feathermoss. Records from Nova Scotia include three collections made by Keith N. Egger, all found in association with Eastern Hemlock (*Tsuga canadensis* (L.) Carrière) and verified by ITS sequences (<https://mushroomobserver.org/470612>, <https://mushroomobserver.org/496070>, <https://mushroomobserver.org/496079>). An additional Nova Scotia record is from an environmental sequence obtained from roots of Red Spruce by Gavin Kernaghan (GenBank MK131480). One of the two New Brunswick collections was clustered among *Dicranum* sp. and Red-stemmed Feathermoss, associated with Heart-leaved Birch and Balsam Fir (NBM-F-009376). The other was among *Dicranum* spp. and Red-stemmed Feathermoss in wet forest, associated with Balsam Fir, Black Spruce (*Picea mariana* (Mill.) Britton, Sterns & Poggenburg), Tamarack (*Larix laricina* (Du Roi) K. Koch), and Heart-leaved Birch (NBM-F-009369).

Cortinarius* section *Fulvescentes—position in *Cortinarius* currently unresolved

***Cortinarius fulvescens* Fr.** (Figures 4d, 5d)

Pileus convex-hemispherical at first, expanding to more broadly so at maturity, with a low inconspicuous umbo, moist, glabrous to very finely appressed fibrillose, chestnut brown (HSV00:60–70:40) throughout at first, later becoming orange yellow (HSV45:50:100) beneath the reddish colour at the margin, not hygrophanous, 18–30 mm in diameter. *Stipe* equal down to the slightly enlarged base, dull greyish white but becoming light reddish brown (HSV15:30:70) where handled, dry, minutely fibrillose, 25–38 × 3–6 (9) mm. *Lamellae* light yellow brown (HSV35:30–40:80–90) at first, bright orange brown (HSV35:70:90) at maturity, subclose, adnexed, not marginate. *Cortina* white. *Flesh* concolorous with the surface tissue in the pileus, bright orange brown (HSV35:70:60–80) in the stipe, lacking a distinctive odour and taste.

Basidiospores bright rusty orange brown (HSV 35:80:80) in spore print, narrowly ovate to elliptical in profile, less frequently obovate, coarsely roughened, unchanging in Melzer's solution, $7.4\text{--}9.7 \times 4.5\text{--}5.7 \mu\text{m}$, $Q = 1.48\text{--}2.00$ (mean [56]: $8.5 \pm 0.5 \times 4.9 \pm 0.2 \mu\text{m}$, $Q = 1.73 \pm 0.10$). *Basidia* clavate, four-spored, with a basal clamp connection. *Hymenial*

cystidia lacking. *Pileipellis* duplex, a thin cutis of narrow finely encrusted hyphae over a subpellis of short-celled broad hyphae. *Clamp connections* present on most septa.

Specimen examined—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.490°W, 18 October 2020, D. Malloch 18-10-20/02 (NBM-F-009372), GenBank no. OP352902 (ITS).

The overall appearance of this collection is similar to that of *C. valgus*. It differs in the more orange-brown colour of the lamellae and in the orange-brown colour of the flesh of the stipe. Landry *et al.* (2021) note that the bands of reddish-brown veil material on the surface of the stipe are a diagnostic feature of the Quebec material. This may also be true of our collection, although much of the brown colour appears to be due to bruising.

The habitat range of *C. fulvescens* appears to be fairly broad. The neotype from Finland was collected in submesic forest dominated by Norway Spruce mixed with some birch and European Aspen (*Populus tremula* L.; Hyde *et al.* 2016). Soop (2021) reported it in Swedish spruce forests, often near *Sphagnum*. According to Hyde *et al.* (2016), it grows in mesic to dry coniferous forests with spruce and/or pine and hemlock (*Tsuga* (Endler) Carrière). Landry et Labbé (2022) report sequenced material from Quebec collected in sandy soil among mosses in coniferous forests and plantations with fir, pine, and spruce. The New Brunswick collection was gregarious in gravel at the edge of a driveway, associated with Heart-leaved Birch and Balsam Fir. The uncharacteristically short stipe in this collection was probably because of the rather thin disturbed soil.

Discussion

Seven species, *C. caninoides*, *C. cincinnata*, *C. fulvescens*, *C. harvardensis*, *C. plumulosus*, *C. pseudo-biformis*, and *C. valgus*, are new distribution records for New Brunswick. The collection of *C. plumulosus* may also be a new record for North America. Although previous collections of *C. evernius*, *C. gentilis*, and *C. tortuosus* from New Brunswick have been accessioned in the herbarium of the NBM, their identification has not been confirmed genetically. Most datasets for species of *Cortinarius* generated using molecular techniques have been based on the ITS and LSU regions (Landry *et al.* 2021; Liimatainen *et al.* 2022). Our results are thus consistent with recent usage.

All of the collections presented here, except *C. cincinnata*, were made close to the shore of the Bay of Fundy in southeastern Charlotte County, New Brunswick. This area is in the Fundy Coast Ecoregion (Zelazny 2007). Clayden *et al.* (2011) characterized this region as having a “perhumid” climate, one

in which precipitation much exceeds evaporation and plant transpiration, resulting in year-round wetness. Fog occurs frequently during the summer. Mean summer temperatures are about 14.5°C and mean annual precipitation is 1000–1400 mm (McAlpine and Smith 2010). The vegetation is mainly boreal to hemiboreal, characterized by low-diversity stands of Red Spruce, Black Spruce, Balsam Fir, and Heart-leaved Birch. Much of the understorey is dominated by bryophytes, especially carpets of the mosses Red-stemmed Feathermoss, Broom Forkmoss (*Dicranum scoparium* Hedw.), Glittering Woodmoss (*Hylocomium splendens* (Hedw.) Schimp.), Knights Plume Moss (*Ptilium crista-castrensis* (Hedw.) De Not.), and *Sphagnum* spp., and the liverwort Greater Whipwort (*Bazzania trilobata* (L.) Gray).

Cortinarius cicindela was collected in the Butter-milk Ecodistrict of the Valley Lowlands Ecoregion, an area characterized by a greater representation of shade-tolerant hardwoods mixed with fir and spruce (Zelazny 2007). The annual precipitation is 1000–1300 mm (McAlpine and Smith 2010), but summers are warmer and less foggy and winters colder than in the Fundy Coast Ecoregion, so more of this may come from snow.

Author Contributions

Conceptualization: D.M. and A.J.; Investigation: D.M., A.J., and J.A.; Writing – Original Draft: D.M., A.J., and J.A.; Writing – Review & Editing: D.M.; Funding Acquisition: A.J. and J.A.

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