Two new *Erythrophylloporus* species (Boletaceae) from Thailand, with two new combinations of American species

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Abstract

*Erythrophylloporus* is a lamellate genus in the family Boletaceae that has been recently described from China based on *E. cinnabarinus*, the only known species. Typical characters of *Erythrophylloporus* are reddish-orange to yellowish-red basidiomata, including lamellae, bright yellow basal mycelium and smooth, broadly ellipsoid, ellipsoid to nearly ovoid basidiospores. During our survey on diversity of Boletaceae in Thailand, several yellowish-orange to reddish- or brownish-orange lamellate boletes were collected. Based on both morphological evidence and molecular analyses of a four-gene dataset (*atp6*, *tef1*, *rpb2* and *cox3*), they were recognised as belonging in *Erythrophylloporus* and different from the already known species. Two new species, *E. paucicarpus* and *E. suthepensis* are therefore introduced from Thailand with detailed descriptions and illustrations. Moreover, two previously described *Phylloporus* species, *P. aurantiacus* and *P. fagicola*, were also revised and recombined in *Erythrophylloporus*. A key to all known *Erythrophylloporus* species is provided.
Keywords
atp6, cox3, Taxonomy, Phylloporus, Pulveroboletus group, multigene phylogeny, Boletales, Southeast Asia

Introduction

Most fungi in the family Boletaceae are pileate-stipitate with poroid hymenophore, but some have a lamellate hymenophore. Lamellate Boletaceae are currently classified in four genera, Phylloporus Quél, which contains about 84 species worldwide, Phylloboletellus Singer from South America and Mexico, the two recently described genera Phylloporopsis Angelini et al., from the New World and Erythrophylloporus Ming Zhang & T.H. Li from Asia, each of which circumscribes only one species (http://www.indexfungorum.org, Farid et al. 2018; Zhang and Li 2018).

The genus Erythrophylloporus was recently described from China, with E. cinnabarinus Ming Zhang & T.H. Li as the type species. According to Zhang & Li (2018), the typical characters of the genus are orange to reddish-orange basidiomes, reddish-orange to yellowish-red lamellae turning greyish-green when bruised, bright yellow to orange yellow context staining blackish-blue to dark blue when exposed, bright yellow basal mycelium, smooth and broadly ellipsoid to nearly ovoid basidiospores and yellowish-brown pigmented cystidia. During our survey on the diversity of Boletaceae in Thailand, several collections of lamellate boletes were discovered. Some collections were recognised to belong to Erythrophylloporus by possessing yellowish-orange to deep orange to reddish-orange basidiomata with bright yellow basal mycelium and smooth basidiospores. We also found that two described Phylloporus species, P. aurantiacus Halling & G.M. Mueller from Costa Rica and P. fagicola Montoya & Bandala from Mexico (Halling et al. 1999, Montoya and Bandala 2011), share similar morphological characters with the genus Erythrophylloporus, but until now, have not been included in a molecular phylogeny. In this study, a combination of phylogenetic and morphological evidence indicated that our Thai collections were new species, that, together with the two aforementioned American Phylloporus species, belong in Erythrophylloporus. Therefore, we introduce two new species with detailed descriptions and illustrations and propose two new combinations. As some of the species we studied have some characters that do not fit with the protologue of the genus, we emend its description.

Materials and methods

Specimen collecting

Specimens were obtained and photographed from community forests and Doi Suthep-Pui National Park, Chiang Mai Province, northern Thailand during the rainy season in 2015 to 2016. The specimens were wrapped in aluminium foil and taken to the laboratory. After description of macroscopic characters, all specimens were dried in an electric drier at 45–50 °C. Examined specimens were deposited in the herbaria CMUB, MFLU, BKF or BR (Index Herbariorum; Thiers, continuously updated).
Morphological studies

Macroscopic descriptions were made based on detailed field notes and photos of fresh basidiomata. Colour codes follow Kornerup and Wanscher (1978). Macrochemical reactions (colour reactions) of fresh basidiomata were determined using 10% potassium hydroxide (KOH) and 28–30% ammonium hydroxide (NH₄OH) in water. Microscopic structures were observed from dried specimens mounted in 5% KOH, NH₄OH, Melzer’s reagent or 1% ammoniacal Congo red. A minimum of 50 basidiospores, 20 basidia and 20 cystidia were randomly measured at 1000× with a calibrated ocular micrometer using an Olympus CX51 microscope. The notation ‘[m/n/p]’ represents the number of basidiospores m measured from n basidiomata of p collections. Dimensions of microscopic structures are presented in the following format: (a–)b–c–d–(e), in which c represents the average, b the 5th percentile, d the 95th percentile and a and e the minimum and maximum values, respectively. Q, the length/width ratio, is presented in the same format. A section of the pileus surface was radially and perpendicularly cut at a point halfway between the centre and margin of the pileus. Sections of stipitipellis were taken from halfway up the stipe and longitudinally cut, perpendicularly to the surface. All microscopic features were drawn by free hand using an Olympus Camera Lucida model U–DA, fitted to the microscope cited above. For scanning electron microscopy (SEM), a spore print was mounted on to a SEM stub with double-sided tape. The sample was coated with gold, examined and photographed with a JEOL JSM–5910 LV SEM (JEOL, Japan).

DNA isolation, PCR amplification and DNA sequencing

Genomic DNA was extracted from fresh tissue preserved in CTAB or about 10–15 mg of dried specimens using a CTAB isolation procedure adapted from Doyle and Doyle (1990). Portions of the genes atp6, tef1, rpb2 and cox3 were amplified by the polymerase chain reaction (PCR) technique. The tailed primers ATP6-1M40F and ATP6-2M (Raspé et al. 2016) and the primer pairs EF1-983F/EF1-2218R (Rehner and Buckley 2005) and bRPB2-6F/bRPB2-7.1R (Matheny 2005) were used to amplify atp6, tef1 and rpb2, respectively. PCR conditions were the same as in Raspé et al. (2016). Part of the mitochondrial gene cox3 was amplified with the primers COX3M1-F and COX3M1-R (Vadthanarat et al. 2019), using KAPA2G™ Robust HotStart polymerase (Kapa Biosystems, Wilmington, MA, USA) and the following PCR programme: 2 min 30 s at 95 °C; 35 cycles of 25 s at 95 °C, 30 s at 48 °C, 30 s at 72 °C; 3 min at 72 °C. PCR products were purified by adding 1 U of Exonuclease I and 0.5 U FastAP Alkaline Phosphatase (Thermo Scientific, St. Leon-Rot, Germany) and incubated at 37 °C for 1 h, followed by inactivation at 80 °C for 15 min. Sequencing was performed by Macrogen Inc. (Korea and The Netherlands) with PCR primers, except for atp6, for which universal primers M13F-pUC(-40) and M13F(-20) were used; for tef1, additional sequencing was performed with two internal primers, EF1-1577F and EF1-1567R (Rehner and Buckley 2005).
Alignment and phylogeny inference

The sequences were assembled in GENEIOUS Pro v. 6.0.6 (Biomatters) and introns were removed prior to alignment, based on the amino acid sequence of previously published sequences. All sequences, including sequences from GenBank, were aligned using MAFFT version 7 (Katoh and Standley 2013) on the server accessed at http://mafft.cbrc.jp/alignment/server/.

Maximum Likelihood (ML) phylogenetic tree inference was performed using RAxML-HPC2 version 8.2.10 (Stamatakis 2006) on the CIPRES web portal (Miller et al. 2009). The phylogenetic tree was inferred from a four-partitions combined data set, using the GTRCAT model with 25 categories. Two Buchwaldoboletus and nine Chalciporus species from subfamily Chalciporoideae were used as the outgroup. Statistical support of clades was obtained with 1,000 rapid bootstrap replicates.

For Bayesian Inference (BI), the best-fit model of substitution amongst those implementable in MrBayes was estimated separately for each gene using jModeltest (Darriba et al. 2012) on the CIPRES portal, based on the Bayesian Information Criterion (BIC). The selected models were GTR+I+G for atp6 and cox3, SYM+I+G for tef1 and K80+I+G for rpb2. Partitioned Bayesian analysis was performed with MrBayes 3.2 (Ronquist et al. 2012) on the CIPRES portal. Two runs of five chains were run for 15,000,000 generations and sampled every 1,000 generations. The chain temperature was decreased to 0.02 to improve convergence. At the end of the run, the average deviation of split frequencies was 0.007058 and the Potential Scale Reduction Factor (PSRF) values of all parameters were close to 1. The burn-in phase (25%) was estimated by checking the stationarity in the plot generated by the sump command.

Results

Phylogenetic analysis

Twenty-five sequences were newly generated and deposited in GenBank (Table 1). The sequences from three specimens, OR0689, OR1135 (E. paucicarpus) and OR0615B (E. suthepensis), were not included in our phylogenetic analyses because they were identical to the sequences of the type specimens of E. paucicarpus and E. suthepensis. The alignment contained 906 sequences (179 for atp6, 313 for tef1, 279 for rpb2, 135 for cox3) from 315 voucher specimens and was 2946 characters long (TreeBase number 24078). ML and BI trees showed similar topologies without any supported conflict (Bootstrap Support values, BS ≥ 70% and posterior probabilities, PP ≥ 0.90; Fig. 1). The four-gene phylogram indicated that the included taxa formed seven major clades, representing the Austroboletoideae, Boletoideae, Chalciporoideae, Leccinoideae, Xerocomoideae, Zangioideae and the Pulveroboletus group. Erythrophylloporus cinnabarinus (typus generis) grouped with the two new Erythrophylloporus species, E. paucicarpus and E. suthepensis, in a highly supported clade (BS = 100% and PP = 1). The two New World Phylloporus species (P. aurantiacus voucher REH7271 and P. fagicola voucher Garay215)
Table 1. List of collections used in this study, with origin and GenBank accession numbers. Newly generated sequences are presented in bold.

| Species                      | Voucher       | Origin   | *atp6*   | *tef1*   | *rpb2*   | *cox3*   | References                           |
|------------------------------|---------------|----------|----------|----------|----------|----------|--------------------------------------|
| Afroboletus aff. multijugus | JD671         | Burundi  | MH614651 | MH614700 | MH614747 | MH614794 | Vadhanarat et al. 2019               |
| Afroboletus costatiporus    | ADK4644       | Togo     | KT823958 | KT824024 | KT823991 | MH614795 | Raspé et al. 2016; Vadhanarat et al. 2019 |
| Afroboletus luteolus        | ADK4844       | Togo     | MH614652 | MH614701 | MH614748 | MH614796 | Vadhanarat et al. 2019               |
| Aureoboletus catarinarius   | HKAS54467     | China    | –        | KT990711 | KT990349 | –        | Wu et al. 2016                       |
| Aureoboletus duplicatoporus | HKAS50498     | China    | –        | KF112230 | KF112754 | –        | Wu et al. 2014                       |
| Aureoboletus gentilis       | ADK4865       | Belgium  | KT823961 | KT824027 | KT823994 | MH614797 | Raspé et al. 2016; Vadhanarat et al. 2019 |
| Aureoboletus miniabilis     | HKAS57776     | China    | –        | KF112229 | KF112743 | –        | Wu et al. 2014                       |
| Aureoboletus monavicus      | VDKO1120      | Belgium  | MG212528 | MG212573 | MG212615 | MH614798 | Vadhanarat et al. 2018; Vadhanarat et al. 2019 |
| Aureoboletus neplpromporus  | HKAS67931     | China    | –        | KT990720 | KT990357 | –        | Wu et al. 2016                       |
| Aureoboletus projectellus   | AFTOL-ID-713  | USA      | DQ534604*| DQ929199 | DQ366279 | –        | *Binder and Hibbett 2006; Binder, Matheny & Hibbett, Unpublished |
| Aureoboletus sbichhanus     | HKAS76852     | China    | –        | KF112237 | KF112756 | –        | Wu et al. 2014                       |
| Aureoboletus sp.            | HKAS56317     | China    | –        | KF112239 | KF112753 | –        | Wu et al. 2014                       |
| Aureoboletus sp. OR0245     | OR0245        | China    | MH614653 | MH614702 | MH614749 | MH614799 | Vadhanarat et al. 2019               |
| Aureoboletus sp. OR0369     | OR0369        | Thailand | MH614654 | MH614703 | MH614750 | MH614800 | Vadhanarat et al. 2019               |
| Aureoboletus tibetanensis   | HKAS76655     | China    | –        | KF112236 | KF112752 | –        | Wu et al. 2014                       |
| Aureoboletus tibetanensis   | AFTOL-ID-450  | China    | DQ534600*| DQ929199 | DQ366279 | –        | *Binder and Hibbett 2006; Binder, Matheny & Hibbett, Unpublished |
| Aureoboletus tomentosus     | HKAS80485     | China    | –        | KT990715 | KT990353 | –        | Wu et al. 2016                       |
| Aureoboletus vicinosus      | OR0361        | Thailand | MH614655 | MH614704 | MH614751 | MH614801 | Vadhanarat et al. 2019               |
| Aureoboletus zangetti       | HKAS74766     | China    | –        | KT990726 | KT990363 | –        | Wu et al. 2016                       |
| Austroboletus cf. dictyorus | OR0045        | Thailand | KT823966 | KT824032 | KT823999 | MH614802*| Raspé et al. 2016; Vadhanarat et al. 2019 |
| Austroboletus cf. subverus  | OR0573        | Thailand | MH614656 | MH614705 | MH614752 | MH614803 | Vadhanarat et al. 2019               |
| Austroboletus eburneus       | REH9487       | Australia| –        | JX889708 | –        | –        | Halling et al. 2012b                 |
| Austroboletus olivacoguttinosus | HKAS57756     | China    | –        | KF112212 | KF112764 | –        | Wu et al. 2014                       |
| Austroboletus sp. OR0981    | OR0981        | Thailand | MH614657 | MH614706 | MH614753 | MH614804 | Vadhanarat et al. 2019               |
| Baorangia pseudocalopus     | HKAS63607     | China    | –        | KF112167 | KF112677 | –        | Wu et al. 2014                       |
| Baorangia pseudocalopus     | HKAS75739     | China    | –        | KJ184570 | KM605179 | –        | Wu et al. 2015                       |
| Baorangia pseudocalopus     | HKAS75081     | China    | –        | KF112168 | KF112678 | –        | Wu et al. 2014                       |
| Baorangia rubromaculata     | BOTH4144      | USA      | MG897415 | MG897425 | MG897435 | MH614805*| Phookamsak et al. 2019; Vadhanarat et al. 2019 |
| Baorangia major             | OR0209        | Thailand | MG897421 | MG897431 | MG897441 | MK372295*| Phookamsak et al. 2019; Vadhanarat et al. 2019 |
| Boletellus aff. ananus      | NY815459      | Costa Rica| –        | KF112308 | KF112760 | –        | Wu et al. 2014                       |
| Boletellus aff. emolensuis  | OR0061        | Thailand | KT823970 | KT824036 | KT824003 | MH614806*| Raspé et al. 2016; Vadhanarat et al. 2019 |
| Boletellus ananus           | K(M)123769    | Belize   | MH614658 | MH614707 | MH614754 | MH614807 | Vadhanarat et al. 2019               |
| Species                        | Voucher | Origin         | *atp6* | *tef1* | *rpb2* | *cox3* | References                                      |
|-------------------------------|---------|----------------|--------|--------|--------|--------|------------------------------------------------|
| Boletus sp.                   | OR0621  | Thailand       |        |        |        |        | Vadhanarat et al. 2018;                        |
| Boletus sp.                   | HKAS55871 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Boletus sp.                   | HKAS55936 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Boletus aerius                | VDKO1055 | Belgium        | MG212530 | MG212575 | MG212617 | MH614809* | Vadhanarat et al. 2018;                        |
| Boletus alboalbomaculatus     | OR0131  | Thailand       | KT823973 | KT824039 | KT824006 | MH614810* | Vadhanarat et al. 2019;                        |
| Boletus boryyioides           | HKAS55403 | China          | –      | –      | –      | –      | Wu et al. 2016                                |
| Boletus edulis                | HMJAU4637 | Russia         | –      | –      | –      | –      | Wu et al. 2014                                |
| Boletus edulis                | VDKO0869 | Belgium        | MG212531 | MG212576 | MG212618 | MH614811* | Vadhanarat et al. 2018;                        |
| Boletus p.p. sp.              | JD0693  | Burundi        | MH645583 | MH645591 | MH645599 | –      | Vadhanarat et al. 2019;                        |
| Boletus p.p. sp.              | OR0832  | Thailand       | MH645584 | MH645592 | MH645600 | MH645605 | Vadhanarat et al. 2019;                        |
| Boletus p.p. sp.              | OR1002  | Thailand       | MH645585 | MH645593 | MH645601 | MH645606 | Vadhanarat et al. 2019;                        |
| Boletus pallidus              | BOTH4336 | USA            | MH614659 | MH614708 | –      | –      | Vadhanarat et al. 2019;                        |
| Boletus pallidus              | TDB-1231- | –              | AF002142 | –      | –      | AF002154 | Kretzer and Bruns 1999                        |
| Boletus reticulocrepioides     | HKAS75671 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Boletus s.s. sp.              | OR0446  | China          | MG212532 | MG212577 | MG212619 | MH614813* | Vadhanarat et al. 2018;                        |
| Boletus sp.                   | HKAS59660 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Boletus sp.                   | HKAS63598 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Boletus evolaceaefuscus       | HKAS62900 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Bornfusus dhakanus            | HKAS73789 | Bangladesh     | –      | –      | –      | –      | Hosen et al. 2013                             |
| Bornfusus dhakanus            | OR0345  | Thailand       | MH614660 | MH614709 | MH614755 | MH614814 | Vadhanarat et al. 2019;                        |
| Buchvataduobolletus lignicola  | HKAS76674 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Buchvataduobolletus lignicola  | VDKO1140 | Belgium        | MH614661 | MH614710 | MH614756 | MH614815 | Vadhanarat et al. 2019;                        |
| Butyriboletopsis appendiculata| VDKO0193b | Belgium        | MG212537 | MG212582 | MG212624 | MH614816* | Vadhanarat et al. 2018;                        |
| Butyriboletus cl. roseatulus  | OR0230  | China          | KT823974 | KT824040 | KT824007 | MH614819* | Vadhanarat et al. 2019;                        |
| Butyriboletus fruticosus      | NY815462 | USA            | –      | –      | –      | –      | Wu et al. 2014                                |
| Butyriboletus pseudoregius    | VDKO0925 | Belgium        | MG212538 | MG212583 | MG212625 | MH614817* | Vadhanarat et al. 2018;                        |
| Butyriboletus pseudopseudopus | HKAS63513 | China          | –      | –      | –      | –      | Wu et al. 2016                                |
| Butyriboletus roseatulus      | HKAS54999 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Butyriboletus roseogrammarus  | BOTH4497 | USA            | MG897418 | MG897428 | MG897438 | MH614818* | Phookamsak et al. 2019;                        |
| Butyriboletus sp.             | HKAS52525 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Butyriboletus sp.             | HKAS59814 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Butyriboletus sp.             | HKAS57777 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Butyriboletus subplendidus     | HKAS50444 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Butyriboletus vicinus         | HKAS55413 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Caloboletus calopus            | ADK4087  | Belgium        | MG212539 | KJ184566 | PK055030 | MH614820 | Vadhanarat et al. 2018;                        |
| Caloboletus inedulis          | BOTH3963 | USA            | MG897414 | MG897424 | MG897434 | MH614821* | Phookamsak et al. 2019;                        |
| Caloboletus parisiiformis     | HKAS55444 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
| Caloboletus radicans          | VDKO1187 | Belgium        | MG212540 | MG212584 | MG212626 | MH614822* | Vadhanarat et al. 2018;                        |
| Caloboletus sp.               | HKAS53353 | China          | –      | –      | –      | –      | Wu et al. 2014                                |
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| Species                          | Voucher     | Origin   | *atp6*  | *tef1*  | *rpb2*  | *cox3*  | References                                      |
|----------------------------------|-------------|----------|---------|---------|---------|---------|------------------------------------------------|
| Caloboletus sp.                  | OR0068      | Thailand | MH614662| MH614711| MH614757| MH614823| Vadthanarat et al. 2019                        |
| Caloboletus yunnanensis          | HKAS60214   | China    | –       | KJ184568| KT990396| –       | Zhao et al. 2014; Wu et al. 2016                |
| Chalciporus aff. pipenatus       | OR0586      | Thailand | KT823976| KT824042| KT824009| MH614824| Raspé et al. 2016; Vadthanarat et al. 2019     |
| Chalciporus aff. rubinus         | OR0139      | China    | MH614663| MH614712| MH614758| –       | Vadthanarat et al. 2019                        |
| Chalciporus africanus            | JD517       | Cameroon | KT823963| KT824029| KT823996| MH614825| Raspé et al. 2016; Vadthanarat et al. 2019     |
| Chalciporus yunnanensis          | OR0068      | China    | –       | KJ184568| KT990396| –       | Zhao et al. 2014; Wu et al. 2016                |
| Chalciporus piperatus            | OR0363      | Thailand | MH645586| MH645594| MH645602| MH645607| Vadthanarat et al. 2019                        |
| Chalciporus rubinus              | OR0373      | Thailand | MH645587| MH645595| MH645603| MH645608| Vadthanarat et al. 2019                        |
| China sp.                        | OR0141      | China    | MH614665| MH614714| MH614760| MH614827| Vadthanarat et al. 2019                        |
| China viridula                   | HKAS76678   | China    | –       | KF112272| KF112793| –       | Wu et al. 2014                                 |
| Crocinoboletus cf. latissimus    | HKAS53424   | China    | –       | KF112206| KF112710| –       | Wu et al. 2014                                 |
| Cyanoboletus rubraeferus         | OR0233      | China    | MG212542| MG212586| MG212628| MH614834| Vadthanarat et al. 2018; Vadthanarat et al. 2019|
| Cyanoboletus instabilis          | HKAS59554   | China    | –       | KF112186| KF112698| –       | Wu et al. 2014                                 |
| Cyanoboletus pulvarulentus       | RW109       | Belgium  | KT823980| KT824046| KT824013| MH614835| Raspé et al. 2016; Vadthanarat et al. 2019     |
| Cyanoboletus sinopulvarulentus   | HKAS59609   | China    | –       | KF112193| KF112700| –       | Wu et al. 2014                                 |
| Cyanoboletus sp.                 | OR0257      | China    | MG212543| MG212587| MG212629| MH614836| Vadthanarat et al. 2018; Vadthanarat et al. 2019|
| Cyanoboletus sp.                 | OR0322      | Thailand | MH614673| MH614722| MH614768| MH614837| Vadthanarat et al. 2019; Vadthanarat et al. 2019|
| Cyanoboletus sp.                 | OR0491      | China    | MH614674| MH614723| MH614769| MH614838| Vadthanarat et al. 2019                        |
| Cyanoboletus sp.                 | OR0961      | Thailand | MH614675| MH614724| MH614770| MH614839| Vadthanarat et al. 2019; Vadthanarat et al. 2019|
| Erythrophylloporus auranticus     | REH7271     | Costa Rica | MH614666| MH614715| MH614761| MH614829| This study                                    |
| Erythrophylloporus cinnabarinus  | GDGM70536   | China    | –       | MH378802| MH374035| –       | Zhang and Li 2018                              |
| Erythrophylloporus fugicola       | Garay215    | Mexico   | MH614667| MH614716| MH614762| MH614830| This study                                    |
| Erythrophylloporus pasciicarpus   | OR1151      | Thailand | MH614670| MH614719| MH614765| MH614831| This study                                    |
| Erythrophylloporus pasciicarpus   | OR0689      | Thailand | MH614668| MH614717| MH614763| –       | This study                                    |
| Erythrophylloporus pasciicarpus   | OR1135      | Thailand | MH614669| MH614718| MH614764| –       | This study                                    |
| Erythrophylloporus subhispinosus  | SV0236      | Thailand | MH614672| MH614721| MH614767| MH614832| This study                                    |
| Erythrophylloporus subhispinosus  | OR0615B     | Thailand | MH614671| MH614720| MH614766| –       | This study                                    |
| Fistulinella pruniolaris         | REH9880     | Australia| MH614676| MH614725| MH614771| MH614840| Vadthanarat et al. 2019                        |
| Fistulinella pruniolaris         | REH9502     | Australia| MG212544| MG212588| MG212630| –       | Vadthanarat et al. 2018                        |
| Gymnogaster boltudis             | NY01194009  | Australia| –       | KT990768| KT990406| –       | Wu et al. 2016                                 |
| Harrya atriceps                  | REH7403     | Costa Rica| –       | JX889702| –       | Halling et al. 2012b                          |
| Species                        | Voucher          | Origin  | atp8 | tef1 | rpb2 | cox3 | References                  |
|-------------------------------|------------------|---------|------|------|------|------|----------------------------|
| *Harrya chronapes*            | HKAS50527        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Harrya chronopes*            | HKAS49416        | China   | –    | –    | –    | –    | Li et al. 2011              |
| *Harrya montifloriformis*     | HKAS49626        | China   | –    | –    | –    | –    | Wu et al. 2016              |
| *Heimioporus cl. mandarinus*  | OR0661           | Thailand| MG212545 | MG212589 | MG212631 | MH614841* | Vadthanarat et al. 2018; |
| *Heimioporus japonicus*       | OR0114           | Thailand| KT823971 | KT824037 | KT824004 | MH614842* | *Vadthanarat et al. 2019; |
| *Heimioporus retiporus*       | HKAS52237        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Heimioporus sp.*             | OR0218           | Thailand| MG212546 | MG212590 | MG212632 | –    | Vadthanarat et al. 2018;   |
| *Heimiolccinum depitatum*     | AF2845           | Belgium | MG212547 | MG212591 | MG212633 | MH614843* | *Vadthanarat et al. 2018; |
| *Heimiolccinum impolitus*     | ADK4078          | Belgium | MG212548 | MG212592 | MG212634 | MH614844* | *Vadthanarat et al. 2018; |
| *Heimiolccinum incorosus*     | OR0863           | Thailand| MH614677 | MH614726 | MH614772 | MH614845 | Vadthanarat et al. 2019;   |
| *Heimiolccinum rugosum*       | HKAS84970        | China   | –    | KT990773 | KT990412 | –    | Wu et al. 2016              |
| *Hormiboletus amygdalinus*    | HKAS54166        | China   | –    | KT990773 | KT990416 | –    | Wu et al. 2016              |
| *Hormiboletus rubellus*       | VDKO0603         | Belgium | MH614679 | –    | MH614774 | MH614847 | *Vadthanarat et al. 2019;  |
| *Hormiboletus sp.*            | HKAS51239        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Hormiboletus sp.*            | HKAS50466        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Hormiboletus sp.*            | HKAS51292        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Hormiboletus sp.*            | HKAS76673        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Hormiboletus subpudolusus*   | HKAS59608        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Houangia cf. pumila*         | OR0762           | Thailand| MH614680 | MH614728 | MH614775 | MH614848 | Vadthanarat et al. 2019;   |
| *Houangia cheoi*              | HKAS74744        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Houangia cheoi*              | Zhu108           | China   | –    | –    | –    | –    | Zhu et al. 2015             |
| *Houangia nigropunctata*      | HKAS57427        | China   | –    | –    | –    | –    | Zhu et al. 2015             |
| *Hymenolccinum lateopurpureus*| HKAS46334        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Imleria badia*               | VDKO0709         | Belgium | KT823983 | KT824049 | KT824016 | MH614849* | Raspé et al. 2016;         |
| *Imleria obscurerunnea*        | OR0263           | China   | MH614681 | MH614729 | MH614776 | MH614850 | *Vadthanarat et al. 2019;  |
| *Imleria subalpina*           | HKAS74712        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Lanmaoa angustipora*         | HKAS74759        | China   | –    | KM605153 | KM605178 | –    | Wu et al. 2015              |
| *Lanmaoa angustipora*         | HKAS74765        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Lanmaoa asiatica*           | HKAS54094        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Lanmaoa asiatica*           | HKAS63603        | China   | –    | KM605153 | KM605176 | –    | Wu et al. 2015              |
| *Lanmaoa asiatica*           | OR0228           | China   | MH614682 | MH614730 | MH614777 | MH614851 | Vadthanarat et al. 2019;   |
| *Lanmaoa cernitipes*          | BOTH4591         | USA     | MG897419 | MG897429 | MG897439 | MH614852* | Phookamsak et al. 2019,   |
| *Lanmaoa flavolubna*          | NY775777         | Costa Rica | –    | –    | –    | –    | *Vadthanarat et al. 2019;  |
| *Lanmaoa pallidolubna*        | BOTH4432         | USA     | MG897417 | MG897427 | MG897437 | MH614853* | Phookamsak et al. 2019,   |
| *Lanmaoa sp.*                 | HKAS52518        | China   | –    | –    | –    | –    | *Vadthanarat et al. 2019;  |
| *Lanmaoa sp.*                 | OR0130           | Thailand| MH614683 | MH614731 | MH614778 | MH614854 | Vadthanarat et al. 2019;   |
| *Lanmaoa sp.*                 | OR0370           | Thailand| MH614684 | MH614732 | MH614779 | MH614855 | Vadthanarat et al. 2019;   |
| *Leccinellum aff. crocipodium*| HKAS76658        | China   | –    | –    | –    | –    | Wu et al. 2014              |
| *Leccinellum aff. griseum*    | KPM-NC-0017832   | Japan   | KC552164 | JN378450* | –    | –    | unpublished, *Orithara et al. 2012 |
| *Leccinellum coriscum*        | Buf4507          | USA     | –    | –    | –    | –    | Nuhn et al. 2013            |
| Species                  | Voucher | Origin  | *atp6* | *tef1* | *rpb2* | *cox3* | References                                                                 |
|-------------------------|---------|---------|--------|--------|--------|--------|---------------------------------------------------------------------------|
| **Erythrophylloporus**   |         |         |        |        |        |        |                                                                            |
| *Erythrophylloporus*     |         |         |        |        |        |        |                                                                            |
| *Erythrophylloporus*     |         |         |        |        |        |        |                                                                            |
| Two new Erythrophylloporus species (Boletaceae) from Thailand ... |         |         |        |        |        |        |                                                                            |
| Lecinellum cremeum       | HKAS90639 | China   | –      | KT990781 | KT990420 | –        | Wu et al. 2016                                                            |
| Lecinellum cryptodidum   | VDKO1006 | Belgium | KT823988 | KT824054 | KT824021 | MH614856* | Raspé et al. 2016; Vadhvanarath et al. 2019 |
| Lecinellum sp.           | KPM-NC-0018041 | Japan  | KC552165 | KC552094 | –        | –        | Orihara et al. 2016                                                        |
| Lecinellum sp.           | OR0711 | Thailand | MH614685 | MH614733 | MH614780 | –        | Vadhvanarath et al. 2019                                                   |
| Lecinum monticola        | HKAS76669 | China   | –      | KF112249 | KF112723 | –        | Wu et al. 2014                                                            |
| Lecinum quercinum        | HKAS63502 | China   | –      | KF112250 | KF112724 | –        | Wu et al. 2014                                                            |
| Lecinum scabrum          | RW105a | Belgium | KT823979 | KT824045 | KT824012 | MH614857* | Raspé et al. 2016; Vadhvanarath et al. 2019 |
| Lecinum scabrum          | VDKO0938 | Belgium | MG212549 | MG212593 | MG212635 | MH614858* | Vadhvanarath et al. 2018; Vadhvanarath et al. 2019                        |
| Lecinum scabrum          | KPM-NC-0017840 | Scotland | KC552170 | JN378455 | –        | –        | Orihara et al. 2016; Orihara et al. 2012                                    |
| Lecinum schwaeptilum     | VDKO1128 | Belgium | KT823989 | KT824055 | KT824022 | MH614859* | Raspé et al. 2016; Vadhvanarath et al. 2019 |
| Lecinum varicolumn       | VDK00844 | Belgium | MG212550 | MG212594 | MG212636 | MH614860* | Vadhvanarath et al. 2018; Vadhvanarath et al. 2019; Vadhvanarath et al. 2019 |
| Maculipilus catanecips   | HKAS79045 | China   | –      | KF112211 | KF112735 | –        | Wu et al. 2014                                                            |
| Neoboletus brunenitius   | HKAS52660 | China   | –      | KF112143 | KF112650 | –        | Wu et al. 2014                                                            |
| Neoboletus brunenitius   | HKAS57451 | China   | –      | KM605149 | KM605172 | –        | Wu et al. 2015                                                            |
| Neoboletus brunenitius   | OR0249 | China   | MG212551 | MG212595 | MG212637 | MH614861* | Vadhvanarath et al. 2018; Vadhvanarath et al. 2019                        |
| Neoboletus hainanensis   | HKAS59469 | China   | –      | KF112175 | KF112669 | –        | Wu et al. 2014                                                            |
| Neoboletus hainanensis   | AF2922 | France  | MG212552 | MG212596 | MG212638 | MH614862* | Vadhvanarath et al. 2018; Vadhvanarath et al. 2019                        |
| Neoboletus junquilleus   | HKAS54096 | China   | –      | KF112149 | KF112654 | –        | Wu et al. 2014                                                            |
| Neoboletus magnificus    | HKAS74939 | China   | –      | KF112148 | KF112653 | –        | Wu et al. 2014                                                            |
| Neoboletus magnificus    | HKAS55440 | China   | –      | KF112145 | KF112652 | –        | Wu et al. 2014                                                            |
| Neoboletus sanguineoides | HKAS76851 | China   | –      | KF112144 | KF112651 | –        | Wu et al. 2014                                                            |
| Neoboletus tasmanica     | OR0128 | Thailand | MH614686 | MH614734 | MH614781 | MH614863 | Vadhvanarath et al. 2019                                                   |
| Neoboletus tomentulosus  | HKAS53369 | China   | –      | KF112154 | KF112659 | –        | Wu et al. 2014                                                            |
| Neoboletus erythropus    | VDKO0690 | Belgium | KT823982 | KT824048 | KT824015 | MH614864* | Raspé et al. 2016; Vadhvanarath et al. 2019 |
| Octaviania asahimontana  | KPM-NC-17824 | Japan  | KC552154 | JN378430 | –        | –        | Orihara et al. 2016; Orihara et al. 2012                                   |
| Octaviania aestromerita  | AQUI3899 | Italy    | KC552159 | KC552093 | –        | –        | Orihara et al. 2016                                                        |
| Octaviania celatifilia   | KPM-NC17766 | Japan   | KC552147 | JN378416 | –        | –        | Orihara et al. 2016; Orihara et al. 2012                                   |
| Octaviania cyanescens    | PNW-FUNGI-5603 | USA    | KC552160 | JN378438 | –        | –        | Orihara et al. 2016; Orihara et al. 2012                                   |
| Octaviania decima        | KPM-NC17763 | Japan   | KC552145 | JN378409 | –        | –        | Orihara et al. 2016; Orihara et al. 2012                                   |
| Octaviania tamanica      | MEL2128484 | Australia | KC552157 | JN378437 | –        | –        | Orihara et al. 2016; Orihara et al. 2012                                   |
| Octaviania tamanica      | MEL2341996 | Australia | KC552156 | JN378436 | –        | –        | Orihara et al. 2016; Orihara et al. 2012                                   |
| Octaviania zelleri       | MES270 | USA      | KC552161 | JN378440 | –        | –        | Orihara et al. 2016; Orihara et al. 2012                                   |
| Patruxenosporus pseudonriki | OR0155 | China   | MG212553 | MG212597 | MG212639 | MH614865 | Vadhvanarath et al. 2019                                                   |
| Phylloporus bellus       | OR0473 | China   | MH580778 | MH580798 | MH580818 | MH614866* | Chuankid et al. 2019; Vadhvanarath et al. 2019                            |
| Species                  | Voucher | Origin   | atp6     | tefl     | rpb2     | cox3     | References                                      |
|-------------------------|---------|----------|----------|----------|----------|----------|------------------------------------------------|
| *Phylloporus brunneiceps* | OR0050  | Thailand | KT823968 | KT824034 | KT824001 | MH614867* | Raspé et al. 2016; *Vadhanarat et al. 2019 |
| *Phylloporus castanopsidus* | OR0052  | Thailand | KT823969 | KT824035 | KT824002 | MH614868* | Raspé et al. 2016; *Vadhanarat et al. 2019 |
| *Phylloporus imbricatus*  | HKAS68642 | China    | –        | KF112299 | KF112786 | –        | Wu et al. 2014                                  |
| *Phylloporus lucerensis*  | HKAS75077 | China    | –        | KF112298 | KF112785 | –        | Wu et al. 2014                                  |
| *Phylloporus maculatus*   | OR0285  | China    | MH580780 | MH580800 | MH580820 | –        | Chuankid et al. 2019                           |
| *Phylloporus pelletieri*  | WU18746 | Austria  | MH580781 | MH580801 | MH580821 | MH614869* | Chuankid et al. 2019; *Vadhanarat et al. 2019 |
| *Phylloporus psallus*     | OR1158  | Thailand | MH580783 | MH580803 | MH580823 | MH614870* | Chuankid et al. 2019; *Vadhanarat et al. 2019 |
| *Phylloporus rhodacanthus*| WU17978 | USA      | MH580785 | MH580805 | MH580824 | MH614871* | Chuankid et al. 2019; *Vadhanarat et al. 2019 |
| *Phylloporus rubrobolus*  | OR0251  | China    | MH580876 | MH580806 | MH580825 | MH614872* | Chuankid et al. 2019; *Vadhanarat et al. 2019 |
| *Phylloporus rubinosus*   | OR0169  | China    | MH580788 | MH580808 | MH580827 | MH614873* | Chuankid et al. 2019; *Vadhanarat et al. 2019 |
| *Phylloporus sp.*         | OR0896  | Thailand | MH580790 | MH580810 | MH580829 | MH614874* | Chuankid et al. 2019; *Vadhanarat et al. 2019 |
| *Phylloporus subbacinophorus* | OR0436  | China    | MH580792 | MH580812 | MH580831 | MH614875* | Chuankid et al. 2019; *Vadhanarat et al. 2019 |
| *Phylloporus subrubrobolus* | BC022   | Thailand | MH580793 | MH580813 | MH580832 | MH614876* | Chuankid et al. 2019; *Vadhanarat et al. 2019 |
| *Phylloporus yunnanensis* | OR0448  | China    | MG212554 | MG212598 | MG212640 | MH614877* | Chuankid et al. 2019; *Vadhanarat et al. 2019 |
| *Porphyrellia castaneus*  | OR0241  | China    | MG212555 | MG212599 | MG212641 | MH614878* | Chuankid et al. 2019; *Vadhanarat et al. 2019 |
| *Porphyrellia cf. nigropurpureus* | ADK3733 | Benin    | MH614687 | MH614735 | MH614782 | MH614879 | Vadhanarat et al. 2019                        |
| *Porphyrellia nigropurpureus* | HKAS54938 | China    | –        | KF112246 | KF112763 | –        | Wu et al. 2014                                |
| *Porphyrellia porphyrophorus* | MB97-023 | Germany  | DQ534609 | GU187734 | GU187800 | –        | Binder & Hibbett 2006; Binder et al. 2010 |
| *Porphyrellia sp.*        | HKAS53366 | China    | –        | KF112241 | KF112716 | –        | Wu et al. 2014                                |
| *Porphyrellia sp.*        | JD659   | Burundi  | MH614688 | MH614736 | MH614783 | MH614880 | Vadhanarat et al. 2019                        |
| *Porphyrellia sp.*        | OR0222  | Thailand | MH614689 | MH614737 | MH614784 | MH614881 | Vadhanarat et al. 2019                        |
| *Pulveroboletus aff. ravenetti* | ADK4360 | Togo     | KT823957 | KT824023 | KT823990 | MH614882* | Raspé et al. 2016; *Vadhanarat et al. 2019 |
| *Pulveroboletus aff. ravenetti* | ADK4650 | Togo     | KT823959 | KT824025 | KT823992 | MH614883* | Raspé et al. 2016; *Vadhanarat et al. 2019 |
| *Pulveroboletus aff. ravenetti* | HKAS53351 | China    | –        | KF112261 | KF112712 | –        | Wu et al. 2014                                |
| *Pulveroboletus fragrans* | OR0673  | Thailand | KT823977 | KT824043 | KT824010 | MH614884* | Raspé et al. 2016; *Vadhanarat et al. 2019 |
| *Pulveroboletus ravenetti* | REH2565 | USA      | KU665635 | KU665636 | KU665637 | MH614885* | Raspé et al. 2016; *Vadhanarat et al. 2019 |
| *Pulveroboletus sp.*      | HKAS574933 | China    | –        | KF112262 | KF112713 | –        | Wu et al. 2014                                |
| Retiboletus aff. nigerrimus | OR0049  | Thailand | KT823967 | KT824033 | KT824000 | MH614886* | Raspé et al. 2016; *Vadhanarat et al. 2019 |
| Retiboletus brunneolus    | HKAS52680 | China    | –        | KF112179 | KF112690 | –        | Wu et al. 2014                                |
| Retiboletus fuscus         | HKAS59460 | China    | –        | JQ928580 | JQ928601 | –        | Hosen et al. 2013                             |
| Retiboletus fuscus         | OR0231  | China    | MG212556 | MG212600 | MG212642 | MH614887* | Vadhanarat et al. 2018; *Vadhanarat et al. 2019 |
| Retiboletus grisius        | MB03-079 | USA      | KT823964 | KT824030 | KT823997 | MH614888* | Raspé et al. 2016; *Vadhanarat et al. 2019 |
| Retiboletus kauffmannii    | OR0278  | China    | MG212557 | MG212601 | MG212643 | MH614889* | Vadhanarat et al. 2018; *Vadhanarat et al. 2019 |
| Retiboletus nigerrimus     | HKAS53418 | China    | –        | KT990824 | KT990462 | –        | Wu et al. 2016                                |
Two new *Erythrophylloporus* species (Boletaceae) from Thailand ...

| Species                        | Voucher | Origin   | atp6   | tef1   | rpb2  | cox3 | References                      |
|-------------------------------|---------|----------|--------|--------|-------|------|---------------------------------|
| Retiboletus rineris           | HKAS59832 | China   | –      | KT990827 | KT990464 | –    | Wu et al. 2016                  |
| Retiboletus Zhangfei          | HKAS59699 | China   | –      | JQ928582 | JQ928603 | –    | Hosen et al. 2013               |
| Rhodactina himalayensis       | CMU25117 | Thailand | MG212558 | MG212602, | MG212603 | –    | Vadhanarat et al. 2018          |
| Rhodactina rotatispora        | SV170   | Thailand | MG212560 | MG212605  | MG212645 | –    | Vadhanarat et al. 2018          |
| Rousbeenvia cryptocephala     | KPM-NC17843 | Japan   | KT581441 | KC552072 | –      | –    | Orihara et al. 2016             |
| Rousbeenvia cyanata           | TNS-F-36986 | Japan   | KC552115 | KC552068 | –      | –    | Orihara et al. 2016             |
| Rousbeenvia griseovelutina    | KPM-NC23336 | New Zealand | KJ001064 | KP222912 | –      | –    | Orihara et al. 2016             |
| Rousbeenvia pachydermiformis  | OSC61484 | Australia | KCS52109 | JN378446 | –      | –    | Orihara et al. 2016;            |
| Rhodactina himalayensis       | HKAS52253 | China   | –      | KT990786 | KT990427 | –    | Wu et al. 2016                  |
| Rhodactina rubina             | HKAS53379 | China   | –      | KF112274 | KF112796 | –    | Wu et al. 2014                  |
| Rubroboletus latiporus        | HKAS80358 | China   | –      | KP055020 | KP055029 | –    | Wu et al. 2016                  |
| Rubroboletus legioides        | VDK00936 | Belgium | KT823985 | KT824051 | KT824018 | MH614890* | Raspé et al. 2016;              |
| Rubroboletus rhodosanguineus  | BOTH4263 | USA     | MG897416 | MG897426 | MG897436 | MH614891* | *Vadhanarat et al. 2019         |
| Rubroboletus rhodoxanthus     | HKAS84879 | Germany | –      | KT990831 | KT990468 | –    | Wu et al. 2016                  |
| Rubroboletus satanae          | VDK00968 | Belgium | KT823986 | KT824052 | KT824019 | MH614892* | Raspé et al. 2016;              |
| Rubroboletus sinicus          | HKAS68620 | China   | –      | KF112146 | KF112661 | –    | Wu et al. 2014                  |
| Rubroboletus sp.              | HKAS68679 | China   | –      | KF112147 | KF112662 | –    | Wu et al. 2014                  |
| Rugiboletus brunneiporus      | HKAS85856 | China   | –      | KF112197 | KF112719 | –    | Wu et al. 2014                  |
| Rugiboletus brunneiporus      | HKAS83209 | China   | –      | Km605144 | Km605168 | –    | Wu et al. 2015                  |
| Rugiboletus extremiorientalis | HKAS63635 | China   | –      | KF112198 | KF112720 | –    | Wu et al. 2014                  |
| Rugiboletus extremiorientalis | HKAS76663 | China   | –      | Km605147 | Km605170 | –    | Wu et al. 2015                  |
| Rugiboletus extremiorientalis | OR0406   | Thailand | MG212562 | MG212607 | MG212647 | MH614893* | *Vadhanarat et al. 2018;         |
| Rugiboletus sp.               | HKAS55373 | China   | –      | KF112303 | KF112804 | –    | Wu et al. 2014;                 |
| Singerocormus inundabilis     | TWH91999 | Guyana  | MH645588 | MH645596 | LC043089* | MH645609 | *Vadhanarat et al. 2019          |
| Singerocormus rubrilatus      | TWH9585  | Guyana  | MH645589 | MH645597 | –      | MH645610 | Vadhanarat et al. 2019          |
| Spongiforma thailandica       | DED7873  | Thailand | MG212563 | KF030436* | MG212648 | MH614894** | *Nuhn et al. 2013;              |
| Strobilomyces atrosquamosus   | HKAS55368 | China   | –      | KT990839 | KT990476 | –    | Wu et al. 2016                  |
| Strobilomyces echinocephalus  | OR0243   | China   | MG212564 | MG212608 | MG212649 | –    | Vadhanarat et al. 2018          |
| Strobilomyces strobilaceus    | RW103    | Belgium | KT823978 | KT824044 | KT824011 | MH614895* | Raspé et al. 2016;              |
| Strobilomyces sp.             | MB-03-102 | USA     | DQ534607* | AY883428 | AY786065 | –    | *Vadhanarat et al. 2019         |
| Strobilomyces mirandus        | OR0115   | Thailand | KT823972 | KT824038 | KT824005 | MH614896* | Raspé et al. 2016;              |
| Strobilomyces sp.             | OR0259   | China   | MG212565 | MG212609 | MG212650 | MH614897* | *Vadhanarat et al. 2018;         |
| Strobilomyces sp.             | OR0778   | Thailand | MG212566 | MG212610 | MG212651 | MH614899* | *Vadhanarat et al. 2019         |

*References:
- Wu et al. 2016
- Hosen et al. 2013
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- Orihara et al. 2016
- Phookamsak et al. 2019
- Orihara et al. 2016
- Orihara et al. 2012
- Vadhanarat et al. 2019
- Orihara et al. 2014
- Orihara et al. 2016
- Orihara et al. 2012
- Phookamsak et al. 2019
- Vadhanarat et al. 2019
- Henkel et al. 2015
- Phookamsak et al. 2019
- *Unpublished
- Raspé et al. 2016;
- Vadhanarat et al. 2019
- Nuhn et al. 2013;
- Vadhanarat et al. 2019; **Vadhanarat et al. 2019

*Vadhanarat et al. 2019
**Vadhanarat et al. 2019

| Species                  | Voucher          | Origin   | atp6  | tef1  | rpb2  | Cox3 | References                  |
|-------------------------|------------------|----------|-------|-------|-------|------|-----------------------------|
| *Strobilomyces* sp.     | OR0319           | Thailand | MH614690 | MH614738 | MH614785 | MH614898 | Vadhanarat et al. 2019     |
| *Strobilomyces* sp.     | OR1092           | Thailand | MH614691 | MH614739 | MH614786 | MH614900 | Vadhanarat et al. 2019     |
| *Strobilomyces* verruculosus | HKA555389    | China    | —     | —     | —     | —     | Wu et al. 2014             |
| *Saullia* amyggdalinus  | 112605ba        | USA      | —     | JQ327024 | —     | —     | Halling et al. 2012a       |
| *Saullia* litorada       | VDKO0241b       | Belgium  | KT823981 | KT824047 | KT824014 | MH614901  | *Raspé et al. 2016;        |
| *Saullia* quelfetti      | VDKO1185        | Belgium  | MH645590 | MH645598 | MH645604 | MH645611 | Vadhanarat et al. 2019     |
| *Saullia* subamyggdalinus | HKA557262    | China    | —     | —     | —     | —     | Wu et al. 2014             |
| *Satorius* australiensis | REH9441        | Australia | MG212567 | JQ327032  | MG212652 | —     | *Halling et al. 2012a;     |
| *Satorius* eximius      | REH9400         | USA      | MG212568 | JQ327029  | MG212653 | MH614902  | *Vadhanarat et al. 2018;   |
| *Satorius* ferrugineus  | HKA577718       | China    | —     | KT990789 | KT990431 | —     | Wu et al. 2016             |
| *Satorius* flavidus     | HKA559443       | China    | —     | KU974136 | KU974144 | —     | Wu et al. 2016             |
| *Satorius* rubriporus   | HKA583026       | China    | —     | KT990795 | KT990437 | —     | Wu et al. 2016             |
| *Satorius* sanguineus   | HKA580823       | China    | —     | KT990802 | KT990442 | —     | Wu et al. 2016             |
| *Satorius* sp.          | OR0378B         | Thailand | MH614692 | MH614740 | MH614787 | MH614903 | Vadhanarat et al. 2019     |
| *Satorius* sp.          | OR0379          | Thailand | MH614693 | MH614741 | MH614788 | MH614904 | Vadhanarat et al. 2019     |
| *Tengioboletus* glutinosus | HKA553425     | China    | —     | —     | —     | —     | Wu et al. 2014             |
| *Tengioboletus* reticulatus | HKA576661     | Japan    | —     | —     | —     | —     | Wu et al. 2014             |
| *Tormulinea* persicina  | KPM-NC18001     | Japan    | K552130 | K552082 | —     | —     | Orihara et al. 2016        |
| *Tormulinea* yunnanensis | KPM-NC1801    | Japan    | K552138 | K552089 | —     | —     | Orihara et al. 2016        |
| *Tylocinum* griseolum   | HKAS50281       | China    | —     | —     | —     | —     | Wu et al. 2014             |
| *Tylopilus* alpinus     | HKAS55438       | China    | —     | —     | —     | —     | Wu et al. 2014             |
| *Tylopilus* atripurpureus | HKAS50208     | China    | —     | —     | —     | —     | Wu et al. 2014             |
| *Tylopilus* balloui s.l.| OR0039          | Thailand | KT823965 | KT824031 | KT823998 | MH614905  | *Raspé et al. 2016;        |
| *Tylopilus* brunneirubens | HKA553388     | China    | —     | KT12192  | KT121892 | —     | *Vadhanarat et al. 2019;   |
| *Tylopilus* felleus     | VDKO0999        | Belgium  | KT823987 | KT824053 | KT824020 | MH614906  | *Raspé et al. 2016;        |
| *Tylopilus* ferrugineus | BOTH3639        | USA      | MH614694 | MH614742 | MH614789 | MH614907  | *Vadhanarat et al. 2019    |
| *Tylopilus* otsuensis   | HKA553401       | China    | —     | KT121224 | KT121229 | —     | Wu et al. 2014             |
| *Tylopilus* sp.         | HKA574925       | China    | —     | KT121222 | KT121239 | —     | Wu et al. 2014             |
| *Tylopilus* sp.         | HKA550229       | China    | —     | KT121216 | KT121276 | —     | Wu et al. 2014             |
| *Tylopilus* sp.         | JD598           | Gabon    | MH614695 | MH614743 | MH614790 | MH614908  | Vadhanarat et al. 2019     |
| *Tylopilus* sp.         | OR0252          | China    | MG212569 | MG212611 | MG212654 | MH614909  | Vadhanarat et al. 2018;    |
| *Tylopilus* sp.         | OR0542          | Thailand | MG212570 | MG212612 | MG212655 | MH614910  | *Vadhanarat et al. 2019;    |
| *Tylopilus* sp.         | OR0583          | Thailand | MH614696 | MH614744 | —     | —     | *Vadhanarat et al. 2019     |
| *Tylopilus* sp.         | OR1009          | Thailand | MH614697 | —     | MH614791 | MH614911 | Vadhanarat et al. 2019     |
| *Tylopilus* vinaceipallidus | HKA550210    | China    | —     | —     | KT121221 | KT121238 | Wu et al. 2014             |
| *Tylopilus* violaceobrunneus | OR0137        | China    | MG212571 | MG212613 | MG212656 | MH614912  | *Vadhanarat et al. 2018;    |
| *Tylopilus* virens      | HKA589443       | China    | —     | KT990886 | KT990504 | —     | Wu et al. 2016             |

Unpublished
also clustered in the Erythrophylloporus clade indicating that they are close relatives. Erythrophylloporus formed a clade sister to the genus Singerocomus T.W. Henkel & M.E. Sm. with high Bootstrap support (96%) but low posterior probability support (0.86) within the Pulveroboletus group. Some undescribed species formed two different generic clades in the Pulveroboletus group. Boletus p.p. spp. clade 1 contains two specimens, HKAS63598 and HKAS9660, named "Boletus sp." in Wu et al. (2016), as well as two of our specimens, OR0832 and OR1002. Boletus p.p. sp. clade 2 contains a single African specimen, JD0693, sister to and morphologically different from Cyanoboletus.
Taxonomy

*Erythrophyllorpus* Ming Zhang & T.H. Li, *Mycosystema* 37(9): 1111–1126 (2018)

**Description.** Basidiomata stipitate-pileate with lamellate hymenophore, small to medium-sized; *Pileus* subhemispheric to convex when young becoming convex to plano-convex to plano-subdepressed when old, dry, pruinose or velutinous, submentose to tomentose, yellowish-orange to red; *pileus context* vivid yellow to yellowish-orange. *Hymenophore* lamellae, slightly thick, decurrent, deeply yellowish-orange to deep orange or reddish-orange to orange red or brownish-orange to red. *Stipe* central to slightly excentric, cylindrical or clavate, yellowish- to reddish-orange to yellowish red, with scattered yellowish- to reddish-orange to red scales on surface, with bright yellow basal mycelium; *stipe context* solid, yellow to reddish-yellow or yellow with olivaceous
Two new *Erythrophylloporus* species (Boletaceae) from Thailand ...

Brown. Staining none or slightly reddening or greening or gradually bluing or dark violet, greyish to blackish-blue when bruised on the basidiomata or context or lamellae. Spore print olivaceous brown. Basidiospores ovoid or ellipsoid to broadly ellipsoid to subovoid, thin-walled, with non-bacillate surface. Basidia clavate to narrowly clavate. Cheilocystidia and pleurocystidia present, subcylindrical or narrowly conical to narrowly fusiform to ventricose with slightly or obtuse apex, thin-walled, sometimes thick-walled, originating more or less deeply in the subhymenium or from hymenophoral trama, hyaline or sometimes containing yellowish-brown pigments. Pileipellis a subcutis to cutis to trichoderm to palisadoderm, composed of thin to slightly thick-walled hyphae. Clamp connection absent in all tissues.

**Typus species.** *Erythrophylloporus cinnabarinus* Ming Zhang & T.H. Li.

**Known Distribution.** Asia (China and Thailand), North America (Mexico) and Central America (Costa Rica).

**Remarks.** *Erythrophylloporus* is easily distinguished from other lamellate Boletaceae genera by a combination of the following characters: the intense orange to red colour of the pileus and lamellae; bright yellow basal mycelium; ovoid or ellipsoid to broadly ellipsoid to subovoid basidiospores with non-bacillate surface; pleurocystidia originating more or less deeply in the subhymenium or from hymenophoral trama.

**Erythrophylloporus paucicarpus** Raspé, Vadthanarat & Lumyong, sp. nov.

*Mycobank*: MB823605

Figs. 2A, 3A, 4A and 5

Holotype. THAILAND, Chiang Mai Province, Mae On District, Huay Kaew, 18°52’0”N, 99°17’30”E, elev. 700 m, 16 August 2016, O. Raspé & S. Vadthanarat, OR1151, (holotype: CMUB, isotype: BR).

**Etymology.** from Latin “pauci-” meaning few and “carpus” meaning fruits or what is harvested, refers to the low number of basidiomata produced.

**Description.** Basidiomata stipitate-pileate with lamellate hymenophore, small to medium-sized. *Pileus* 2.3–5.5 cm in diameter, plano-convex with involute margin at first becoming almost plane to slightly depressed with inflexed to straight margin, irregularly and coarsely crenate in age, sometimes with low and broad umbo and a few to several verrucae, especially when young; surface more or less even, tomentose, dull, slightly moist, colour distribution patchy with red to brownish-orange (9B8 to 9C8), brownish-red (10E8 to 10D8) becoming orange-red to orange (8B/C8 to 6B7) at the margin when old, abruptly paler at the margin. *Pileus context* 3–4 mm thick half-way to the margin, tough, colour distribution even, yellow (3A6) to yellowish-orange (4A5), slowly reddening when exposed, especially at the centre and above lamellae. *Stipe* 2.4–4.5 × 0.7–1.3 cm, central or sometimes slightly eccentric, clavate with strigose base, straight to curved, terete, even, dull, dry, tomentose, yellowish-orange (4–5A7–8) to orange (6–7A7–8) with orange to yellowish-orange (7B/C7–8 to 4A7–8) coarse scales, with bright yellow (2A6–7) basal mycelium. *Stipe context* solid, fleshy fibrous, yellow
marbled with olivaceous brown (4D5, 5D5). Hymenophore lamellate; lamellae decurrent, close, thick, 40–42 lamellae, with 4–6 different lengths of lamellulae, 2–4.5 mm wide half-way to margin, somewhat anastomosing, especially near the stipe, yellowish-orange (4-5A6-7) with orange to red tinge, slightly reddening when bruised. Odour rubbery; Taste not recorded. Spore print olive-brown (4E7).

Macrochemical reactions. KOH on pileus and stipe surface deep red at first, then red-brown to brown, with pale orange aura on the pileus; brown on pileus context, dark red-brown on stipe context; brownish-orange on hymenophore. NH₄OH on pileus first red, then orange; on pileus context bluing at first then with a greenish tinge; on stipe surface and context briefly bluing; no reaction on hymenophore.

**Basidiospores** [208/4/4] (5.9–)6.1–6.8–7.5(–8) × (4.1–)4.6–5.1–5.5(–6) µm, $Q = (1.2–)1.23–1.33–1.48(–1.56)$; from the type (OR1151) (6–)6.3–6.8–7.5(–7.8) × (4.6–)4.8–5.2–5.5(–6) µm, $Q = (1.2–)1.22–1.31–1.48(–1.56)$, $N = 88$, broadly ellipsoid to ellipsoid, smooth under light microscope and SEM, yellowish to pale brown in water, hyaline in 5% KOH, thin-walled, inamyloid. *Basidia* 4–spored, (37.8–)38–45.6–54.7(–54.8) × (6.2–)–6.3–8–9.5(–9.6) µm, narrowly clavate to subcylindrical, attenuated towards the base, clampless, hyaline to yellowish hyaline in water, Melzer’s reagent and 5% KOH; *Cheilocystidia* (35.4–)35.5–49.9–61.8(–61.9) × (3.9–)3.9–6–7.7(–7.7) µm, narrowly fusiform with obtuse apex, projecting up to 30 µm, thin-walled, smooth, yellowish hyaline in water, in 5% KOH and NH₄OH, inamyloid. *Pleurocystidia* (66.9–)67.4–80.3–93.5(–94.7) × (8.8–)8.9–11.7–16.1(–16.2) µm, abundant, narrowly conical with obtuse, somewhat prolonged apex, projecting up to 32 µm, thin-walled, smooth, yellowish hyaline in water, in 5% KOH and NH₄OH, arising more or less deeply in the subhymenium or from hymenophoral trama, inamyloid. Hymenophoral trama subregular near the pileus context becoming slightly divergent near the edge, 87–238 µm wide, widest near the pileus context then getting narrower when close to the edge, composed of clampsess hyphae 4.5–8 µm wide, yellowish hyaline in water, hyaline in 5% KOH and NH₄OH, inamyloid. *Pileipellis* a palisadoderm to trichoderm 83–165 µm thick, composed of slightly thick-walled, cylindrical hyphae, terminal cells 16–46 × 4–6.5 µm with rounded apex, hyaline or yellowish hyaline to yellowish-orange hyaline hyphae ornamented with scattered fine epiparietal encrustation when observed in water, hyaline to yellowish hyaline in 5% KOH and NH₄OH, inamyloid. *Pileus trama* composed of slightly thick-walled, strongly interwoven hyphae, 4.5–8.5 µm wide, inamyloid. *Stipitipellis* a disrupted palisadoderm perpendicular to the stipe axis, 63–145 µm thick, composed of slightly thick-walled, slightly rough, cylindrical, yellow to yellowish-orange in water, yellowish hyaline hyphae in 5% KOH and NH₄OH, terminal cells 13–57 × 3–8 µm, cylindrical to irregular hyphae with rounded to notched apex; wall covered by dispersed fine encrustations when observed in water. Caulocystidia not seen. *Stipe trama* composed of parallel hyphae, densely packed, 4–8.5 µm wide; hyphae wall covered by dispersed encrustations when observed in water. Clamp connections not seen in any tissue.

**Habit and habitat.** On soil, mostly solitary in dipterocarp forest dominated by *Dipterocarpus tuberculatus, D. obtusifolius, Shorea obtusa, S. siamensis, Quercus* spp. and *Lithocarpus* spp.
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![Image of Erythrophylloporus species](image)

**Figure 2.** Habits of Thai *Erythrophylloporus* species **A** *E. paucicarpus* **B** *E. suthepensis*. Scale bars: 1 cm.

**Known distribution.** Currently known only from Chiang Mai Province, northern Thailand.

**Additional specimens examined.** – THAILAND, Chiang Mai Province, Muang District, Doi Suthep-Pui National Park, 18°48’05”N–98°55’40”E, elev. 800 m, 17 May 2015, *O. Raspé*, OR0615A (CMUB, BKF, BR); Mae Taeng District, Baan Tapa,
Santhiti Vadthanarat et al. / MycoKeys 55: 29–57 (2019)

Remarks. *E. paucicarpus* is characterised by the following combination of features: orange to brownish- to orange-red basidiomata, yellowish-orange lamellae that turn slightly red when bruised; pileus context yellow to yellowish-orange that slowly reddens when exposed and mostly occurring as solitary basidiomata.

In the inferred molecular phylogeny, *E. paucicarpus* clustered close to *E. suthepensis* and *E. cinnabarinus* (65% BS and 1 PP), but the two species are different from

Figure 3. Scanning electron micrographs of basidiospores from Thai *Erythropyllloporus* show smooth surfaces A *E. paucicarpus* B *E. suthepensis*. Scale bars: 1 µm.

Figure 4. Origin of pleurocystidia (white arrow), more or less deep in the subhymenium or from hymenophoral trama A *E. paucicarpus* B *E. suthepensis* – hymenium (H), subhymenium (SH), Scale bars: 25 µm (A–B).

19°08'29"N, 98°45'47"E, elev. 1035 m, 4 August 2015, O. Raspé & A. Thawthong, OR0689 (MFLU, BR); Mae On District, Huay Kaew, 18°52'12"N, 99°18'12"E, elev. 780 m, 15 August 2016, O. Raspé & S. Vadthanarat, OR1135 (CMUB, BR).
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**Figure 5.** Microscopic features of *Erythropylloporus paucicarpus* **A** basidiospores **B** basidia **C** cheilocystidia **D** pleurocystidia **E** pileipellis **F** stipitpellis. – Scale bars: 10 µm (**A–B**); 50 µm (**C–F**). All drawings were made from the type (OR1151).
*E. paucicarpus* in that they have darker lamellae which are orange to orange red or brownish-orange. Moreover, spores of *E. paucicarpus* are wider and longer (5.9–8 × 4.1–6 µm) than those of *E. suthepensis* (4.6–5.9 × 3.5–4.5 µm) and, on average, longer than those of *E. cinnabarinus* (5.5–7 × 4.5–5.5 µm) (Zhang and Li 2018). *Erythrophylloporus paucicarpus* also differs from both species by the slight reddening of the context and lamellae when exposed or bruised, whereas *E. suthepensis* context seems unchanging when exposed and lamellae turn blue when bruised. In *E. cinnabarinus*, the context slowly turns dark violet, blackish-blue to dark blue when exposed and lamellae turn greyish-blue, or greyish-green when bruised (Zhang and Li 2018).

*Erythrophylloporus paucicarpus* is different from the two New World species by the reddening of the context, whereas in *E. fagicola*, it turns blue and, in *E. aurantiacus*, the colour remains unchanged when exposed. Moreover, *E. fagicola* has somewhat thick-walled (0.8–3.5 µm) pleurocystidia (Montoya and Bandala 2011), which are not found in *E. paucicarpus*. Although the basidiospores of *E. paucicarpus* and *E. aurantiacus* are similar in size (*E. aurantiacus* = 6.0–7.5 × 4–5.5 µm), they differ in shape, being more ovoid in *E. aurantiacus* than in *E. paucicarpus*. *Erythrophylloporus paucicarpus* also differs from *E. aurantiacus* by macro-chemical reactions. In the latter, the pileus surface and pileus context are unchanging with NH₄OH (Halling et al. 1999), while in *E. paucicarpus*, the pileus becomes orange to red and the pileus context initially turns blue then with a greenish tinge.

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**Erythrophylloporus suthepensis** Vadthanarat, Raspé & Lumyong, sp. nov.

MycoBank: MB823606

Figs. 2B, 3B, 4B and 6

**Holotype.** THAILAND, Chiang Mai Province, Muang District, Doi Suthep-Pui National Park, 18°48'47"N, 98°55'56"E, elev. 645 m, 25 August 2015, S. Vadthanarat, SV0236, (holotype CMUB, isotype BKF, BR).

**Etymology.** Refers to the type locality Doi Suthep.

**Description.** Basidiomata stipitate-pileate with lamellate hymenophore, small-sized. *Pileus* (1.0–)2.5–3.5 cm in diameter, subumbonate with involute margin at first, becoming convex to plano-convex with inflexed margin; surface even with some small pustules, tomentose, dull, slightly moist, yellow (3–4A4–5) becoming light orange to orange-red (5–6A5–7 to 7–8A–B7–8) with patches of light yellow to light orange (4–5A5–6) becoming brownish-orange to dull red (7B–C8 to 8B–D8) with age, the colour of the margin when young clearly paler than the rest of the pileus, bluing when bruised. *Pileus context* 2–3 mm thick half-way to the margin, tough, yellowish-orange (4A5), unchanging when bruised. *Stipe* 2.5–4.5 × 0.3–0.8 cm, central, slightly curved, terete, dull, dry, yellowish-orange (2A6–7) with greyish-orange (5–6 B7–8) coarse scales at first, then light yellow or reddish-yellow to brownish-orange (4A/B5–6 to 7C6) with brownish-red to reddish-dark brown (7F4–5, 8C7–8, 8F5–7) scales, sub-bulbous, with bright yellow to greyish-yellow (2A6–7 to 3A/B5–6) sparse basal mycelium that extends half-way up the stipe. *Stipe context* solid, tough, reddish-yellow (4A6) near the pileus
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**Figure 6.** Microscopic features of *Erythrophylloporus suthepensis* A basidiospores B basidia C cheilocystidia D pleurocystidia E pileipellis F stipitipellis showing some dark caulocystidia mixed with slightly rough, cylindrical to irregular hyphae. – Scale bars: 10 µm (A–B); 50 µm (C–F). All drawings were made from the type (SV0236).
then paler to light yellow (4A5) near the base, unchanging when bruised. *Hymenophore* lamellate; lamellae decurrent, subdistant, slightly thick, with sinuate edge, of varying lengths, 26–34 lamellae, with 4–6 different lengths of lamellulae, 4–5 mm wide halfway to margin, brownish-orange (7C7–8) with deep yellow to orange (4–5A7–8) edge, bluish-grey when looking tangentially to the surface, bluing when bruised. *Odour* rubbery. *Taste* mild with rubbery texture. *Spore print* olivaceous brown (4F5).

**Macrochemical reactions.** KOH orange-brown on pileus and stipe surface; yellowish-brown on pileus and stipe context and hymenophore. NH$_4$OH yellowish-brown on pileus and stipe context.

*Basidiospores* [218/4/2] (4.6–)4.8–5.2–5.7(–5.9) × (3.5–)3.6–4–4.3(–4.5) µm, Q = (1.15–)1.21–1.32–1.44(–1.57); from the type (SV0236) (4.6–)4.8–5.2–5.7(–5.9) × (3.5–)3.6–3.9–4.4(–4.5) µm, Q = (1.15–)1.21–1.32–1.43(–1.57), N = 80, broadly ellipsoid to subglobule, smooth under light microscope and SEM, yellowish to pale brown in water, hyaline in 5% KOH, thin-walled, inamyloid. *Basidia* 4-spored, (24.7–)25.3–31.1–35.8(–35.9) × (5.3–)5.3–6.6–7.5(–7.5) µm, narrowly clavate to subcylindrical, attenuated towards the base, clampless, hyaline to yellowish hyaline in water, Melzer’s reagent and 5% KOH; *sterigmata* up to 4.5 µm long. *Cheilocystidia* (37.3–)37.9–51–63.8(–64.1) × (5.3–)5.4–8.5–12.4(–13.7) µm, narrowly conical to narrowly fusiform with obtuse apex, projecting up to 25 µm, thin-walled, smooth, yellowish-hyaline in water, hyaline in 5% KOH and NH$_4$OH, inamyloid, more or less forming a sterile edge. *Pleurocystidia* (46.5–)49.2–68.9–95.2(–99.3) × (9.3–)9.6–12.6–18.9(–20) µm, abundant, narrowly conical with obtuse apex, projecting up to 28 µm, thin-walled, mostly yellowish hyaline in water and hyaline in 5% KOH and NH$_4$OH, some containing yellowish-brown to dark brown pigments in water and yellowish-pale brown in 5% KOH and NH$_4$OH, inamyloid, arising more or less deeply in the subhymenium or from hymenophoral trama. *Hymenophoral trama* subregular near the pileus context becoming slightly divergent near the edge, 46–192 µm wide, widest near the pileus context then getting narrower when close to the edge, composed of clampless hyphae 2.5–7.5 µm wide, pinkish-red hyaline in water, especially at the centre of the trama, yellowish hyaline to hyaline in 5% KOH and NH$_4$OH, inamyloid. *Pileispellis* a palisadoderm to trichoderm 71–119 µm thick, composed of slightly thick-walled, cylindrical to irregular hyphae with fine encrustation on the wall, terminal cells 12–46 × 3.5–9 µm with pointed to notched apex or sometimes truncated apex, with 6–15(–28) µm short cells at the base, hyaline or yellowish-orange hyaline to orange hyaline hyphae with scattered fine encrustation on the wall when observed in water, hyaline to yellowish hyaline in 5% KOH and NH$_4$OH, inamyloid. *Pileus context* composed of slightly thick-walled, strongly interwoven hyphae, 5–8.5 µm wide, inamyloid. *Stipitpellis* a disrupted palisadoderm perpendicular to the stipe axis, 47–123 µm thick, composed of slightly thick-walled, cylindrical to irregular hyphae with fine encrustations on the wall, yellow to yellowish-orange, intermixed with mostly yellowish hyaline to yellowish-brown hyphae in 5% KOH and NH$_4$OH, terminal cells 14–47 × 4–8.5 µm with variously notched apex. *Caulocystidia* mixed in a group with the stipitpellis hyphae, same shape and size as the pleurocystidia, dark brown in water, paler in 5% KOH and NH$_4$OH. *Stipe context* composed of parallel,
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densely packed, 4–9.5 µm wide hyphae, hyphae wall with scattered fine encrustations when observed in water. **Clamp connections** not seen in any tissue.

**Habit and habitat.** On soil, gregarious (up to 10 basidiomata) in dipterocarp forest dominated by *Dipterocarpus tuberculatus*, *D. obtusifolius*, *Shorea obtusa* and *S. siamensis*, mixed with scattered fagaceous trees.

**Known distribution.** Currently known only from Doi Suthep-Pui National Park, Chiang Mai Province, northern Thailand.

**Additional specimens examined.** – THAILAND, Chiang Mai Province, Meuang District, Doi Suthep-Pui National Park, 18°48'05”N, 98°55'40”E, elev. 800 m, 17 May 2015, O. Raspé, OR0615B (CMUB, BKF, BR).

**Remarks.** *Erythrophylloporus suthepensis* is characterised by the following combination of features: yellow to light orange to orange red to brownish-orange to dull red pileus; brownish-orange lamellae with deep yellow to orange edge; the colour of the lamellae appears more bluish-grey when observed from an oblique angle to the surface; pileus surface and lamellae turning blue when bruised; some pleurocystidia containing yellowish-brown to dark brown pigments in water; basidiospores that are smaller or shorter (4.6–5.9 × 3.5–4.5 µm) than the other *Erythrophylloporus* species (*E. aurantiacus* = 6.0–7.5 × 4–5.5µm; *E. cinnabarinus* = 5.5–7 × 4.5–5.5 µm; *E. fagicola* = 6.5–11 × 4–7.5 µm; *E. paucicarpus* = 5.9–8 × 4.1–6 µm) (Halling et al. 1999, Montoya and Bandala 2011, Zhang and Li 2018).

Morphologically, *E. suthepensis* is quite similar to *E. cinnabarinus* in that they have similar colours in pileus and lamellae; the lamellae in both species also turn more or less blue to dark blue when bruised. *Erythrophylloporus suthepensis* and *E. cinnabarinus* are also similar, based on some pleurocystidia containing yellowish-brown to dark brown pigments, but those features are not found in *E. paucicarpus* and in the two New World *Erythrophylloporus* species (Halling et al. 1999, Montoya and Bandala 2011). However, the pleurocystidia containing brown pigments seem to be more frequent in *E. cinnabarinus*, which also has, on average, larger basidiospores than *E. suthepensis* (Zhang and Li 2018).

The pinkish-red hymenophoral trama of *E. suthepensis* was not found in either *E. paucicarpus* or in the two American *Erythrophylloporus* species. In our observation of the two American specimens (*E. aurantiacus* voucher REH7271 and *E. fagicola* voucher Garay215), we found that the hymenophoral trama was yellowish hyaline when observed in water. The original description of *E. cinnabarinus* does not mention the colour of the hymenophoral trama and we could not obtain a specimen to observe this character. However, other morphological characters and phylogenetic evidence are enough to differentiate *E. suthepensis* from *E. cinnabarinus*.

Our phylogenetic analyses of a four-gene dataset revealed that *Phylloporus aurantiacus* from Costa Rica and *P. fagicola* from Mexico clustered in the *Erythrophylloporus* clade with high support (BS = 100% and PP = 1). Both species possess the distinctive morphological characters of *Erythrophylloporus*, which include yellowish-orange to reddish-orange basidiomata, orange to orange brown lamellae, bright yellow basal mycelium, ovoid or ellipsoid to broadly ellipsoid basidiospores with smooth surface and subcylindrical to subfusoid to ventricose cheilocystidia and pleurocystidia (Halling et al. 1999, Montoya and Bandala 2011). Therefore, the following two new combinations are proposed:
**Erythrophylloporus aurantiacus** (Halling & G.M. Muell.) Raspé & Vadthanarat, **comb. nov.**
MycoBank: MB823607

**Basionym.** Phylloporus aurantiacus Halling & G.M. Mueller, Mycotaxon 73: 64 (1999)

**Specimen examined.** – COSTA RICA. Near town of Palo Verde, elev. 1600 m, 11 June 1994, Halling 7271 (NY).

**Erythrophylloporus fagicola** (Montoya & Bandala) Raspé & Vadthanarat, **comb. nov.**
MycoBank: MB823608

**Basionym.** Phylloporus fagicola Montoya & Bandala, Mycotaxon 117: 10 (2011)

**Specimen examined.** – MEXICO. Veracruz: Mpio. Acatlán, Acatlán Volcano, 29 September 2009, Garay 215 (XAL).

**Key to the species in** *Erythrophylloporus*

1 Growing in North or Central America.................................2
   – Growing in Southeast Asia or in tropical to subtropical China........3
2 Bluing of the context when exposed; basidiospores ellipsoid to oblong, obtuse, 6.5–11 × 4–7.5 µm; pleurocystidia somewhat thick-walled (0.8–3.5 µm thick)................................................................. *E. fagicola*
   – Context unchanging when exposed; basidiospores ovoid to subellipsoid, 6.0–7.5 × 4–5.5 µm; pleurocystidia thin-walled........ *E. aurantiacus*
3 Yellowish-orange lamellae slightly reddening when bruised; context slowly or slightly reddening when exposed........... *E. paucicarpus*
   – Brownish-orange or orange, deep orange, reddish-orange to orange red lamellae bluing to greyish-green when bruised; context unchanging to gradually turning dark violet, blackish to dark blue.........................4
4 Basidiospores 4.6–5.9 × 3.5–4.5 µm, broadly ellipsoid to subglobose; cystidia mostly hyaline, only some containing yellowish-brown to dark brown pigments....................................................... *E. suthepensis*
   – Basidiospores 5.5–7 × 4.5–5.5 µm, broadly ellipsoid, ellipsoid to nearly ovoid; cystidia usually containing yellowish-brown pigments...... *E. cinnabarinus*

**Discussion**

Both phylogeny and morphology support the placement of the two new species from Thailand, *E. paucicarpus* and *E. suthepensis* in the genus *Erythrophylloporus*. Phylogenetically, both species were highly supported in the *Erythrophylloporus* clade.
Two new *Erythrophylloporus* species (Boletaceae) from Thailand...

Two new *Erythrophylloporus* species (Boletaceae) from Thailand... close to *E. cinnabarinus* (typus generis). Morphologically, they are characterised by having yellowish-orange to reddish- to brownish-orange basidiomata with bright yellow basal mycelium and smooth, ellipsoid, broadly ellipsoid to subglobose basidiospores. The other lamellate Boletaceae in *Phylloporus*, *Phylloboteletellus* and *Phylloporopsis* are solely similar to the new species by having a lamellate hymenophore instead of a poroid hymenophore. However, *Phylloporus* differs from *Erythrophylloporus* species by having whitish- to yellowish-pale brown basidiomata with yellow to golden-yellow lamellae, with off-white to whitish to yellow basal mycelium and most species in the genus have basidiospores with more or less bacillate ornamentation under SEM (Neves & Halling 2010, Neves et al. 2012, Zeng et al. 2013). The single *Phylloboteletellus* species, *Ph. chloephorus* Singer differs from *Erythrophylloporus* by having longitudinally ridged basidiospores (Bandala et al. 2004). The sole species of *Phylloporopsis*, *Phy. boletinoides*, differs by having beige to olive-cream or olive buff lamellate to subporoid hymenophore, with anastomosing and interveined gills and basal mycelium whitish to yellowish (Farid et al. 2018). Moreover, those genera are phylogenetically distant from *Erythrophylloporus*. (Bandala et al. 2004, Neves & Halling 2010, Neves et al. 2012, Zeng et al. 2013, Farid et al. 2018).

Interestingly, *Phylloporus coccineus* Corner, described from Singapore (Corner 1970), is similar to *Erythrophylloporus* species, in that it produces crimson to scarlet, lamellate basidiomata with orange to orange-red lamellae and yellow basal mycelium, broadly ellipsoid to subglobose and smooth basidiospores. It probably should also be transferred to *Erythrophylloporus*, but we refrain from doing so until specimens become available for molecular study. According to the protologue of *P. coccineus*, it differs from the newly described Asian species of *Erythrophylloporus* by having larger basidiospores (7.5–10 × 6.5–8 µm), larger cheilocystidia (70–120 × 10–18 µm) and larger caulocystidia (up to 200 × 10–16 µm) (Corner 1970).

*Erythrophylloporus* species formed two clades, an Asian species clade (BS = 65% and PP = 1) and a New World species clade (BS = 100% and PP = 1) (Fig. 1). The Asian one contains three species, *E. cinnabarinus*, *E. paucicarpus* and *E. suthepensis*, while the American clade contains the remaining two species *E. aurantiacus* and *E. fagicola*. *Erythrophylloporus aurantiacus* and *E. fagicola* seem to be genetically very close to each other, much closer than the species in the Asian clade. Only morphological differences between the two species were used to separate them from each other. *Erythrophylloporus fagicola* produces larger basidiospores than *E. aurantiacus* and pleurocystidia are somewhat thick-walled (0.8–3.5 µm thick) in *E. fagicola*, whereas they are thin-walled in *E. aurantiacus* and the latter has non-staining context, whereas the former has a cyanescent context. However, the descriptions were based on a limited number of collections and more samples are desirable to verify whether the morphological traits observed are good characters differentiating the two species or merely extremes of a continuum in morphological variation within a single species.

Regarding the phylogenetic affinities of *Erythrophylloporus*, Zhang and Li (2018) reported that it was likely close to the genus *Rugiboletus* G. Wu & Zhu L. Yang and *Lanmaoa* G. Wu & Zhu L. Yang, based on a multilocus dataset of nrLSU, *tef1*, *rpb*
and rpb2, although this relationship was not supported in their phylogram. In our phylogeny, based on a multilocus dataset of atp6, tef1, rpb2 and cox3, with wider taxon sampling, Erythrophylloporus also clustered within the Pulveroboletus group, but was sister to Singerocomus with high bootstrap support (96%) but relatively weak posterior probability support (0.86). Singerocomus contains three species, S. atlanticus A.C. Magnago, S. inundabilis (Singer) T.W. Henkel and S. rubriflavus T.W. Henkel & Husbands that have some similar morphological characters to Erythrophylloporus, including red-orange to red pileus and light yellow basal mycelium. The three existing Singerocomus species are clearly different from all known Erythrophylloporus species by having a poroid, non-cyanescent hymenophore (Henkel et al. 2016, Magnago et al. 2018). However, the hymenophore structure (lamellate vs. poroid) is not sufficient to separate genera in Boletaceae. Phylloporus currently contains both lamellate and poroid species, although some poroid species have already been transferred to another genus, Hourangia (Zhu et al. 2015). Phylogenetic analyses, including the remaining poroid Phylloporus species, are needed to verify their taxonomic position.

Erythrophylloporus putatively forms ectomycorrhizal associations with trees in family Fagaceae, including the genera Fagus, Lithocarpus and Quercus (Neves and Halling 2010, Montoya and Bandala 2011, Zhang and Li 2018). The two Thai Erythrophylloporus species were found in forests dominated by Dipterocarpaceae trees, mainly Dipterocarpus, including D. tuberculatus, D. obtusifolius and Shorea, including S. obtusa and S. siamensis. However, some Quercus and Lithocarpus trees (Fagaceae) were also observed in the vicinity and could also be the ectomycorrhizal partners. Further study is needed to confirm the ectomycorrhizal relationships of Erythrophylloporus.

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