New and noteworthy boletes from subtropical and tropical China

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Abstract
The morphology, ecology, and phylogenetic relationships of specimens of the family Boletaceae from subtropical and tropical China were investigated. Four species, Butyriboletus huangnianlaii, Lanmaoa macrocarpa, Neoboletus multipunctatus, and Sutorius subrufus, are new to science. Chalciporus radiatus and Caloboletus xiangtoushanensis are redescribed. Caloboletus guanyui is proposed to replace Boletus quercinus Hongo, an illegitimate later homonym. The recently described Tylopilus callatinus is synonymized with the Japanese Boletus virescens, and the new combination T. virescens (Har. Takah. & Taneyama) N.K. Zeng et al. is proposed. Moreover, Neoboletus is treated as an independent genus based on evidence from morphology and molecular phylogenetic data in the present study, and many previously described taxa of Sutorius are recombined into Neoboletus: N. ferrugineus (G. Wu et al.) N.K. Zeng et al., N. flavidus (G. Wu & Zhu L. Yang) N.K. Zeng et al., N. hainanensis (T.H. Li & M. Zang) N.K. Zeng et al., N. obscurembriinus (Hongo) N.K. Zeng et al., N. rubriporus (G. Wu & Zhu L. Yang) N.K. Zeng et al., N. sanguineoides (G. Wu & Zhu L. Yang) N.K. Zeng et al., N. sanguineus (G. Wu & Zhu L. Yang) N.K. Zeng et al., and N. tomentulosus (M. Zang et al.) N.K. Zeng et al.

Keywords
Molecular phylogeny, morphology, new taxa, taxonomy
Introduction

Boletaceae Chevall. (Boletales) is a large, cosmopolitan family with abundant species. Many of them are interesting and important for their mycorrhizal relationships with trees, edibility, medicinal value, and toxicity (Wang et al. 2004; Roman et al. 2005; Wu et al. 2013; Chen et al. 2016). In China, species of Boletaceae have received much attention by mycologists, and many taxa have been discovered across the country (Chiu 1948; Zang 2013; Zeng et al. 2013, 2016, 2017; Liang et al. 2016, 2017; Wu et al. 2016a). However, the diversity of species still remains poorly known in subtropical and tropical China, a biodiversity hotspot. During field trips in the past several years, many collections of boletes have been made in subtropical and tropical China. Evidence from morphology, molecular phylogenetic analyses, and ecological data indicate that these collections belong to *Butyriboletus* D. Arora & J.L. Frank, *Caloboletus* Vizzini, *Chalciporus* Bataille, *Lanmaoa* G. Wu & Zhu L. Yang, *Neoboletus* Gelardi et al., *Sutorius* Halling et al., and *Tylopilus* P. Karst. Thus, they are described/redescribed in an effort to (i) further demonstrate the species diversity in subtropical and tropical China, (ii) resolve some taxonomic quandaries in Boletaceae.

Materials and methods

Abbreviations of generic names used in the study

The abbreviations of *Boletus*, *Butyriboletus*, *Caloboletus*, *Chalciporus*, *Crocinoboletus*, *Lanmaoa*, *Neoboletus*, *Sutorius*, *Tylopilus* mentioned in this work are *B.*, *But.*, *C.*, *Ch.*, *Cr.*, *L.*, *N.*, *S.* and *T.*, respectively.

Collection sites and sampling

Specimens were collected from subtropical and tropical China including Hainan and Fujian Provinces. Specimens examined are deposited in the Fungal Herbarium of Hainan Medical University (FHMU), Haikou City, Hainan Province, China, the Herbarium of Cryptogams, Kunming Institute of Botany, Chinese Academy of Sciences (HKAS), and the Mycological Herbarium of Pharmacy College, Kunming Medical University (MHKMU).

Morphological studies

The macroscopic descriptions are based on detailed notes and photographs taken from fresh basidiomata. Color codes are from Kornerup and Wanscher (1981). Sections of the pileipellis were cut radial-perpendicularly and halfway between the center and
margin of the pileus. Sections of the stipitpellis were taken from the middle part along the longitudinal axis of the stipe. Five percent KOH was used as a mounting medium for microscopic studies. All microscopic structures were drawn by freehand from rehydrated material. The number of measured basidiospores is given as $n/m/p$, where $n$ represent the total number of basidiospores measured from $m$ basidiomata of $p$ collections. Dimensions of basidiospores are given as $(a)b – c(d)$, where the range $b – c$ represents a minimum of 90% of the measured values (5th to 95th percentile), and extreme values ($a$ and $d$), whenever present ($a < 5$th percentile, $d > 95$th percentile), are in parentheses. $Q$ refers to the length/width ratio of basidiospores; $Q_m$ refers to the average $Q$ of basidiospores and is given with a sample standard deviation.

DNA extraction, primers, PCR and sequencing

Total genomic DNA was obtained with Plant Genomic DNA Kit (TIANGEN Company, China) from materials dried with silica gel according to the manufacturer's instructions. The primers used for amplifying the nuclear ribosomal large subunit RNA (28S) were LROR/LR5 (Vilgalys and Hester 1990; James et al. 2006), ITS5/ITS4 (White et al. 1990) for the nuclear rDNA region encompassing the internal transcribed spacers 1 and 2, along with the 5.8S rDNA (ITS), the translation elongation factor 1-α gene (tef1) with 983F/1567R (Rehner and Buckley 2005) and the RNA polymerase II second largest subunit gene ($rpb2$) with RPB2-B-F1/RPB2-B-R (Wu et al. 2014). PCR products were checked in 1% (w/v) agarose gels, and positive reactions with a bright single band were purified and directly sequenced using an ABI 3730xl DNA Analyzer (Guangzhou Branch of BGI, China) with the same primers used for PCR amplifications. Assembled sequences were deposited in GenBank (Table 1).

Dataset assembly

For the concatenated multilocus dataset of *Butyriboletus*, 14 sequences (four of 28S, four of ITS, four of tef1, and two of $rpb2$) from four collections were newly generated (Table 1) and then combined with selected sequences from previous studies (Table 1). *Rugiboletus extremiorientalis* (Lj.N. Vassiljeva) G. Wu & Zhu L. Yang was chosen as outgroup on the basis of the phylogeny in Wu et al. (2016a). For the concatenated multilocus dataset of *Caloboletus*, *Neoboletus*, and *Sutorius*, 68 sequences (21 of 28S, 16 of ITS, 20 of tef1, 11 of $rpb2$) from 23 collections were newly generated and deposited in GenBank (Table 1) and then combined with selected sequences from previous studies (Table 1). *Crocinoboletus laetissimus* (Hongo) N.K. Zeng et al. and *Cr. rufoaureus* (Massee) N.K. Zeng et al. were chosen as outgroup based on the phylogeny in Wu et al. (2016a). For the concatenated multilocus dataset of *Lanmaoa*, eight sequences (three of 28S, two of ITS, and three of tef1) from
Table 1. Taxa, vouchers, locations, and GenBank accession numbers of DNA sequences used in this study.

| Taxon | Voucher | Locality | 28S | ITS | tef1 | rpb2 | References |
|-------|---------|----------|-----|-----|------|------|------------|
| Baranangi pseudocalopus | HKAS3607 | Yunnan, SW China | KF112355 | – | KF112167 | – | Wu et al. 2014 |
| Baranangi pseudocalopus | HKAS75801 | Yunnan, SW China | KF112356 | – | KF112168 | – | Wu et al. 2014 |
| Butyriboletus abieticola | Arora11087 | California, USA | KC184413 | KC184412 | – | – | Arora and Krank 2014 |
| Butyriboletus appendiculatus | Bap1 | Germany | AF456837 | KJ19923 | JQ327025 | – | Binder and Bresinsky 2002 |
| Butyriboletus appendiculatus | BR5020089390-25 | Meise, Belgium | KT002609 | KT002598 | – | – | Zhao et al. 2015 |
| Butyriboletus appendiculatus | BR50200892955-50 | Zoninwond, Belgium | KJ605677 | KJ60568 | KJ619472 | KP35030 | Zhao et al. 2014a |
| Butyriboletus appendiculatus | MB000286 | Germany | KT002610 | KT002599 | – | – | Zhao et al. 2015 |
| Butyriboletus appendiculatus | Arora11108 | California, USA | KC184424 | KC184423 | – | – | Arora and Krank 2014 |
| Butyriboletus brassunicus | NY00013631 | Connecticut, USA | KT002611 | KT002600 | KT002635 | – | Zhao et al. 2015 |
| Butyriboletus festinari | AT2003097 | – | KF030270 | KJ384784 | – | – | Nuhn et al. 2013 |
| Butyriboletus frustii | JLF2548 | New Hampshire, USA | – | KC812303 | – | – | Arora and Krank 2014 |
| Butyriboletus frustii | NY815462 | Costa Rica | JQ326442 | – | KF112164 | KF112675 | Wu et al. 2014 |
| Butyriboletus hainanensis | N.K. Zeng 1197 (FHMU 2410) | Hainan, southern China | KU961651 | KU961653 | – | KU961658 | Liang et al. 2016 |
| Butyriboletus hainanensis | N.K. Zeng 2418 (FHMU 2437) | Hainan, southern China | KU961652 | KU961654 | KJ453856 | Liang et al. 2016 |
| Butyriboletus huengnienlaii | N.K. Zeng 3245 (FHMU 2206) | Fujian, SE China | MH879688 | MH885350 | MH879717 | MH879740 | this study |
| Butyriboletus huengnienlaii | N.K. Zeng 3246 (FHMU 2207) | Fujian, SE China | MH879689 | MH885351 | MH879718 | MH879741 | this study |
| Butyriboletus peccki | 3959 | Tennessee, USA | JQ326099 | – | JQ327026 | – | Halling et al. 2012 |
| Butyriboletus porridulus | Arora11110 | California, USA | – | KC184444 | – | – | Arora and Krank 2014 |
| Butyriboletus primiregus | DBB00606 | Dunsmuir, California, USA | KC184451 | – | – | – | Arora and Krank 2014 |
| Butyriboletus pseudorugosus | BR50201618465-02 | Etrave, Belgium | KT002613 | KT002602 | KT002637 | – | Zhao et al. 2015 |
| Butyriboletus pseudorugosus | BR50201535559-51 | Meise, Belgium | KT002614 | KT002605 | KT002638 | – | Zhao et al. 2015 |
| Butyriboletus pseudospeciosus | HKAS59567 | Yunnan, SW China | KF112351 | – | KF112176 | KF112672 | Wu et al. 2014 |
| Butyriboletus pseudospeciosus | HKAS35513 | Yunnan, SW China | KT090941 | – | KT990744 | KT990380 | Wu et al. 2016a |
| Butyriboletus pseudospeciosus | HKAS35956 | Yunnan, SW China | KT090942 | – | KT990734 | KT990381 | Wu et al. 2016a |
| Butyriboletus pseudospeciosus | N.K. Zeng 2127 (FHMU 1391) | Yunnan, SW China | MH879687 | MH885349 | MH879716 | – | this study |
| Butyriboletus pseudospeciosus | MG383a | Lazio, Italy | – | KC184458 | – | – | Arora and Krank 2014 |
| Butyriboletus pulvicreps | DS4514 | Arizona, USA | KF030261 | – | KF030409 | – | Nuhn et al. 2013 |
| Butyriboletus pulvicreps | R. Chapman 0945 | Arizona, USA | KT002615 | KT002604 | KT002639 | – | Zhao et al. 2015 |
| Butyriboletus querciregus | Arora11100 | California, USA | – | KC184461 | – | – | Arora and Krank 2014 |
| Butyriboletus regius | MB000287 | Germany | KT002616 | KT002605 | KT002640 | – | Zhao et al. 2015 |
| Butyriboletus regius | MG408a | Lazio, Italy | KC584790 | KC584789 | – | – | Arora and Krank 2014 |
| Butyriboletus regius | PRM923465 | Czech Rep. | KJ419931 | KJ419920 | – | – | Satare et al. 2014 |
| Butyriboletus roosefoxtia | Arora11054 | Yunnan, SW China | KC184435 | KC184434 | – | – | Arora and Krank 2014 |
| Butyriboletus roosefoxtia | HKAS35953 | Yunnan, SW China | KJ184559 | KJ909517 | KJ184571 | – | Zhao et al. 2015 |
| Butyriboletus roosefoxtia | HKAS54099 | Yunnan, SW China | KJ380665 | KJ909519 | KJ379779 | – | Zhao et al. 2015 |
| Butyriboletus roosefoxtia | N.K. Zeng 2123 (FHMU 1387) | Yunnan, SW China | MH879686 | MH885348 | MH879715 | – | this study |
| Butyriboletus rooseporpanus | E.E. Both3765 | New York, USA | KT002617 | KT002606 | KT002641 | – | Zhao et al. 2015 |
| Butyriboletus rooseporpanus | JLF2566 | West Virginia, USA | KC184467 | KC184466 | – | – | Arora and Krank 2014 |
| Butyriboletus rooseporpanus | MB06-059 | New York, USA | KF030262 | KJ184464 | KF030410 | – | Nuhn et al. 2013 |
| Butyriboletus suaviceps | Arora99241 | Yunnan, SW China | KC184470 | KC184469 | – | – | Arora and Krank 2014 |
| Butyriboletus suaviceps | MHH147456 | China | KJ909539 | – | KJ909741 | KT990378 | Wu et al. 2016a |
| Butyriboletus sp. | HKAS52525 | Yunnan, SW China | KF112337 | – | KF112163 | KF112671 | Wu et al. 2014 |
| Butyriboletus sp. | HKAS57774 | Yunnan, SW China | KF112330 | – | KF112155 | KF112670 | Wu et al. 2014 |
| Taxon                          | Voucher  | Locality               | 28S         | ITS          | tef1       | rpb2       | References                |
|-------------------------------|----------|------------------------|-------------|--------------|------------|------------|---------------------------|
| Butyriboletus sp.             | HKAS59814| Hunan, central China    | KF112336    | –            | KF112199   | KF112699   | Wu et al. 2014             |
| Butyriboletus sp.             | HKAS63528| Sichuan, SW China       | KF112332    | –            | KF112156   | KF112673   | Wu et al. 2014             |
| Butyriboletus subappendiculatus| MB000260 | Germany                 | KT002618    | KT002607     | KT002642   | –          | Zhao et al. 2015           |
| Butyriboletus subplendens     | HKAS52661| Yunnan, SW China        | KF112339    | –            | KF112169   | KF112676   | Wu et al. 2014             |
| Butyriboletus ycinus          | Anora2727| Yunnan, SW China        | KC184475    | KC184474     | –          | –          | Arora and Kranck 2014      |
| Butyriboletus ycinus          | HKAS57503| Yunnan, SW China        | KT002620    | KT002608     | KT002644   | –          | Zhao et al. 2015           |
| Butyriboletus ycinus          | HKAS68010| Yunnan, SW China        | KT002619    | KJ095521     | KT002643   | –          | Zhao et al. 2015           |
| Caloboletus calopus           | Bc1      | Bavaria, Germany        | AF456833    | DQ679806     | JQ327019   | –          | Zhao et al. 2014a          |
| Caloboletus calopus           | BR50215963805| Montenau, Belgium    | KJ184554    | KJ605655     | KJ184566   | –          | Zhao et al. 2014a          |
| Caloboletus calopus           | 112060   | California, USA         | KF030279    | –            | –          | –          | Nuhn et al. 2013           |
| Caloboletus firmus            | MB06-060 | New York, USA           | KF030368    | –            | KF030408   | –          | Nuhn et al. 2013           |
| Caloboletus firmus            | NY00796115| Cayo, Belize           | KJ605678    | KJ605656     | KJ619464   | –          | Zhao et al. 2014a          |
| Caloboletus guanyui           | N.K. Zeng | Hainan, southern China  | MH879708    | MH885365     | MH879734   | MH879751   | this study                |
| Caloboletus guanyui           | N.K. Zeng | Hainan, southern China  | MH879709    | MH885366     | MH879736   | MH879752   | this study                |
| Caloboletus guanyui           | N.K. Zeng | Fujian, SE China       | MH879705    | –            | MH879732   | MH879748   | this study                |
| Caloboletus guanyui           | N.K. Zeng | Fujian, SE China       | MH879706    | –            | MH879733   | MH879749   | this study                |
| Caloboletus guanyui           | N.K. Zeng | Fujian, SE China       | MH879707    | MH885364     | MH879735   | MH879750   | this study                |
| Caloboletus guanyui           | N.K. Zeng | Hainan, southern China  | –           | –            | MK061357   | –          | this study                |
| Caloboletus inedulis          | MB06-044 | New York, USA           | JQ327013    | –            | JQ327020   | –          | Halling et al. 2012       |
| Caloboletus inedulis          | HKAS80478| Florida, USA            | KJ095671    | KJ605657     | KJ619465   | –          | Zhao et al. 2014a          |
| Caloboletus panniformis       | HKAS56164| Yunnan, SW China        | KJ095674    | KJ605667     | KJ619466   | –          | Zhao et al. 2014a          |
| Caloboletus panniformis       | HKAS57410| Yunnan, SW China        | KJ184555    | KJ605659     | KJ184567   | –          | Zhao et al. 2014a          |
| Caloboletus panniformis       | HKAS77530| Yunnan, SW China        | KJ095670    | KJ605661     | KJ619470   | –          | Zhao et al. 2014a          |
| Caloboletus polygonosum       | KU307624 | Greece                 | KU317763    | KU317753     | –          | –          | GenBank                   |
| Caloboletus radiicans         | HKAS80856| France                 | KJ184557    | KJ605652     | KJ184569   | –          | Zhao et al. 2014a          |
| Caloboletus sp.               | HKAS53353| China                  | KF112410    | –            | KF112188   | KF112668   | Wu et al. 2014             |
| Caloboletus taienus           | GDGM44081| Guangdong, southern China | KJ800414  | KJ800420     | –          | –          | Zhang et al. 2017          |
| Caloboletus xiangtoushanensis | GDGM44725| Guangdong, southern China | KJ800416  | KJ800422     | –          | –          | Zhang et al. 2017          |
| Caloboletus xiangtoushanensis | GDGM44833| Guangdong, southern China | KJ800415  | KJ800421     | KJ800418   | –          | Zhang et al. 2017          |
| Caloboletus xiangtoushanensis | GDGM45160| Guangdong, southern China | KJ800417  | KJ800423     | KJ800419   | –          | Zhang et al. 2017          |
| Caloboletus xiangtoushanensis | N.K. Zeng | Fujian, SE China       | MH879702    | –            | –          | –          | this study                |
| Caloboletus xiangtoushanensis | N.K. Zeng | Fujian, SE China       | MH879703    | MH885362     | –          | –          | this study                |
| Caloboletus xiangtoushanensis | N.K. Zeng | Fujian, SE China       | MH879704    | MH885363     | –          | –          | this study                |
| Caloboletus yuenanensis       | HKAS62714| Yunnan, SW China        | KJ184556    | KJ605663     | KJ184568   | –          | Zhao et al. 2014a          |
| Caloboletus yuenanensis       | HKAS58604| Yunnan, SW China        | KJ095672    | KJ605664     | KJ619470   | –          | Zhao et al. 2014a          |
| Chalciporus radialis          | N.K. Zeng | Fujian, SE China       | MH879710    | MH885367     | MH879738   | –          | this study                |
| Chalciporus radialis          | N.K. Zeng | Fujian, SE China       | MH879711    | –            | MH879739   | –          | this study                |
| Chalciporus radialis          | N.K. Zeng | Hainan, southern China | –           | –            | MH879737   | –          | this study                |
| Contantepper cayennes         | Henke9067| Guyana                 | LC053662    | LC054831     | –          | –          | Smith et al. 2015          |
| Crocinoboletus lactissimus    | HKAS50252| Yunnan, SW China        | KT990657    | –            | KT990762   | –          | Wu et al. 2016a            |
| Taxon                          | Voucher                 | Locality                  | 28S           | ITS            | tef1         | rpb1         | References                  |
|-------------------------------|-------------------------|---------------------------|---------------|----------------|--------------|--------------|-----------------------------|
| Crocinoboletus rufipesicrus   | HKAS53424               | Hunan, central China      | KF112435      | –              | KF112206     | KF112710     | Wu et al. 2014              |
| Cynobolus brunneoruber        | HKAS63504               | Yunnan, SW China          | KF112368      | –              | KF112194     | –            | Wu et al. 2014              |
| Cynobolus brunneoruber        | HKAS80579-1             | Yunnan, SW China          | KT990568      | –              | KT990763     | –            | Wu et al. 2016a             |
| Cynobolus brunneoruber        | HKAS80579-2             | Yunnan, SW China          | KT990569      | –              | KT990764     | –            | Wu et al. 2016a             |
| Cynobolus hygrophilolentus    | DC14-010                | India                     | KT860060      | –              | KT907355     | –            | Li et al. 2016              |
| Cynobolus instabilis          | HKAS59554               | Yunnan, SW China          | KF112412      | –              | KF112186     | –            | Wu et al. 2014              |
| Cynobolus instabilis          | FHMIU1839               | Yunnan, SW China          | MG030466      | MG030473       | MG030478     | –            | Chai et al. 2018            |
| Cynobolus pulversidentus      | 9606                    | USA                       | KF030315      | –              | KF030418     | –            | Nuhn et al. 2013            |
| Cynobolus pulversidentus      | RW109                   | Belgium                   | –             | –              | KT824046     | –            | Raspe et al. 2016           |
| Cynobolus pulversidentus      | MG126a                  | Azores Islands, Portugal  | KT157062      | KT157053       | –            | –            | Gelardi et al. 2015         |
| Cynobolus pulversidentus      | MG456a                  | Italy                     | KT157063      | KT157054       | –            | –            | Gelardi et al. 2015         |
| Cynobolus pulversidentus      | HKAS959609              | Yunnan, SW China          | KF112366      | –              | KF112193     | –            | Wu et al. 2014              |
| Cynobolus sp.                 | HKAS76850               | Hainan, southern China    | KF112345      | –              | KF112187     | –            | Wu et al. 2014              |
| Cynobolus sp.                 | HKAS52639               | Yunnan, SW China          | KF112367      | –              | KF112195     | –            | Wu et al. 2014              |
| Cynobolus sp.                 | HKAS52601               | Yunnan, SW China          | KF112469      | –              | –            | –            | Wu et al. 2014              |
| Cynobolus sp.                 | HKAS50292               | Yunnan, SW China          | KF112470      | –              | –            | –            | Wu et al. 2014              |
| Cynobolus sp.                 | HKAS959418              | China                     | KT990570      | KT990765       | –            | –            | Wu et al. 2016a             |
| Cynobolus sp.                 | HKAS99208-1             | China                     | KT990571      | KT990766       | –            | –            | Wu et al. 2016a             |
| Cynobolus sp.                 | HKAS99208-2             | China                     | –             | –              | KT990767     | –            | Wu et al. 2016a             |
| Cynobolus sp.                 | PRM044518               | USA                       | MF373585      | –              | –            | –            | Brauer et al. 2018          |
| Exsudoporus frosti            | SAT121151               | Tennessee, USA            | KP050231      | KP055018       | KP055027     | Zhao et al. 2014b           |
| Exsudoporus frosti            | TENN067311              | Tennessee, USA            | KT002612      | KT002601       | KT002636     | –            | Zhao et al. 2015            |
| Lanmaoa angustiopora          | HKAS74765               | Yunnan, SW China          | KF112322      | –              | KF112159     | –            | Wu et al. 2014              |
| Lanmaoa angustiopora          | HKAS74752               | Yunnan, SW China          | KF030466      | MG030473       | MG030478     | –            | Chai et al. 2018            |
| Lanmaoa angustiopora          | HKAS74759               | Yunnan, SW China          | KF030466      | MG030473       | MG030478     | –            | Chai et al. 2018            |
| Lanmaoa asiatica             | HKAS54094               | Yunnan, SW China          | KF112355      | –              | KF112161     | –            | Wu et al. 2014              |
| Lanmaoa asiatica             | HKAS54156               | Yunnan, SW China          | KT990584      | KT990780       | –            | –            | Wu et al. 2016a             |
| Lanmaoa asiatica             | HKAS56303               | Yunnan, SW China          | KM605142      | KM605153       | –            | –            | Wu et al. 2016b             |
| Lanmaoa asiatica             | FHMIU1389               | Yunnan, SW China          | MG030470      | MG030477       | MG030481     | –            | Chai et al. 2018             |
| Lanmaoa asiatica             | FHMIU1775               | Yunnan, SW China          | MG030469      | MG030480       | –            | –            | Chai et al. 2018             |
| Lanmaoa flavoviridus          | NYTS72777               | Costa Rica                | JQ024339      | –              | KF112160     | –            | Wu et al. 2014              |
| Lanmaoa macrorcarpa           | N.K. Zeng 3021          | Hainan, southern China    | MH879684      | –              | MH879713     | –            | this study                  |
| Lanmaoa macrorcarpa           | N.K. Zeng 3251          | Fujian, SE China          | MH879685      | MH885347       | MH879714     | –            | this study                  |
| Lanmaoa pseudoenesticili      | DS615-07                | USA                       | KF030257      | –              | KF030407     | –            | Nuhn et al. 2013            |
| Lanmaoa rubriceps             | FHMIU 1756              | Hainan, southern China    | MG030465      | MG030472       | –            | –            | Chai et al. 2018             |
| Lanmaoa rubriceps             | FHMIU 1757              | Hainan, southern China    | MG030467      | MG030474       | –            | –            | Chai et al. 2018             |
| Lanmaoa rubriceps             | FHMIU 1763              | Hainan, southern China    | MG030468      | MG030475       | MG030479     | –            | Chai et al. 2018             |
| Lanmaoa rubriceps             | FHMIU 2801              | Hainan, southern China    | MG030471      | MG030476       | –            | –            | Chai et al. 2018             |
| Lanmaoa rubriceps             | N.K. Zeng 3006          | Hainan, southern China    | MH879683      | MH885346       | MH879712     | –            | this study                  |
| Lanmaoa sp.                   | HKAS552518              | Yunnan, SW China          | KF112354      | –              | KF112162     | –            | Wu et al. 2014              |
| Neiboletus brunnevisinus      | HKAS552660              | Yunnan, SW China          | KF112314      | KF112143       | KF112650     | Wu et al. 2014              |
| Neiboletus ferrugineus        | HKAS77617               | Guangdong, southern China | KT990595      | KT990788       | KT990430     | Wu et al. 2016a             |
| Taxon                          | Voucher            | Locality                      | 28S      | ITS     | rpb2    | References              |
|-------------------------------|--------------------|-------------------------------|----------|---------|---------|-------------------------|
| Neoboletus ferrugineus        | HKAS77718          | Guangdong, southern China     | KT990596 | –       | –       | Wu et al. 2016a          |
| Neoboletus flavidus           | HKAS58724          | Yunnan, SW China              | KT974140 | –       | –       | Wu et al. 2016a          |
| Neoboletus flavidus           | HKAS59443          | Yunnan, SW China              | KT974139 | –       | –       | Wu et al. 2016a          |
| Neoboletus hainanensis        | HKAS59469          | Yunnan, SW China              | KF112359 | –       | KF112175 | Wu et al. 2016a          |
| Neoboletus hainanensis        | HKAS90209          | Hainan, southern China        | KT990615 | –       | KF112089 | Wu et al. 2016a          |
| Neoboletus hainanensis        | HKAS63515          | Yunnan, SW China              | KT990614 | –       | KF112089 | Wu et al. 2016a          |
| Neoboletus hainanensis        | HKAS74880          | Yunnan, SW China              | KT990597 | –       | KF112089 | Wu et al. 2016a          |
| Neoboletus hainanensis        | N.K. Zeng 2128     | (FHMU 1392) Hainan, southern China | MH879690 | –       | MH879719 | this study              |
| Neoboletus liridiformis       | AT2001087          | Berkshire, England            | JQ326995 | –       | JQ327023 | Halling et al. 2012     |
| Neoboletus magnificus         | HKAS54096          | Yunnan, SW China              | KF112324 | –       | KF112149 | Wu et al. 2014          |
| Neoboletus magnificus         | HKAS74939          | Yunnan, SW China              | KF112320 | –       | KF112148 | Wu et al. 2014          |
| Neoboletus multipunctatus     | HKAS76851          | Hainan, southern China        | KF112321 | –       | KF112144 | Wu et al. 2014          |
| Neoboletus multipunctatus     | N.K. Zeng 2498     | (FHMU 1620) Hainan, southern China | MH879693 | MH885354 | MH879722 | this study              |
| Neoboletus multipunctatus     | N.K. Zeng 3324     | (FHMU 2808) Hainan, southern China | MK061360 | MK061359 | MK061358 | this study              |
| Neoboletus obscureumbrinus    | HKAS63498          | Yunnan, SW China              | KT990598 | –       | KT990791 | Wu et al. 2016a          |
| Neoboletus obscureumbrinus    | HKAS89027          | Yunnan, SW China              | KT990600 | –       | KT990794 | Wu et al. 2016a          |
| Neoboletus obscureumbrinus    | N.K. Zeng 3091     | (FHMU 2052) Hainan, southern China | MH879694 | MH885355 | MH879723 | this study              |
| Neoboletus obscureumbrinus    | N.K. Zeng 3094     | (FHMU 2055) Hainan, southern China | MH879695 | MH885356 | MH879724 | this study              |
| Neoboletus obscureumbrinus    | N.K. Zeng 3098     | (FHMU 2059) Hainan, southern China | MH879696 | MH885357 | MH879725 | this study              |
| Neoboletus rubriporus         | HKAS83026          | Yunnan, SW China              | KT990601 | –       | KT990795 | Wu et al. 2016a          |
| Neoboletus rubriporus         | HKAS89174          | Yunnan, SW China              | KT990602 | –       | KT990786 | Wu et al. 2016a          |
| Neoboletus rubriporus         | HKAS98918          | Yunnan, SW China              | KT990603 | –       | KT990787 | Wu et al. 2016a          |
| Neoboletus rubriporus         | HKAS90210          | Yunnan, SW China              | KT990604 | –       | KT990798 | Wu et al. 2016a          |
| Neoboletus rubriporus         | HKAS68587          | Yunnan, SW China              | KF112329 | –       | KF112150 | Wu et al. 2014          |
| Neoboletus rubriporus         | MHKMU-L.P. Tang 1958 | Yunnan, SW China               | –       | MH885358 | MH879726 | this study              |
| Neoboletus sanguineoides      | HKAS55440          | Yunnan, SW China              | KF112315 | –       | KF112145 | Wu et al. 2014          |
| Neoboletus sanguineoides      | HKAS57766          | Yunnan, SW China              | KT990605 | –       | KF112089 | Wu et al. 2016a          |
| Neoboletus sanguineoides      | HKAS63530          | Sichuan, SW China             | KT990607 | –       | KF112089 | Wu et al. 2016a          |
| Neoboletus sanguineoides      | HKAS80823          | Yunnan, SW China              | KT990605 | –       | KF112089 | Wu et al. 2016a          |
| Neoboletus sanguineoides      | HKAS80849          | Yunnan, SW China              | KT990609 | –       | KF112089 | Wu et al. 2016a          |
| Neoboletus sanguineoides      | HKAS90211          | Xizang, SW China              | KT990610 | –       | KF112089 | Wu et al. 2016a          |
| Neoboletus sanguineoides      | HKAS68587          | Yunnan, SW China              | KF112329 | –       | KF112150 | Wu et al. 2014          |
| Neoboletus sp.                | CMU58-ST-0237      | –                              | –       | MH885358 | MH879726 | this study              |
| Neoboletus sp.                | HKAS76851          | Hainan, southern China        | KF112321 | –       | KF112144 | Wu et al. 2014          |
| Neoboletus sp.                | HKAS509351         | Yunnan, SW China              | KF112318 | –       | KF112180 | Wu et al. 2014          |
| Neoboletus sp.                | HKAS76660          | Hainan, Central China         | KF112328 | –       | KF112180 | Wu et al. 2014          |
| Neoboletus subcarnosus        | HKAS57093          | Xizang, China                 | KF112326 | –       | KF112089 | Wu et al. 2014          |
| Neoboletus torrenticulus      | HKAS53369          | Fujian, SE China              | KF112323 | –       | KF112154 | Wu et al. 2014          |
| Neoboletus torrenticulus      | HKAS77656          | Guangdong, southern China     | KT990611 | –       | KT990806 | Wu et al. 2016a          |
| Neoboletus torrenticulus      | N.K. Zeng 1285     | (FHMU 841) Fujian, SE China   | MH879691 | MH885352 | MH879720 | this study              |
| Neoboletus torrenticulus      | N.K. Zeng 1286     | (FHMU 842) Fujian, SE China   | MH879692 | MH885353 | MH879721 | this study              |
| Neoboletus venenatus          | HKAS57489          | Yunnan, SW China              | KF112325 | –       | KF112158 | Wu et al. 2014          |
| Neoboletus venenatus          | HKAS65355          | Sichuan, SW China             | KT990613 | –       | KF112087 | Wu et al. 2016a          |
| Rugoboletus brunneiporus      | HKAS68586          | Xizang, SW China              | KF112402 | –       | KF112197 | Wu et al. 2014          |
| Taxon                  | Voucher                  | Locality                  | 28S          | ITS           | tef1         | rpb2         | References           |
|-----------------------|--------------------------|----------------------------|--------------|---------------|--------------|---------------|----------------------|
| Rugiboletus brunneiporus | HKAS83009                | Xizang, SW China           | KM605133     | –             | KM605146     | –             | Wu et al. 2016b      |
| Rugiboletus extremiorientalis | HKAS76663              | Henan, Central China       | KM605135     | –             | KM605147     | KM605170     | Wu et al. 2016b      |
| Rugiboletus extremiorientalis | HKAS74754              | China                      | KT990639     | –             | KT990832     | KT990469     | Wu et al. 2016a      |
| Rubroboletus latiporus  | HKAS63517                | Yunnan, SW China           | KP055022     | –             | KP055019     | KP055028     | Zhao et al. 2014b    |
| Rubroboletus latiporus  | HKAS80358                | Chongqing, SW China        | KP055023     | –             | KP055020     | KP055029     | Zhao et al. 2014b    |
| Rugiboletus cinnicus   | HKAS68620                | Yunnan, SW China           | KF112139     | –             | KF112146     | KF112808     | Wu et al. 2014       |
| Sutorius aff. eximius  | HKAS56291                | Yunnan, SW China           | KF112400     | –             | KF112208     | –             | Wu et al. 2014       |
| Sutorius aff. eximius  | MHKMU-S.D. Yang 010      | Yunnan, SW China           | MH879697     | MH885359     | MH879727     | –             | this study           |
| Sutorius australiensis | REH9280                  | Australia                  | JQ327031     | –             | JQ327031     | –             | Arora and Krank 2014 |
| Sutorius australiensis | REH9441                  | Australia                  | JQ327006     | –             | JQ327032     | MG212652     | Halling et al. 2012  |
| Sutorius eximius       | REH9400                  | USA                        | JQ327004     | –             | JQ327029     | –             | Arora and Krank 2014 |
| Sutorius eximius       | HKAS52672                | Yunnan, SW China           | KF112399     | –             | KF112207     | KF112802     | Wu et al. 2014       |
| Sutorius eximius       | HKAS50420                | Yunnan, SW China           | KF1190549    | –             | KF1190750    | KF1190387    | Wu et al. 2016a      |
| Sutorius eximius       | HKAS59657                | China                      | KT990707     | –             | KT990887     | KF1190505    | Wu et al. 2016a      |
| Sutorius eximius       | 8594                     | Costa Rica                 | JQ327008     | –             | JQ327027     | –             | Halling et al. 2012  |
| Sutorius eximius       | 995                      | Costa Rica                 | JQ327010     | –             | JQ327030     | –             | Halling et al. 2012  |
| Sutorius eximius       | 986                      | Costa Rica                 | JQ327009     | –             | JQ327028     | –             | Halling et al. 2012  |
| Sutorius eximius       | 8069                     | Indonesia                  | JQ327003     | –             | –             | –             | Halling et al. 2012  |
| Sutorius sp.           | N.K. Zeng 3297 (FHMU 2258) | Fujian, SE China           | MH879701     | –             | MH879731     | –             | this study           |
| Sutorius sp.           | ECV9603                  | Thailand                   | JQ327000     | –             | JQ327033     | –             | Halling et al. 2012  |
| Sutorius sp.           | 01-528                   | Zambia                     | JQ327002     | –             | –             | –             | Halling et al. 2012  |
| Sutorius subrufus       | N.K. Zeng 3043 (FHMU 2004) | Hainan, southern China     | MH879698     | MH885360     | MH879728     | MH879745     | this study           |
| Sutorius subrufus       | N.K. Zeng 3045 (FHMU 2006) | Hainan, southern China     | MH879699     | MH885361     | MH879729     | MH879746     | this study           |
| Sutorius subrufus       | N.K. Zeng 3140 (FHMU 2101) | Hainan, southern China     | MH879700     | –             | MH879730     | MH879747     | this study           |

Three collections were newly generated and deposited in GenBank (Table 1), and then combined with selected sequences from previous studies (Table 1). Rugiboletus brunneiporus G. Wu & Zhu L. Yang was chosen as outgroup on the basis of the phylogeny in Wu et al. (2016a). To test for phylogenetic conflict among the different genes in three combined datasets (Butyriboletus, Caloboletus + Neoboletus + Sutorius, Lanmaoa), the partition homogeneity (PH) or incongruence length difference (ILD) test was performed with 1000 randomized replicates, using heuristic searches with simple addition of sequences in PAUP* 4.0b10 (Swofford 2002). The results of the partition homogeneity test showed that the phylogenetic signals present in the different gene fragments were not in conflict. Then the sequences of different genes in three combined datasets (Butyriboletus, Caloboletus + Neoboletus + Sutorius, Lanmaoa) were aligned with MAFFT v. 6.8 using algorithm E-INS-i (Katoh et al. 2005) and manually optimized on BioEdit v. 7.0.9 (Hall 1999). The sequences of the different genes were concatenated in three combined datasets (Butyriboletus, Caloboletus + Neoboletus + Sutorius, Lanmaoa) using Phyutility v. 2.2 for further analyses (Smith and Dunn 2008).
Phylogenetic analyses

The three combined datasets (Butyriboletus, Caloboletus + Neoboletus + Sutorius, Lant-maoa) were all analyzed by using maximum likelihood (ML) and Bayesian inference (BI). Maximum likelihood tree generation and bootstrap analyses were performed with the program RAxML 7.2.6 (Stamatakis 2006) running 1000 replicates combined with an ML search. Bayesian analysis with MrBayes 3.1 (Huelsenbeck and Ronquist 2005) implementing the Markov Chain Monte Carlo (MCMC) technique and parameters predetermined with MrModeltest 2.3 (Nylander 2004) was performed. The model of evolution used in the Bayesian analysis was determined with MrModeltest 2.3 (Nylander 2004). For the combined dataset of Butyriboletus, the best-fit likelihood models of 28S, ITS1+ITS2, 5.8S, tef1 and rpb2 were GTR+I+G, HKY+I+G, K80, SYM+I+G and K80+I+G, respectively; for the combined dataset of Caloboletus, Neoboletus, and Sutorius, the best-fit likelihood models of 28S, ITS1+ITS2, 5.8S, tef1 and rpb2 were GTR+I+G, HKY+I+G, K80, SYM+I+G and SYM+I+G, respectively; for the combined dataset of Lanmaoa, the best-fit likelihood models of 28S, ITS1+ITS2, 5.8S and tef1 were GTR+I+G, GTR+I, K80 and SYM+G, respectively. Bayesian analysis was run with one cold and three heated chains and sampled every 100 generations; trees sampled from the first 25% of the generations were discarded as burn-in; the average standard deviation of split frequencies was restricted to be below 0.01, and Bayesian posterior probabilities (PP) were then calculated for a majority consensus tree of the retained Bayesian trees.

Results

Molecular data

The four-locus dataset (28S + ITS + tef1 + rpb2) of Butyriboletus consisted of 52 taxa and 3116 nucleotide sites (Fig. 1). The aligned dataset was submitted to TreeBASE (http://purl.org/phylo/treebase/phyloWs/study/TB2:S23508). The molecular phylogenetic analyses showed that the collections numbered as FHMU 2206 and FHMU 2207 respectively grouped together with a high statistical support (BS = 100, PP = 1), forming an independent lineage within Butyriboletus (Fig. 1).

The four-locus dataset (28S + ITS + tef1 + rpb2) with Caloboletus, Neoboletus, and Sutorius consisted of 93 taxa and 3228 nucleotide sites (Fig. 2). The aligned dataset was submitted to TreeBASE (http://purl.org/phylo/treebase/phyloWs/study/TB2:S23509). The molecular phylogenetic analyses indicated each of the previously described genera, viz. Neoboletus, Sutorius, Costatisporus T.W. Henkel & M.E. Sm., and Caloboletus, forms an independent clade with a high statistical support respectively (Fig. 2). In the genus Neoboletus, one collection numbered as FHMU 1392 and one previously described S. hainanensis (T.H. Li & M. Zang) G. Wu and Zhu L. Yang grouped together with a strong statistical support (BS = 100, PP = 1), forming an independent lineage; two collections numbered as FHMU 841 and FHMU 842 respectively and one previously described
Figure 1. Phylogenetic placement of *Butyriboletus huangnianlaii* inferred from a multilocus (28S, ITS, tef1, rpb2) dataset using RAxML. BS ≥ 50% and PP ≥ 0.95 are indicated above or below the branches as RAxML BS/PP.

*S. tomentulosus* (M. Zang et al.) G. Wu & Zhu L. Yang grouped together with a high statistical support (BS = 100, PP = 1), forming an independent lineage; one collection tentatively named *Sutorius* sp. (HKAS 76851) in a previous study (Wu et al. 2016a) and one specimen numbered as FHMU 1620 grouped together with a high statistical support (BS = 100, PP = 1), forming an independent lineage; three specimens numbered as FHMU 2052, FHMU 2055, FHMU 2059 respectively and one previously described *S. obscureumbrinus* (Hongo) G. Wu & Zhu L. Yang grouped together with a high statistical support (BS = 100, PP = 1), forming an independent lineage (Fig. 2). In the genus *Sutorius*, the specimens numbered as FHMU 2004, FHMU 2006 and FHMU 2101 respectively grouped together with a high statistical support (BS = 100, PP = 1), forming an independent lineage (Fig. 2). In the genus *Caloboletus*, the materials numbered as FHMU 883, FHMU 884, FHMU 906 respectively and the holotype of *C. xiangtoushanensis* Ming Zhang et al. grouped together with a high statistical support (BS = 100, PP = 1),
Figure 2. Phylogenetic placement of *Neoboletus multipunctatus*, *Sutorius subrufus* and *Caloboletus guanyui* inferred from a multilocus (28S, ITS, *tef1*, *rpb2*) dataset using RAxML. BS ≥ 50% and PP ≥ 0.95 are indicated above or below the branches as RAxML BS/PP.
Figure 3. Phylogenetic placement of *Lanmaoa macrocarpa* inferred from a multilocus (28S, ITS, tef1) dataset using RAxML. BS ≥ 50% and PP ≥ 0.95 are indicated above or below the branches as RAxML BS/PP.

forming an independent lineage; the collections numbered as FHMU 2019, FHMU 2040, FHMU 2218, FHMU 2222 and FHMU 2224 respectively grouped together with a strong statistical support (BS = 100, PP = 1), forming an independent lineage (Fig. 2).

The three-locus dataset (28S + ITS + tef1) of *Lanmaoa* consisted of 40 taxa and 2007 nucleotide sites (Fig. 3). The aligned dataset was submitted to TreeBASE (http://purl.org/phylo/treebase/phylocs/study/TB2:S23510). The molecular phylogenetic analyses showed that the collections numbered as FHMU 1982 and FHMU 2212 respectively grouped together with a high statistical support (BS = 100, PP = 1), forming an independent lineage within *Lanmaoa* (Fig. 3).
Taxonomy

Butyroboletus D. Arora & J.L. Frank

Butyroboletus, typified by But. appendiculatus (Schaeff.) D. Arora & J.L. Frank, was erected to accommodate the “butter boletes”, which are mainly characterized by yellow hymenophore and context staining blue when injured and stipe surface usually covered with reticulations (Arora and Frank 2014; Zhao et al. 2015). Until now, six species, including But. hainanensis N.K. Zeng et al., But. pseudospeciosus Kuan Zhao & Zhu L.Yang, But. roseoflavus (Hai B. Li & Hai L.Wei) D. Arora & J.L. Frank, But. sanicibus D. Arora & J.L. Frank, But. subsplendidus (W.F. Chiu) Kuan Zhao et al., and But. yicibus D. Arora & J.L. Frank have been described from China (Arora and Frank 2014; Liang et al. 2016; Wu et al. 2016a). Herein, we describe another novel species.

1. Butyroboletus huangnianlaii N.K. Zeng, H. Chai & Zhi Q. Liang, sp. nov.
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Figures 4a, b, 7

Typification. CHINA. Fujian Province: Sanming City, Geshikao National Forest Park, elev. 420 m, 16 August 2017, N.K. Zeng 3246 (FHMU 2207, holotype). GenBank accession numbers: 28S = MH879689, ITS = MH885351, tef1 = MH879718, rpb2 = MH879741.

Etymology. Latin, “huangnianlaii” is named after Chinese mycologist Nian-Lai Huang, in honor of his contribution to mycology.

Description. Basidiomata medium-sized to large. Pileus 5–11 cm in diameter, convex to aplannate; surface dry, finely tomentose, pale brown (5D1–4D2), brown to reddish brown (5C2–6C2); context 0.6–2.2 cm thick in the center of the pileus, yellowish to yellow, changing blue quickly when injured. Hymenophore poroid, adnate or slightly depressed around apex of stipe; pores angular, about 0.5 mm in diameter, yellowish white (30A2) to yellowish brown (4A4), changing blue quickly when injured; tubes 0.4–0.8 cm in length. Stipe 4.5–8 × 1.3–2.5 cm, central, subcylindric, solid; surface dry, yellowish white (30A2) to yellowish brown (4A4), changing blue quickly when injured; tubes 0.4–0.8 cm in length. Hymenophoral trama boletoid; composed of colorless to yellowish in KOH, 3–10 μm wide, thin- to slightly thick-walled (to 0.5 μm) hyphae. Cheilocystidia 32–53 × 7–12 μm, fusiform or subfusiform, thin-walled, yellowish in KOH, no
encrustations. *Pleurocystidia* 40–60 × 8–13 μm, fusiform or subfusiform, thin-walled, yellowish in KOH, no encrustations. *Pileipellis* a trichoderm about 110 μm thick, composed of slightly interwoven, nearly colorless in KOH, 4–6 μm wide, thin-walled hyphae; terminal cells 30–50 × 4–8 μm, clavate or subclavate, with obtuse apex. *Pileal trama* made up of hyphae 8–12 μm in diameter, thin-walled, colorless in KOH. *Stipitipellis* hymeniform about 120–140 μm thick, composed of thin- to slightly thick-walled (to 0.5 μm) emergent hyphae, colorless to yellowish in KOH, with clavate, subclavate, fusiform or subfusiform terminal cells (15–45 × 4–9 μm), and occasionally with scattered clavate, 4-spored basidia. *Stipe trama* composed of longitudinally arranged, paral-
lel hyphae 3.5–7 μm wide, cylindrical, thin- to slightly thick-walled (up to 0.5 μm), colorless to yellowish in KOH, parallel hyphae. Clamp connections absent in all tissues. **Habitat.** Scattered on the ground in forests dominated by *Castanopsis kawakamii* Hay. **Distribution.** Southeastern China.

**Additional specimens examined.** CHINA. Fujian Province: Sanming City, Geshi-kao National Forest Park, elev. 420 m, 16 August 2017, N.K. Zeng 3245 (FHMU 2206).

**Note.** *Butyroboletus huangnianlaii* is characterized by a medium-sized to large basidioma, pileal surface densely covered with pale brown to reddish brown squamules, smaller basidiospores, and its association with fagaceous trees. It is both morphologically similar and phylogenetically related to *But. pseudospeciosus* and *But. roseoflavus* (Fig. 1). However, *But. pseudospeciosus*, originally described from Yunnan Province of southwestern China, has a tomentose pileus without a reddish tinge, surface of pileus and stipe promptly staining blue when bruised, narrower cystidia and longer basidiospores measuring 9–11 × 3.5–4 μm (Wu et al. 2016a); *But. roseoflavus*, originally described from Zhejiang Province of southeastern China, has a pinkish to purplish red or rose-red pileus with tomentose surface, longer basidiospores measuring 9–12 × 3–4 μm, and its association with *Pinus* spp. (Arora and Frank 2014; Li et al. 2014; Wu et al. 2016a).

**Caloboletus Vizzini**

*Caloboletus*, typified by *C. calopus* (Pers.) Vizzini, is mainly characterized by yellow tubes, yellow or more rarely orange to red pores changing to blue when injured, bitter taste of the context due to the presence of calopin and cyclocalopin (Hellwig et al. 2002; Vizzini 2014; Zhao et al. 2014a; Wu et al. 2016a; Zhang et al. 2017). Until now, four species, including *C. panniformis* (Taneyama & Har. Takah.) Vizzini, *C. taienus* (W.F. Chiu) Ming Zhang and T.H. Li, *C. xiangtoushanensis* Ming Zhang et al., and *C. yunnanensis* Kuan Zhao & Zhu L. Yang, have been found in China (Zhao et al. 2014a; Wu et al. 2016a; Zhang et al. 2017). We describe two *Caloboletus* species here.

### 2. *Caloboletus guanyui* N.K. Zeng, H. Chai & S. Jiang, nom. nov.

Mycobank: MB828522
Figures 4c–f, 8

*Boletus quercinus* Hongo, Memoirs of Shiga University 17: 92, 1967 (nom. illeg., later homonym)
non *Boletus quercinus* Schrad., Spicilegium Florae Germaniae 1: 157, 1794
non *Boletus quercinus* (Pilát) Hlaváček, Mykologický Sborník 67(3): 87, 1990 (nom. illeg., later homonym)

**Etymology.** Latin, “guanyui” is named for Guan Yu, a historic Chinese hero, said to have a reddish face, and thus sharing the same color of pores of the species when young.
Description. Basidiomata medium-sized to large. Pileus 5–10 cm in diameter, convex to applanate; surface dry, finely tomentose, dirty white to pale brown; context 0.5–1.8 cm thick in the center of the pileus, white, changing bluish quickly when injured, then back to white. Hymenophore poroid, depressed around apex of stipe; pores subround, 0.3–0.5 mm in diameter, reddish to reddish brown when young, then yellow or yellowish brown, changing bluish black when injured; tubes about 0.5–1 cm in length, yellowish, changing bluish quickly when injured. Stipe 5.5–9 × 0.7–1.5 cm, central, subcylindric, solid, usually flexuous; surface dry, densely covered with pale brown, brown to reddish brown, minute squamules; context white, sometimes tinged with pale red, unchanging in color when injured; basal mycelium white. Odor indistinct.

Basidia 21–30 × 6–8 μm, clavate, thin-walled, colorless to yellowish in KOH; four-spored, sterigmata 3–4 μm in length. Basidiospores [220/12/5] (8.5–)9–11(–12) × 3.5–4.5 μm, Q=(2.00–)2.22–2.67(–2.86), Qm =2.43 ± 0.17, subfusoid and inequilateral in side view with a weak or distinct suprahilar depression, elliptic-fusiform to subfusciform in ventral view, slightly thick-walled (to 0.5 μm), olive-brown to yellowish brown in KOH, smooth. Hymenophoral trama boletoid; composed of yellowish in KOH, 4–10 μm wide, thin-walled hyphae. Cheilocystidia 25–40 × 7–10 μm, fusiform or subfusciform, thin-walled, colorless to yellowish in KOH, no encrustations. Pleurocystidia 35–45 × 6–11 μm, fusiform or subfusciform, thin-walled, colorless to yellowish in KOH, no encrustations. Pileipellis a trichoderm about 100–200 μm thick, composed of slightly interwoven, nearly colorless in KOH, 5–8 μm wide, thin-walled hyphae; terminal cells 28–35 × 5–10 μm, clavate or subclavate, with obtuse apex. Pileal trama made up of hyphae 4–8 μm in diameter, slightly thick-walled (to 0.5 μm), colorless to yellowish in KOH. Stipitipellis hymeniform about 80–100 μm thick, composed of thin-walled emergent hyphae, yellowish in KOH, with clavate, subclavate, fusiform or subfusciform terminal cells (27–43 × 6–11 μm), and occasionally with scattered clavate, 4-spored basidia. Stipe trama composed of longitudinally arranged, parallel hyphae 3–6 μm wide, cylindrical, thin-walled, colorless to yellowish in KOH. Clamp connections absent in all tissues.

Habitat. Gregarious on the ground in forests dominated by Castanopsis kawakamii Hay. or Lithocarpus spp.

Distribution. Southeastern and southern China; Japan (Hongo 1967).

Specimens examined. CHINA. Hainan Province: Ledong County, Yinggeling National Nature Reserve, elev. 650 m, 4 June 2017, N.K. Zeng 3058 (FHMU 2019); same location, 5 June 2017, N.K. Zeng 3079 (FHMU 2040). Fujian Province: Zhangping County, Tiantai National Forest Park, elev. 350 m, 28 August 2009, N.K. Zeng 635 (FHMU 399); Sanming City, Geshikao National Forest Park, elev. 420 m, 16 August 2017, N.K. Zeng 3257 (FHMU 2218); same location and date, N.K. Zeng 3261 (FHMU 2222); Yongan City, Tianbaoyan National Nature Reserve, elev. 600 m, 17 August 2017, N.K. Zeng 3263 (FHMU 2224).

Note. Caloboletus guanyui was originally described as B. quercinus from Japan (Hongo 1967). Nomenclaturally, the epithet quercinus of this species is an illegitimate
name, because Schrader (1794) described a species using the same epithet before Hong-go (1967). Therefore, the new epithet guanyui is proposed here for this species. Moreover, morphological and molecular evidence indicates the taxon is a member of the genus Caloboletus (Fig. 2), and is characterized by a dirty-white to pale-brown pileus, pores reddish to reddish brown when young, then yellow or yellowish brown, changing bluish black when injured, and a stipe densely covered with pale-brown, brown to reddish-brown squamules. Morphologically, *C. taenius* and *C. xiangtoushanensis* also have reddish pores (Bessette et al. 2016; Zhang et al. 2017), however, a dirty-white to pale-brown pileus easily distinguishes *C. guanyui* from the two taxa. Phylogenetically *C. guanyui* is closely related to *C. firmus* (Frost) Vizzini (Fig. 2), however, *C. firmus* has a stipe covered with whitish or reddish reticula, and it is restricted to North and Central America (Bessette et al. 2016).

3. *Caloboletus xiangtoushanensis* Ming Zhang, T.H. Li & X.J. Zhong, Phytotaxa 309: 119, 2017
Figures 4g–j, 9

**Description.** Basidiomata medium-sized to large. *Pileus* 5.5–11 cm in diameter, convex to plane; surface dry, tomentose, yellowish brown, pale brown to brown; context 1–1.5 cm thick in the center of the pileus, yellowish, changing blue quickly when injured. *Hymenophore* poroid, adnate to depressed around apex of stipe; pores subround to angular, 0.5–1 mm in diameter, yellow, sometimes brownish red, changing blue quickly when injured; tubes 0.5–1.4 cm in length, yellowish, changing blue quickly when injured. *Stipe* 5–9 × 0.9–1.6 cm, central, subcylindric, solid, usually flexuous; surface dry, upper part covered with reddish brown, minute squamules, middle and lower part covered with brown minute squamules; context yellowish, changing blue quickly when injured; basal mycelium white. *Odor* indistinct.

**Basidia** 25–35 × 5–10 μm, clavate, thin-walled, colorless to yellowish in KOH; four-spored, sterigmata 3–4 μm in length. **Basidiospores** [140/8/3] (9.5–)10–11.5(–13) × 3.5–4.5 μm, Q=(2.11–)2.44–3.00(–3.29), $Q_m=2.76 \pm 0.21$, subfusoid and inequilateral in side view with a weak or distinct suprahilar depression, elliptic-fusiform to subfusiform in ventral view, slightly thick-walled (to 0.5 μm), olive-brown to yellowish brown in KOH, smooth. **Hymenophoral trama** boletoid; composed of colorless to yellowish in KOH, 4–10 μm wide, thin-walled hyphae. **Cheilocystidia** 25–45 × 7–10 μm, fusiform or subfusiform, thin-walled, colorless in KOH, no encrustations. **Pleurocystidia** 30–50 × 7–12 μm, fusiform or subfusiform, thin-walled, colorless in KOH, no encrustations. **Pileipellis** a trichoderm about 70–100 μm thick, composed of slightly interwoven, colorless or yellowish in KOH, 4–7 μm wide, thin-walled hyphae; terminal cells 35–55 × 4–7 μm, clavate or subclavate, with obtuse apex. **Pileal trama** made up of hyphae 3.5–7 μm in diameter, thin-walled, colorless to yellowish in KOH. **Stipitipellis** hymeniform about 60–80 μm thick, composed of thin- to slightly thick-walled (to 0.5 μm) emergent hyphae, colorless to yellowish in KOH, with clavate, subclavate,
fusiform or subfusiform terminal cells (15–46 × 5–8 μm), and occasionally with scattered clavate, four-spored basidia. *Stipe trama* composed of longitudinally arranged, parallel hyphae 3.5–8 μm wide, cylindrical, thin- to slightly thick-walled (to 0.5 μm), yellowish in KOH. *Clamp connections* absent in all tissues.

**Habitat.** Solitary or gregarious on the ground in forests dominated by fagaceous trees.

**Distribution.** Southeastern and southern China.

**Specimens examined.** CHINA. Fujian Province: Zhangping County, Xinqiao Town, Chengkou Village, elev. 350 m, 30 July 2013, N.K. Zeng 1330 (FHMU 883); same location and date, N.K. Zeng 1331 (FHMU 884); same location, 1 August 2013, N.K. Zeng 1354 (FHMU 906).

**Notes.** Our recent collections and the holotype of *C. xiangtoushanensis*, a species originally described from Guangdong Province of southern China (Zhang et al. 2017), phylogenetically group together with a strong statistical support (Fig. 2), which indicates that these specimens should be recognized as *C. xiangtoushanensis*. It is new to Fujian Province. Morphologically, several features of our collections also match well with the protologue of *C. xiangtoushanensis* (Zhang et al. 2017), but reticulations on the stipe were not observed in our specimens. Moreover, pores of our specimens are sometimes brownish red. In appearance, *C. xiangtoushanensis* is highly similar to Japanese *B. bannaensis* Har. Takah., which needs further confirmation for generic placement (Takahashi 2007). However, *B. bannaensis* has rufescent and faintly cyanescent context, small basidiospores measuring 6.5–9 × 3.5–4 μm, and narrower cystidia (Takahashi 2007). The molecular analyses also indicates that *C. xiangtoushanensis* is closely related to *C. taienus* (W.F. Chiu) Ming Zhang and T.H. Li (Fig. 2), a species originally described from Yunnan Province (Chiu 1948); their morphological differences have been elucidated in a previous study (Zhang et al. 2017).

**Chalciporus Bataille**

*Chalciporus*, typified by *Ch. piperatus* (Bull.) Bataille, is an early branching lineage in the Boletaceae (Nuhn et al. 2013; Wu et al. 2014, 2016b) and is characterized by a pinkish-red to reddish-brown hymenophore. Several taxa, including *Ch. citrinoaurantius* Ming Zhang & T.H. Li, *Ch. hainanensis* Ming Zhang & T.H. Li, *Ch. radiatus* Ming Zhang & T.H. Li, and *Ch. rubinelloides* G.Wu & Zhu L. Yang, were recently described from China (Zhang et al. 2015, 2017; Wu et al. 2016b). Here, *Ch. radiatus* is redescribed based on new collections from subtropical and tropical China.

**4. Chalciporus radiatus** Ming Zhang & T.H. Li, Mycoscience 57: 21, 2016

Figures 4k, l, 10

**Description.** *Basidiomata* small. *Pileus* 2.5–5 cm in diameter, subhemispherical to convex when young, then planate; surface dry, pale yellowish brown, densely cov-
ered with pale yellowish-brown, yellowish-brown, brown to reddish-brown squamules; margin decurved; context 0.6–1 cm thick in the center of the pileus, yellowish, unchanging in color when injured. *Hymenophore* poroid, slightly decurrent; pores radially strongly elongated, yellow to pale yellowish brown, reddish with age, unchanging in color when injured; tubes 0.2–0.4 cm in length, yellowish, unchanging in color when injured. *Stipe* 2.5–4.5 × 0.5–1 cm, central, subcylindric, solid; surface dry, yellow, covered with yellowish brown, brown to reddish-brown squamules; context yellowish, unchanging in color when injured; annulus absent; basal mycelium yellow. *Odor* indistinct.

*Basidia* 23–34 × 7–10 μm, clavate, thin-walled, four-spored; sterigmata 5–6 μm in length. *Basidiospores* [101/5/4] 6–7(–8) × 3–4 μm, $Q = (1.63–)1.71–2.14(–2.33)$, $Q_m = 1.91 \pm 0.15$, subfusoid and inequilateral in side view with a weak or distinct suprahilar depression, elliptic-fusiform to subfusiform in ventral view, slightly thick-walled (to 0.5 μm), olive-brown to yellowish brown in KOH, smooth. *Hymenophoral trama* boletoid. *Cheilocystidia* 57–75 × 8–10 μm, abundant, subfusiform or fusiform, thin-walled, with pale yellowish-brown to yellowish-brown contents, without encrustations. *Pleurocystidia* 60–76 × 7–9 μm, abundant, fusiform or subfusiform, thin-walled, with pale yellowish-brown to yellowish-brown contents, without encrustations. *Pileipellis* a trichoderm 200–230 μm thick, composed of rather vertically arranged, sometimes slightly interwoven, pale yellowish-brown to yellowish-brown in KOH, thin-walled hyphae 4–10 μm in diameter; terminal cells 25–50 × 6–9 μm, narrowly clavate or subcylindrical, with obtuse apex. *Pileal trama* composed of thin- to slightly thick-walled (up to 0.5 μm) hyphae 2–8 μm in diameter. *Stipitipellis* hymeniform composed of thin-walled hyphae with clavate, subclavate, subfusiform or fusiform terminal cells (13–80 × 5–9 μm). *Stipe trama* composed of cylindrical, thin- to slightly thick-walled (to 0.5 μm) parallel hyphae 5–11 μm in diameter. *Clamp connections* absent in all tissues.

**Habitat.** Solitary, scattered or gregarious on the ground in forests of *Pinus massoniana* Lamb. or *P. latteri* Mason.

**Distribution.** Central (Zhang et al. 2015), southeastern, and southern China.

**Specimens examined.** CHINA. Fujian Province: Zhangping County, Xinqiao Town, Chengkou Village, elev. 370 m, 4 August 2013, N.K. Zeng 1379 (FHMU 930); same location, 17 August 2013, N.K. Zeng 1414 (FHMU 959); same location, 16 August 2014, N.K. Zeng 1633 (FHMU 2493). Hainan Province: Dongfang County, Exian Mountain, elev. 633 m, 5 October 2014, N.K. Zeng 1808 (FHMU 2494).

**Notes.** Our molecular phylogenetic analyses indicate that the new collections and the holotype of *Ch. radiatus*, a species first described from Hunan Province of central China, group together with a strong statistical support based on a two-locus dataset (28S + *tef1*) (data not shown). This indicates that our specimens should be recognized as *Ch. radiatus* (Zhang et al. 2015). This species is new to Fujian and Hainan Province. Zhang et al. (2015) reported *Ch. radiatus* from under *Cunninghamia lanceolata* (Lamb.) Hook, *Cyclobalanopsis* spp. and *Castanopsis* spp. We found the species associated with *Pinus* spp.
Lanmaoa G. Wu & Zhu L. Yang

Lanmaoa, typified by *L. asiatica* G. Wu & Zhu L. Yang, was erected recently. However, *Lanmaoa* and its closely related genus *Cyanoboletus* share overlapping morphological features and the most important diagnostic feature of *Lanmaoa* defined by Wu et al. (2016a) is not constant (Chai et al. 2018). Here, we treat *Lanmaoa* as an independent genus until the true taxonomic relationship between *Lanmaoa* and *Cyanoboletus* can be studied.

5. *Lanmaoa macrocarpa* N.K. Zeng, H. Chai & S. Jiang, sp. nov.
MycoBank: MB828523
Figures 5a–c, 11

**Typification.** CHINA. Hainan Province: Qiongzhong County, Yinggeling National Nature Reserve, elev. 750 m, 28 May 2017, N.K. Zeng 3021 (FHMU 1982, holotype). GenBank accession numbers: 28S = MH879684, tef1 = MH879713.

**Etymology.** Latin, “*macrocarpa*”, meaning the new species has a large pileus.

**Description.** Basidiomata large. Pileus 10–13 cm in diameter, subhemispherical when young, then convex to applanate; surface dry, finely tomentose, brownish red (8B6–9B6); context about 2.5 cm thick in the center of the pileus, yellowish, changing blue quickly when injured. Hymenophore poroid, depressed around apex of stipe; pores subround to angular, 1–2 mm in diameter, yellow (3A5), changing blue quickly, then turning brown slowly when injured; tubes about 1.5 cm in length. Stipe 8–11 × 1.5–2 cm, central, subcylindric, solid; surface dry, brownish red (9C6), sometimes reticulate at apex; context yellow, changing blue quickly when injured; basal mycelium yellowish (2A4). Odor indistinct.

*Basidia* 18–28 × 6–10 μm, clavate, thin-walled, colorless to yellowish in KOH; four-spored, sterigmata 3–4 μm in length. *Basidiospores* [40/2/2] (9–)10–12(–13) × 4.5–5 μm, Q=(2.00–)2.10–2.60(–2.67), \( Q_m = 2.39 \pm 0.16 \), subfusoid and inequilateral in side view with a weak or distinct suprahilar depression, elliptic-fusiform to subfusiform in ventral view, slightly thick-walled (to 0.5 μm), olive-brown to yellowish brown in KOH, smooth. *Hymenophoral trama* boletoid; composed of colorless to yellowish in KOH, 4.5–9 μm wide, thin- to slightly thick-walled (to 0.5 μm) hyphae. *Cheilocystidia* 25–45 × 7–10 μm, ventricose, fusiform or subfusiform, thin-walled, yellowish in KOH, no encrustations. *Pleurocystidia* 25–45 × 7–11 μm, fusiform or subfusiform, thin-walled, yellowish in KOH, no encrustations. *Pileipellis* a trichoderm 120–160 μm thick, composed of rather vertically arranged, nearly colorless in KOH, 4.5–6 μm wide, thin-walled hyphae; terminal cells 21–32 × 4–6 μm long, clavate or subclavate, with obtuse apex. *Pileal trama* made up of hyphae 3–10 μm in diameter, thin-walled, nearly colorless in KOH. *Stipitipellis* hymeniform about 100 μm thick, composed of thin- to slightly thick-walled (to 0.5 μm) emergent hyphae, colorless in KOH, with clavate, subclavate, fusiform, or subfusiform terminal cells (22–43 × 3–9 μm), and oc-
New and noteworthy boletes from subtropical and tropical China

Casionally with scattered clavate, 4-spored basidia. **Stipe trama** composed of longitudinally arranged, parallel hyphae 3–8 μm wide, cylindrical, thin- to slightly thick-walled (to 0.5 μm), yellowish in KOH. **Clamp connections** absent in all tissues.

**Habitat.** Solitary on the ground in forests dominated by *Castanopsis kawakamii* Hay. or *C. fissa* (Champ. ex Benth.) Rehd. et Wils.

**Distribution.** Southeastern and southern China.

**Additional specimens examined.** CHINA. Fujian Province: Sanming City, Geshi-kao National Forest Park, elev. 400 m, 16 August 2017, N.K. Zeng 3251 (FHMU 2212).

**Note.** *Lanmaoa macrocarpa* is characterized by its large basidioma, brownish red pileus and stipe, thickness of hymenophore 3/5 times that of pileal context, and its

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**Figure 5.** Basidiomata of boletes. **a–c** *Lanmaoa macrocarpa* (a from FHMU 2212; b–c from FHMU 1982, holotype) **d–f** *Neoboletus bainanensis* (HKAS 90209) **g–l** *Neoboletus multipunctatus* (g, i–j, l from FHMU 2808 h, k from FHMU 1620, holotype). Photos by N.K. Zeng.
association with *Castanopsis* spp. It is both morphologically similar and phylogenetically related to Chinese *L. rubriceps* N.K. Zeng & Hui Chai (Chai et al. 2018) and one collection tentatively named “*Lanmaoa* sp. HKAS 52518” (Fig. 3). However, *L. rubriceps* has a red to crimson, orange-red pileus, pores stuffed when young, sometimes tinged with reddish when old, and smaller basidiospores measuring 8–11 × 4–5 μm (Chai et al. 2018); careful examinations showed that *Lanmaoa* sp. HKAS 52518 has a smaller basidioma, a reddish to red or blackish-red pileus, and surface of stipe turning blue when injured.

**Neoboletus** Gelardi, Simonini & Vizzini

*Neoboletus*, typified by *N. luridiformis* (Rostk.) Gelardi et al., is characterized by stipitate-pileate or sequestrate; when basidiomata stipitate-pileate, pores brown, dark brown to reddish brown when young, becoming yellow when old (Fig. 6c, d, f), tubes always yellow (Figs 5f, 6e, h), hymenophore and context staining blue, and stipe usually covered with punctuations (Vizzini 2014; Wu et al. 2016a). The monophyly of *Neoboletus* has been assessed, and many species of the genus were described (Wu et al. 2014, 2016b). Astonishingly, the same authors recombined *Neoboletus* species in the genus *Sutorius* after a short time (Wu et al. 2016a). As a matter of fact, the stipe ornamentation pattern, spore print color, and colors of pores and tubes are fully different between the two genera (Halling et al. 2012; Vizzini 2014; Gelardi 2017). Furthermore, with more sequences added, our molecular data infers that *Neoboletus* forms an independent clade with strong support, and the genus *Sutorius* is sister to *Costatisporus* T.W. Henkel & M.E. Sm. (Smith et al. 2015) (Fig. 2). Thus, we recognize *Neoboletus* as an independent genus.

6. **Neoboletus hainanensis** (T.H. Li & M. Zang) N.K. Zeng, H. Chai & Zhi Q. Liang, comb. nov.

MycoBank: MB828527

Figure 5d–f

*Boletus hainanensis* T.H. Li & M. Zang, Mycotaxon 80: 482, 2001

*Sutorius hainanensis* (T.H. Li & M. Zang) G. Wu & Zhu L. Yang, Fungal Diversity 81: 135, 2016

**Habitat.** Solitary on the ground in forests dominated by fagaceous trees including *Lithocarpus* spp.

**Distribution.** Southern and southwestern China.

**Note.** *Boletus hainanensis* T.H. Li & M. Zang was first described from Hainan Province of southern China (Zang et al. 2001). It was later also reported from Yunnan Province of southwestern China (Wu et al. 2016a) and was transferred to the genus
Sutorius. It is called the “Black bolete” in Yunnan Province, and largely traded in local mushroom markets (Wang et al. 2004).

**Specimens examined.** CHINA. Hainan Province: Changjiang County, Bawangling National Nature Reserve, elev. 650 m, 20 August 2009, N.K. Zeng 523 (HKAS 90209). Yunnan Province: Kunming City, bought from market, 11 July 2015, N.K. Zeng 2128 (FHMU 1392).

7. *Neoboletus multipunctatus* N.K. Zeng, H. Chai & S. Jiang, sp. nov.

*Mycobank:* MB828528

Figures 5g–l, 12

**Typification.** CHINA. Hainan Province: Qiongzhong County, Yinggeling National Nature Reserve, elev. 800 m, 3 August 2015, N.K. Zeng 2498 (FHMU 1620, holotype). GenBank accession numbers: 28S = MH879693, ITS = MH885354, *tef1* = MH879722.

**Etymology.** Latin, “*multipunctatus*”, referring to the many punctuations on the stipe.

**Description.** *Basidiomata* medium-sized. *Pileus* 5.7–7 cm in diameter, convex to applanate; surface dry, finely tomentose, brown (4D7), dark brown (5C7) to blackish brown (5D5); context 1–1.5 cm thick in the center of the pileus, yellowish (1A5), changing blue quickly when injured. *Hymenophore* poroid, depressed around apex of stipe; pores subround, 0.3–0.4 mm in diameter, brown (7B5) to reddish brown (6C8), changing bluish black quickly when injured; tubes 0.5–0.7 cm in length, yellowish (1A5), changing blue quickly when injured. *Stipe* 7–7.4 × 1–1.3 cm, central, subcylindric, solid, usually flexuous; surface dry, covered with reddish-brown (7B5) squamules; context yellow (1A3), changing blue (21B3) quickly when injured; basal mycelium yellow (1A3). *Odor* indistinct.

*Basidia* 27–37 × 6–10 μm, clavate, thin-walled, colorless to yellowish in KOH; four-spored, sterigmata 5–6 μm in length. *Basidiospores* [80/4/3] 8.5–11(–12) × 4–5 μm, Q=(1.80–)1.90–2.50(–2.75), \(Q_m=2.22 \pm 0.22\), subfusoid and inequilateral in side view with a weak or distinct suprahilar depression, elliptic-fusiform to subfusiform in ventral view, slightly thick-walled (to 0.5 μm), olive-brown to yellowish brown in KOH, smooth. *Hymenophoral trama* boletoid; composed of colorless to yellowish in KOH, 4–8 μm wide, thin-walled hyphae. *Cheilocystidia* 27–34 × 5–7 μm, fusiform or subfusiform, thin-walled, fawn to tawny in KOH, no encrustations. *Pleurocystidia* 38–61 × 6–8 μm, fusiform or subfusiform, thin-walled, colorless to tawny in KOH, no encrustations. *Pileipellis* a trichoderm about 120 μm thick, composed of vertically arranged, nearly colorless to yellowish in KOH, 3–5 μm wide, thin-walled hyphae; terminal cells 21–70 × 3–5 μm, clavate or subclavate, with obtuse apex. *Pileal trama* made up of hyphae 3–8 μm in diameter, thin-walled, colorless to yellowish in KOH. *Stipitipellis* hymeniform about 100 μm thick, composed of thin-walled emergent hyphae, colorless to yellowish in KOH, with clavate, subclavate, fusiform or subfusiform
terminal cells (25–44 × 3–9 μm), and occasionally with scattered clavate, 4-spored basidia. Stipe trama composed of longitudinally arranged, parallel hyphae 4–9 μm wide, cylindrical, thin to slightly thick-walled (to 0.5 μm), colorless in KOH. Clamp connections absent in all tissues.

**Habitat.** Solitary on the ground in forests dominated by fagaceous trees including *Lithocarpus* spp.

**Distribution.** Southern China.

**Additional specimens examined.** CHINA. Hainan Province: Changjiang County, Bawangling National Nature Reserve, elev. 600 m, 22 August 2009, N.K. Zeng 559 (HKAS 76851); Ledong County, Yinggeling National Nature Reserve, elev. 620 m, 6 May 2018, N.K. Zeng 3324 (FHMU 2808).

**Note.** *Neoboletus multipunctatus* is characterized by a brown, dark brown to blackish brown pileus, brown to reddish-brown pores changing bluish black when injured, stipe surface densely covered with brown to reddish-brown punctuations, smaller basidiospores, and its association with fagaceous trees. It is both morphologically similar and phylogenetically related to *N. brunneissimus* (W.F. Chiu) Gelardi et al. (Fig. 2), a species originally described from Yunnan Province of southwestern China. However, *N. brunneissimus* has larger basidiospores measuring 10–14 × 4.5–5 μm, and it occurs in temperature regions in addition to subtropical belts (Wu et al. 2016a). *Neoboletus multipunctatus* is also similar to *N. hainanensis* and *N. sinensis* (T.H. Li & M. Zang) Gelardi et al. morphologically. However, both pileal and stipe surface of *N. hainanensis* stain blue when injured, with white basal mycelium on the stipe, relatively larger basidiospores measuring 9.5–13.5 × 4–5 μm, and a trichodermium to ixotrichodermium pileipellis (Zang et al. 2001; Wu et al. 2016a). *Neoboletus sinensis*, a species also described from Hainan Province, has a cherry red stipe with reticulations, larger basidiospores measuring 13–19 × 5–6.5 μm, and wider cystidia (Zang et al. 2001; Vizzini 2014).

### 8. *Neoboletus obscureumbrinus* (Hongo) N.K. Zeng, H. Chai & Zhi Q. Liang, **comb. nov.**

MycoBank: MB828529

Figure 6a–e

*Boletus obscureumbrinus* Hongo, Mem. Fac. Lib. Arts. Educ. Shiga Univ. Nat. Sci., 18: 4, 1968

*Sutorius obscureumbrinus* (Hongo) G. Wu & Zhu L. Yang, Fungal Diversity 81: 138, 2016

**Habitat.** Solitary or gregarious on the ground in forests dominated by fagaceous trees including *Lithocarpus* spp.

**Distribution.** Southern and southwestern China; Japan (Hongo 1968).

**Note.** *Boletus obscureumbrinus* Hongo was originally described from Japan (Hongo 1968) and later reported from Guangdong Province of southern China and Yunnan Province of southwestern China (Wu et al. 2016a). It was transferred to the genus...
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*Sutorius* by Wu et al. (2016a); in the present study, we place the species in *Neoboletus* according to the evidence referred to above (Fig. 2). It is new to Hainan Province. The fruit body of this species is eaten by the Li people who live in the region (our own investigations).

**Specimens examined.** CHINA. Hainan Province: Ledong County, Yinggeling National Nature Reserve, elev. 620 m, 5 June 2017, *N.K. Zeng* 3091, 3094, 3098 (FHMU 2052, 2055, 2059); same location, 6 May 2018, *N.K. Zeng* 3310, 3353 (FHMU 2271, 2814).

9. *Neoboletus tomentulosus* (M. Zang, W.P. Liu & M.R. Hu) N.K. Zeng, H. Chai & Zhi Q. Liang, comb. nov.

*Mycobank:* MB828530

*Figure 6f–h*

*Boletus tomentulosus* M. Zang, W.P. Liu & M.R. Hu, *Acta Botanica Yunnanica* 13: 150, 1991

*Sutorius tomentulosus* (M. Zang, W.P. Liu & M.R. Hu) G. Wu & Zhu L. Yang, *Fungal Diversity* 81: 142, 2016

**Habitat.** Solitary or gregarious on the ground in forests dominated by *Castanopsis kawakamii* Hay.

**Distribution.** Southeastern China.

**Note.** *Boletus tomentulosus* M. Zang et al. was first described from Fujian Province of southeastern China (Zang et al. 1991) and later reported from Guangdong Province of southern China (Wu et al. 2016a). Although the description of the protologue was brief (Zang et al. 1991), it has been well studied by Wu et al. (2016a). Our new collections were encountered near the type locality and augments our understanding of the species and the genus *Neoboletus*.

**Specimens examined.** CHINA. Fujian Province: Zhangping County, Xinqiao Town, Chengkou Village, elev. 350 m, 27 July 2013, *N.K. Zeng* 1285, 1286 (FHMU 841, 842).

*Sutorius* Halling, Nuhn & N.A. Fechner

*Sutorius*, typified by *S. eximius* (Peck) Halling et al., is mainly characterized by pores and tissues that are tinged with reddish at all growth stages, tissues not stained blue, a reddish-brown spore print, and transversely scissurate scales on stipe surface (Smith and Thiers 1971; Halling et al. 2012). Until now, only two taxa, *S. australiensis* (Bougher & Thiers) Halling and N.A. Fechner, and *S. eximius* (Peck) Halling et al., were described, excluding those in Wu et al (2016a). Herein, we describe another species new to science.
Figure 6. Basidiomata of boletes. a–e *Neoboletus obscureumbrinus* (a, e from FHMU 2271 b, d from FHMU 2055 c from FHMU 2814) f–h *Neoboletus tomentulosus* (h–i from FHMU 842, j from FHMU 841) i–k *Sutorius subrufus* (FHMU 2004, holotype) l *Tylopilus virescens* (FHMU 1004). Photos by N.K. Zeng.

10. *Sutorius subrufus* N.K. Zeng, H. Chai & S. Jiang, sp. nov.
MycoBank: MB828531
Figures 6i–k, 13

**Typification.** CHINA. Hainan Province: Qiongzhong County, Yinggeling National Nature Reserve, elev. 850 m, 29 May 2017, *N.K. Zeng 3043* (FHMU 2004, holotype). GenBank accession numbers: 28S = MH879698, ITS = MH885360, tef1 = MH879728, rpb2 = MH879745.
Etymology. Latin, “subrufus” refers to the stipe surface and context of the species turning reddish when injured.

Description. Basidiomata medium to large. Pileus 5–10 cm in diameter, subhemispherical to convex when young, then planarate; surface dry, finely tomentose, brown to pale reddish brown (10C2–11C3); context about 1.6 cm thick in the center of the pileus, white (6A1), changing reddish (9C3) when injured. Hymenophore poroid, adnate or slightly depressed around apex of stipe; pores angular, about 0.3 mm in diameter, pale brown (8C3), brown (7E2) to pale reddish brown (10C2), mostly unchanging in color when injured, but sometimes changing reddish; tubes about 1 cm in length, pale brown (8D3), unchanging in color when injured, but sometimes changing reddish. Stipe 6–10 × 1–2.2 cm, central, subcylindrical, solid; surface dry, gray-white, but brownish yellow at base, covered with pale reddish-brown (7B2) to blackish-brown squamules, usually changing reddish when injured; context white (1D1–2), changing reddish (9C3) when injured; annulus absent; basal mycelium white (1A1). Odor indistinct.

Basidia 18–30 × 6–9 μm, clavate, thin-walled, colorless to yellowish in KOH; four-spored, sterigmata 2–3 μm in length. Basidiospores [200/24/3] (8–)9–12(–13.5) × 3.5–4.5 μm, Q=(2.25–)2.50–3.00(–3.29), Q_m=2.79 ± 0.21, subfusoid and inequilateral in side view with a weak or distinct suprahilar depression, elliptic-fusiform to subfusiform in ventral view, slightly thick-walled (to 0.5 μm), olive-brown to yellowish brown in KOH, smooth. Hymenophoral trama boletoid; composed of colorless to yellowish in KOH, 5–10 μm wide, thin- to slightly thick-walled (up to 0.5 μm) hyphae. Cheilocystidia 28–45 × 7–10 μm, ventricose, fusiform or subfusiform, thin-walled, colorless to yellowish in KOH, no encrustations. Pleurocystidia 35–50 × 7–10 μm, fusiform or subfusiform, thin-walled, colorless to yellowish in KOH, no encrustations. Pileipellis a trichoderm about 100–150 μm thick, composed of rather vertically arranged, yellowish in KOH, 3.5–6 μm wide, thin-walled hyphae; terminal cells 30–43 × 3.5–6 μm, clavate or subclavate, with obtuse apex. Pileal trama made up of hyphae 4.5–10 μm in diameter, thin-walled, nearly colorless in KOH. Stipitipellis hymeniform about 60–80 μm thick, composed of thin-walled emergent hyphae, colorless in KOH, with clavate, subclavate terminal cells (22–28 × 4–9 μm), and occasionally with scattered clavate, four-spored basidia. Stipe trama composed of longitudinally arranged, parallel hyphae 4–8 μm wide, cylindrical, thin- to slightly thick-walled (to 0.5 μm), fawn to tawny in KOH, parallel hyphae. Clamp connections absent in all tissues.

Habitat. Scattered, gregarious or caespitose on the ground in forests dominated by fagaceous trees, including Lithocarpus spp.

Distribution. Southern China.

Additional specimens examined. CHINA. Hainan Province; Qiongzhong County, Yinggeling National Nature Reserve, elev. 860 m, 29 May 2017, N.K. Zeng 3045 (FHMU 2006); Ledong County, Yinggeling National Nature Reserve, elev. 650 m, 27 July 2017, N.K. Zeng 3140 (FHMU 2101).

Note. Sutorius subrufus is characterized by a brown to pale reddish-brown pileus, stipe surface and context turning reddish when injured, relatively smaller basidi-
ospores, and it is restricted in tropical China. It is both morphologically similar and phylogenetically related to *S. eximius* (Peck) Halling et al. and *S. australiensis* (Bougher & Thiers) Halling and N.A. Fechner. However, stipe surface and context of *S. eximius* does not change when injured. Moreover, *S. eximius* has larger basidiospores, and a distribution in North and Central America (Singer 1947; Smith and Thiers 1971; Halling et al. 2012); *S. australiensis* has relatively larger basidiospores, a distribution in Australia, and is associated with Myrtaceae and Casuarinaceae (Halling et al. 2012).

**Tylopilus** P. Karst.

*Tylopilus*, typified by *T. felleus* (Bull.) P. Karst., is characterized by the pallid, pinkish, vinaceous and pinkish-brown hymenophore, white to pallid context without color change, but some species becoming rufescent or sea-green when injured, and the bitter taste of the context (Baroni and Both 1998; Henkel 1999; Fulgenzi et al. 2007; Osmundson and Halling 2010; Wu et al. 2016a; Magnago et al. 2017; Liang et al. 2018).

In China, although lots of species of the genus have been previously discovered (Li et al. 2002; Fu et al. 2006; Gelardi et al. 2015; Wu et al. 2016a; Liang et al. 2018), still there are a large number of undescribed taxa in this region.

11. *Tylopilus virescens* (Har. Takah. & Taneyama) N.K. Zeng, H. Chai & Zhi Q. Liang, comb. nov.
MycoBank: MB828532
Figure 6l

*Boletus virescens* Har. Takah. & Taneyama, The fungal flora in southwestern Japan, agarics and boletes 1: 45, 2016

*Tylopilus callainus* N.K. Zeng, Zhi Q. Liang & M.S. Su, Phytotaxa 343 (3): 271, 2018

**Habitat.** Solitary or gregarious on the ground in forests dominated by fagaceous trees including *Lithocarpus* spp. or *Castanopsis kawakami* Hay.

**Distribution.** Southeastern and southern China; Japan (Terashima et al. 2016).

**Note.** *Tylopilus callainus* N.K. Zeng et al. was described from the south of China (Liang et al. 2018). This taxon was previously thought to be different from *B. virescens* Har. Takah. & Taneyama, a species described from Japan (Terashima et al. 2016). After a careful re-evaluation of specimens, we now know that the two taxa are conspecific, and *T. callainus* is synonymized with *B. virescens*. Clarifying the taxonomic relationship between the two taxa also indicated that the *B. virescens* is a member of *Tylopilus*, and thus the new combination is proposed. Illustrations and a full description have been provided by Liang et al. (2018).

**Specimens examined.** CHINA. Fujian Province: Zhangping County, Xinqiao Town, Chengkou Village, elev. 350 m, 22 August 2013, N.K. Zeng 1360, 1459 (FHMU
New and noteworthy boletes from subtropical and tropical China

Figure 7. Microscopic features of *Butyriboletus huangnianlaii* (FHMU 2207, holotype). a Basidia and pleurocystidium b Basidiospores c Cheilocystidia d Pleurocystidia e Pileipellis f Stipitipellis. Scale bars: 10 μm.
Figure 8. Microscopic features of Caloboletus guanyui (FHMU 2040). a Basidia and pleurocystidia b Basidiospores c Cheilocystidia d Pleurocystidia e Pileipellis f Stipitipellis. Scale bars: 10 μm.
**Figure 9.** Microscopic features of *Caloboletus xiangtoushanensis* (FHMU 883). a Basidia and pleurocystidia b Basidiospores c Cheilocystidia d Pleurocystidia e Pileipellis f Stipitipellis. Scale bars: 10 μm.

same location, 27 May 2017, *N.K. Zeng 3001* (FHMU 1962); Ledong County, Jianfengling National Nature Reserve, elev. 850 m, 27 June 2018, *N.K. Zeng 3426, 3431* (FHMU 2810, 2811).
Figure 10. Microscopic features of *Chalciporus radiatus* (FHMU 930). a Basidia and pleurocystidium b Basidiospores c Cheilocystidia d Pileipellis e Stipitipellis. Scale bars: 10 μm.
Figure 11. Microscopic features of *Lanmaoa macrocarpa* (a–e from FHMU 1982, holotype f from FHMU 2212). a Basidia and pleurocystidium b Basidiospores c Cheilocystidia d Pleurocystidia e Pileipellis f Stipitipellis. Scale bars: 10 μm.
Figure 12. Microscopic features of *Neoboletus multipunctatus* (FHMU 1620, holotype). a Basidia and pleurocystidium b Basidiospores c Cheilocystidia d Pileipellis e Stipitipellis. Scale bars: 10 μm.

New combinations

According to the analytical results presented here, the following new combinations are proposed:

*Neoboletus ferrugineus* (G. Wu, F. Li & Zhu L. Yang) N.K. Zeng, H. Chai & Zhi Q. Liang, comb. nov.
MycoBank: MB828533

*Sutorius ferrugineus* G. Wu, Fang Li & Zhu L. Yang, Fungal Diversity 81: 134, 2016
Figure 13. Microscopic features of *Sutorius subrufus* (FHMU 2004, holotype). a Basidia and pleurocystidium b Basidiospores c Cheilocystidia d Pleurocystidia e Pileipellis f Stipitipellis. Scale bars: 10 μm.

*Neoboletus flavidus* (G. Wu & Zhu L. Yang) N.K. Zeng, H. Chai & Zhi Q. Liang, comb. nov.
MycoBank: MB828534

*Sutorius flavidus* G. Wu & Zhu L. Yang, Fungal Diversity 81: 135, 2016
**Neoboletus rubriporus** (G. Wu & Zhu L. Yang) N.K. Zeng, H. Chai & Zhi Q. Liang, **comb. nov.**  
MycoBank: MB828535

*Sutorius rubriporus* G. Wu & Zhu L. Yang, Fungal Diversity 81: 139, 2016

**Neoboletus sanguineoides** (G. Wu & Zhu L. Yang) N.K. Zeng, H. Chai & Zhi Q. Liang, **comb. nov.**  
MycoBank: MB828536

*Sutorius sanguineoides* G. Wu & Zhu L. Yang, Fungal Diversity 81: 140, 2016

**Neoboletus sanguineus** (G. Wu & Zhu L. Yang) N.K. Zeng, H. Chai & Zhi Q. Liang, **comb. nov.**  
MycoBank: MB828537

*Sutorius sanguineus* G. Wu & Zhu L. Yang, Fungal Diversity 81: 141, 2016

**Discussion**

Molecular phylogenetic analyses have been used widely to define the genera of boletes, and as a result, many genera were erected or merged (Zeng et al. 2012, 2014b; Nuhn et al. 2013; Wu et al. 2014, 2016a, b). Recently, the genus *Neoboletus* was synonymized with *Sutorius* solely based on the evidence of molecular data (Wu et al. 2016a). Our molecular phylogenetic analyses based on a four-locus dataset (28S + ITS + tef1 + rpb2) with sequences from taxa of *Neoboletus*, *Sutorius*, *Costatisporus*, and *Caloboletus* (Fig. 2) indicate those species that morphologically match the concept of genus *Neoboletus* do not belong in *Sutorius*; instead, they form an independent clade with strong support (Fig. 2). At the same time, the morphological features including the stipe ornamentation pattern, spore print color, and color change of tissues are different between the two genera and has been noted in previous studies (Halling et al. 2012; Gelardi 2017). It is noteworthy that the color of tubes of *Neoboletus* is always yellow (Figs 5f, l, 6e, h), and in this genus the pores usually become yellow when old (Fig. 6d, f), whereas the color of tubes and pores of *Sutorius* are always tinged with reddish at different growth stages (Fig. 6i–k).

The present study further shows that the most important diagnostic feature of the genus *Lanmaoa*, viz. “short hymenophoral tubes (thickness of hymenophore 1/3–1/5 times that of pileal context at the position halfway to the pileus center) and a slow color change when injured” defined by Wu et al. (2016b) is not constant (Chai et al. 2018), for the thickness of hymenophore is about 3/5 times that of pileal context in our newly described *L. macrocarpa*. Additionally, context and hymenophore of our new species turn quickly and strongly when injured (Fig. 5c).
According to current molecular data, 10 lineages (lineages 1–10) of *Sutorius* were found (Fig. 2). Lineages 4 and 6 were identified as *S. australiensis* and *S. eximius* respectively in a previous study (Halling et al. 2012). Lineages 1, 2, 3, 5, 7 and 9 may have not diverged enough (Fig. 2) and are treated here as a series of closely related taxa or disjunct populations of previously described entities; these will be assessed in the future with more DNA sequences and more collections. As to lineages 8 and 10, they should be treated as independent taxa due to their high degree divergence. Moreover, morphological and ecological features (described above) of specimens (FHMU 2004, FHMU 2006, FHMU 2101) in lineage 8 from Hainan Province are also different from the described taxa of *Sutorius*, and thus, the new taxon *S. subrufus* was proposed.

Lineage 10 was not described due to the paucity of the materials (Halling et al. 2012). Subtropical and tropical China is believed to be a biodiversity hotspot. Mycologists have paid much attention to boletes of the region in the past decade, and many taxa have been discovered (Bi et al. 1997; Zeng and Yang 2011; Zeng et al. 2012, 2013, 2014a, b, 2015a, b, 2016, 2017, 2018; Zang 2013; Liang et al. 2016, 2017, 2018; Chai et al. 2018; Xue et al. 2018). Among of them, many have been found to be as North American or European species (Bi et al. 1997; Zang 2013), and recent studies have shown that species shared between subtropical/tropical China and North America/Europe are rare but that there are many common species between Japan and subtropical/tropical China (Zeng et al. 2013, 2016, 2017). Our study now reveals that the geographic distributions of the Japanese *C. guanyui*, *N. obscureumbrinus*, and *T. virescens* extend into subtropical or tropical China.

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