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Description of the Yunnan shoot borer, *Tomicus yunnanensis* Kirkendall & Faccoli sp. n. (Curculionidae, Scolytinae), an unusually aggressive pine shoot beetle from southern China, with a key to the species of *Tomicus*

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Abstract

We describe a new and highly aggressive species of pine shoot beetle, *Tomicus yunnanensis* Kirkendall & Faccoli, which has been decimating *Pinus yunnanensis* forests in southwest China for almost three decades. This species was confused with *T. piniperda* until recent molecular studies showed the SW China populations to be quite divergent from *T. piniperda* of northeast China and Europe. The clearest morphological differences between these two species lie in the surface sculpture of the elytra: the new species has more widely spaced interstrial granules on the elytral disc, the punctures of interstria 2 on the declivity arranged irregularly and those of striae 1 and 3 smaller. The new species also has dense small hairs on the tip of the antennal club, while *T. piniperda* has only scattered small hairs on that segment. Mature *T. piniperda* specimens are uniformly black, while those of *T. yunnanensis* have the bulk of the elytra lighter than the base of the elytra and the pronotum. The new species is actually more similar to the Mediterranean species *T. destruens*, which differs in geographical distribution and in having the punctures of interstria 2 dense on the declivity and light-colored antennae. Species of *Tomicus* are of general concern to foresters because of their impact on conifer growth, but good illustrations for many species are lacking. We here provide a detailed key to all seven species of the genus (*T. minor*, *T. piniperda*, *T. destruens*, *T. brevipilosus*, *T. yunnanensis* and the virtually unknown *T. puellus* and *T. pilifer*) as well as diagnostic photographs and drawings. We summarize the biological differences between the new species and *T. piniperda* and recommend improved communication between taxonomists and forest entomologists, as avoidable taxonomic confusion such as that of *T. yunnanensis* and *T. destruens* with *T. piniperda* hinders the combatting of outbreaks of forest insects.

Key words: Yunnan, *Pinus yunnanensis*, bark beetle, forest pest, *Tomicus piniperda, Tomicus minor, Tomicus destruens, Tomicus brevipilosus, Tomicus puellus, Tomicus pilifer*

Introduction

The pine shoot beetles of the genus *Tomicus* Latreille (= *Blastophagus* Eichhoff, *Myelophilus* Eichhoff) (Coleoptera, Curculionidae, Scolytinae) are among the more damaging insects in Eurasian pine forests (Escherich, 1923; Stark, 1952; Postner, 1974; Långström, 1983; Ye, 1991; Ye & Lieutier, 1997; Sun *et al.*, 2005). Adults have a period of maturation feeding, during which they tunnel in branch tips. The cumulative damage of large numbers of individuals feeding on the same tree can be considerable, due to loss of needles and depressed growth (Escherich, 1923; Postner, 1974; Långström & Hellqvist, 1990; Czokajlo *et al.*, 1997). Three species, *T. puellus* (Reitter), *T. pilifer* (Spessivtsew) and *T. brevipilosus* (Eggers), occur only in Asia and are rare in European and North American collections, while *T. piniperda* and *T. minor* (Hartig) are widespread

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in Eurasia and *T. destruens* (Wollaston) has a circum-Mediterranean distribution (Schedl, 1946; Wood & Bright, 1992). All species normally breed in *Pinus* spp., except for *T. puellus*, which usually develops on Asian *Picea* species (*P. jezoensis* and *P. ajanensis*) although it has been reported occasionally from pine (Schedl, 1946). *Tomicus* species are phloeophagous (breed in inner bark) and monogamous. The life cycle involves reproduction in the phloem of the trunks and larger branches of dead or weakened trees, followed by a long maturation feeding by callow adults in shoots of healthy host trees (Eichhoff, 1881; Escherich, 1923; Stark, 1952; Chararas, 1962; Bakke, 1968; Postner, 1974; Långström, 1983).

Tomicus piniperda (L.) has recently become established in the midwestern and northeastern USA and southeastern Canada (Haack, 2006; Humble & Allen, 2006). There are now quarantines on the export of pine trees and certain pine products from the affected areas, though current economic damage seems to be primarily to the Christmas tree industry (Haack & Poland, 2001). Given the increasing trade with countries of the Far East and the ease with which bark beetles in particular are transported between continents (e.g. Haack, 2001; LaBonte *et al*., 2005; Brockerhoff *et al*., 2006; Haack, 2006), it seems only a matter of time before other *Tomicus* species are discovered in conifer forests to which they are not native. Since species can differ importantly in such details of their behavior and ecology as the timing of reproduction or the virulence of fungi which they transport, it is imperative that forest entomologists and quarantine officials be able to identify *Tomicus* species correctly. Currently, no tools exist for discriminating among all species of this taxonomically difficult genus.

This problem takes on new urgency now that recent molecular data have clearly revealed the existence of an undescribed *Tomicus* species causing massive tree mortality in southwestern China, though tree-killing is considered to be atypical for pine shoot beetles (Chararas, 1962; Långström & Hellqvist, 1993). A recent DNA sequencing study revealed that populations from Yunnan, long assumed to be the widespread Eurasian *T. piniperda*, are strongly differentiated from *T. piniperda* from northeast China, which populations are only weakly differentiated from (and clearly conspecific with) European *T. piniperda* (Duan *et al*., 2004). Genetic distances between southern China specimens and those from northeastern China or France are an order of magnitude larger than those within regions or between France and northeastern China. Duan *et al.* conclude that Yunnan populations comprise an unrecognized, undescribed species.

The populations from southwest China are unusually aggressive. The beetles aggregate densely for maturation feeding in individual *Pinus yunnanensis* trees and subsequently attack the trunks of these same trees, leading to their rapid decline and death. Outbreaks have decimated over 200,000 ha of pine forest in Yunnan (Ye & Ding, 1999), leading to considerable research into the ecology and control of these populations (Ye, 1991, 1994; Ye & Li, 1995; Ye & Zhao, 1995; Ye & Lieutier, 1997; Ye & Ding, 1999; Långström *et al*., 2002; Lieutier *et al*., 2003; Sun *et al*., 2005). We here describe this new species, illustrate all seven species of the genus *Tomicus* and present the first dichotomous key allowing their identification.

Methods and Materials

Material examined

Our concepts of these species are based on past experience with the three European species and on material in the collections of LRK and MF and borrowed from museums or colleagues. Three specimens of *T. pilifer* from Russia (Vladivostok) and two from northeastern China (Ussuri) were available to us, as well as three specimens of *T. puellus* from Vladivostok. Table 1 details the material of *T. minor*, *T. brevipilosus* and *T. yunnanensis* from Yunnan that we examined. It includes four specimens of *T. piniperda* from Jilin in northeast China available from the material studied by Duan *et al*. (2004) as well as records based on collections of at least 50 specimens per site made during routine forest pest surveys in Yunnan from 2006–2007 (Ye, unpublished data).

TABLE 1. Material of *Tomicus* species studied from counties of Yunnan Province, China (identified by LRK or MF). Numbers refer to specimens collected from *Pinus yunnanensis* between 1999 and 2004 except for fields marked with +, which denotes specimens collected in 2006–2007 and identified by YH. Numbers in last column represent specimens sequenced by Duan *et al*. (2004).

Yunnan county	**Latitude**	**Longitude**	***T. yunnanensis***	***T. brevipilosus***	***T. minor***	**Duan et al. 2004**
Gejiu	23° 20’ N	102° 57’ E	44		6	5 Ty, 1 Tm
Shizong	24° 46’ N	103° 57’ E	33		4	
Xiundian	25° 33’ N	103° 14’ E	11	1	14	
Shilin	24° 51’ N	103° 28’ E	50	+	4	5 Ty
Lufeng	25° 09’ N	101° 53’ E	32	+	+	
Midu	25° 12’ N	100° 33’ E	28	+	+	
Xiangyun	25° 30’ N	100° 30’ E	28	9	3	5 Ty, 1 Tm
Luliang	25° 07’ N	103° 37’ E	27	4	+	5 Ty, 1 Tm
Zhanyi	25° 38’ N	103° 48’ E	44	9	6	2 Ty, 2 Tb
Chuxiong	25° 10’ N	101° 33’ E	15	12	10	5 Ty
Anning	24° 57’ N	102° 25’ E	+	9	+	1 Ty, 4 Tb
Eshan	24° 10’ N	102° 20’ E	6	6	7	4 Ty, 1 Tm
Yimen	24° 51’ N	102° 11’ E	2	+	+	2 Ty, 3 Tb, 1 Tm
Xinping	24° 03’ N	102° 09’ E	27		+	5 Ty, 1 Tm
Yiliang	24° 57’ N	103° 10’ E	20	16	+	5 Ty
Luxi	24° 32’ N	103° 42’ E	6		+	5 Ty
TOTAL			**373**	**66**	**54**	

Lighting and measurements

Tomicus species can be readily distinguished by the pattern of the spatial distribution of the punctures and granules in the elytral striae and interstriae. These characters are best examined in using flat lighting, which readily shows up details of surface sculpture and setation of the frons, pronotum and elytra in shiny insects. Lighting from standard microscope lamps, including most fibre-optic lights, creates reflections that obscure diagnostic taxonomic features. An easy and inexpensive solution is to use flexible desk lamps with high-intensity fluorescent or energy-saving light bulbs. Flat lighting can also be achieved by reflecting light off a white surface such as that of styrofoam cup, which gives excellent results especially in photography (Longino, 2002).

Body length was measured in lateral view and not corrected for variation in the distance between pronotum and elytra, in order to make our measurements comparable with data in the forestry literature. Intraspecific variation in body length is large in phloeophagous bark beetles (Wood, 1982; Andersen & Nilssen, 1983), and in *Tomicus* body length alone cannot discriminate even species that differ significantly in size. Maximum and minimum lengths given in the key are the extremes from the literature (Schedl, 1946; Stark, 1952; Murayama, 1963; Nobuchi, 1966; Wang, 1981) or from our measurements (Table 2). Elytral length was also measured in lateral view but pronotal and elytral widths in dorsal view (couplet 5), all at 12x magnification using an ocular micrometer.

In selected specimens the elytra were parted and the apical tergites examined. In males tergites 7 and 8 are visible but in females only tergite 7 (Wood, 1982: Fig. 14C). We found no consistent sexual differences in the structure of frons or elytral declivity. The sex of the holotype of the new species could not be determined as we did not want to risk damaging it by dissection.

Terminology

The following terms are used in the key and description:

disc: flat portion of the elytra.
declivity: the sloping posterior portion of the elytra.
striae: rows of large punctures (indentations) on the elytra.
interstriae: the interspaces between the striae (= "interspaces" as used by some earlier taxonomists).
confused: not in distinct rows.
ground vestiture: short hairs arising from interstrial punctures, often abraded or difficult to see.
decumbent: lying flat, as opposed to **erect** (= recumbent of some authors).
club: the fused terminal three segments of the antenna.
funicle: the six small segments between the club and the scape.
scape: the enlarged basal segment of the antenna.
monoramous: tunnel consisting of one branch or 'arm'.
biramous: with two branches.
longitudinal: directed with the grain of the wood, or along the long axis of the body.
transverse: across the grain.

Key to the species of *Tomicus* Latreille

No key to the six previously published species of *Tomicus* exists. The bark beetles killing trees in Yunnan, identified in the literature as *T. piniperda*, are clearly morphologically distinct from that taxon and are described as a new, seventh species below. The following key to all seven species of the genus is based on specimens examined by us. *Tomicus puellus* and *T. pilifer* are rare in Western collections and nowhere well illustrated, and although we could study only a few specimens of these two species, they proved readily identifiable. Many characters used in the key vary intraspecifically and the extreme character states may overlap interspecifically; however, combinations of these characters reliably distinguish otherwise similar species.

1. **Interstria 2 on declivity with rows of small granules**, not impressed (weakly impressed in some *T. minor*) (Fig. 1)..2
- **Interstria 2 devoid of granules**, clearly impressed (Fig. 2) 4

2(1). **Elytral vestiture consisting of longer, erect interstrial hairs (arising from granules) in uniseriate rows and shorter decumbent hairs** (ground vestiture), erect hairs longer on declivity (Figs. 1c, d). Elytral declivity with conspicuous interstrial tubercles in regular uniseriate rows. Larger species, length 3.1–5.2 mm. Normal hosts *Pinus* spp. 3
- **Elytral interstrial hairs and ground vestiture equally short, dense, confused**, **decumbent or nearly so**, not longer on declivity (Figs. 1a, b). Elytral interstriae strongly crenulate; interstrial tubercles large, transversely confluent, confused. Interstrial punctures confused on declivity, only slightly larger than strial punctures; interstrial tubercles inconspicuous on declivity. Smallest species, length 2.9–3.5 mm (ours 3.0–3.2). Maternal gallery monoramous, longitudinal. Distribution: Siberia, Russian Far East and Sakhalin Island. Normal hosts: *Picea jezoensis*, *P. ajanensis*, *Abies holophylla*, *A. nephrolepis* but also recorded from *Pinus koraiensis*..*T. puellus* (Reitter)

3(2). **Interstrial punctures on disc and declivity fine points, difficult to see with normal lighting, not dense** (Fig. 1c). Declivital ground vestiture absent or sparse and difficult to see, inconspicuous. Pronotal punctures sparse, most separated by much more than their diameter; most specimens with a distinct central impunctate longitudinal median strip (Fig. 6a). Antennal club pale to medium brown, at most little darker than funicle (Fig. 3b). Larger, length 3.2–5.2 mm (Yunnan, 4.1–4.6 mm). Maternal gallery biramous, transverse. Distribution: Europe and Asia. Host-trees: all *Pinus* spp in its range .... *T. minor* (Hartig)

- **Interstrial punctures on disc and declivity conspicuous, uniformly dense** (Fig. 1d), on declivity only slightly smaller than, or equal to, strial punctures. **Declivity densely hairy** due to abundant conspicuous decumbent ground vestiture (but hairs can be completely worn away in older specimens). Pronotal punctures dense, separated on average by about their diameter, no impunctate median strip (Fig. 6b). Antennal club brown to dark brown, distinctly darker than funicle (Fig. 3d). Smaller, length 3.0–4.3 mm (3.0–3.8 mm in the specimens examined). Maternal gallery monoramous, longitudinal. Distribution: Siberia and Russian Far East, Heilongjiang Province in China. Hosts: *Pinus koraiensis*, *P. armandii*, *P. tabulaeformis* ....*T. pilifer* (Spessivtsew)

FIGURE 1. Eytral declivity of *Tomicus* species: (a, b) *T. puellus* (Reitter), (c) *T. minor* (Hartig), (d) *T. pilifer* (Spessivtsew).

4(1). **Fine punctures of interstria 2 on declivity uniseriate;** punctures of striae 1 to 3 on declivity more than twice as large as fine interstrial punctures (Figs. 2a, b). Granules on interstriae 2 and 3 on disc closely spaced, most by a distance equal to 1.5–2.5 punctures of adjacent striae. Antennal club brown, same color as or darker than funicle (Figs. 3a, 4c) 5

- **Fine punctures of interstria 2 on declivity confused or appearing biseriate**, punctures of striae 1 to 3 on declivity less than or equal to twice as large as fine interstrial punctures (Figs. 2c, d). Granules on interstriae 2 and 3 on disc closely or distantly spaced. Antenna uniformly colored, club yellow to yellow-brown (Figs. 4a, b, d)..6

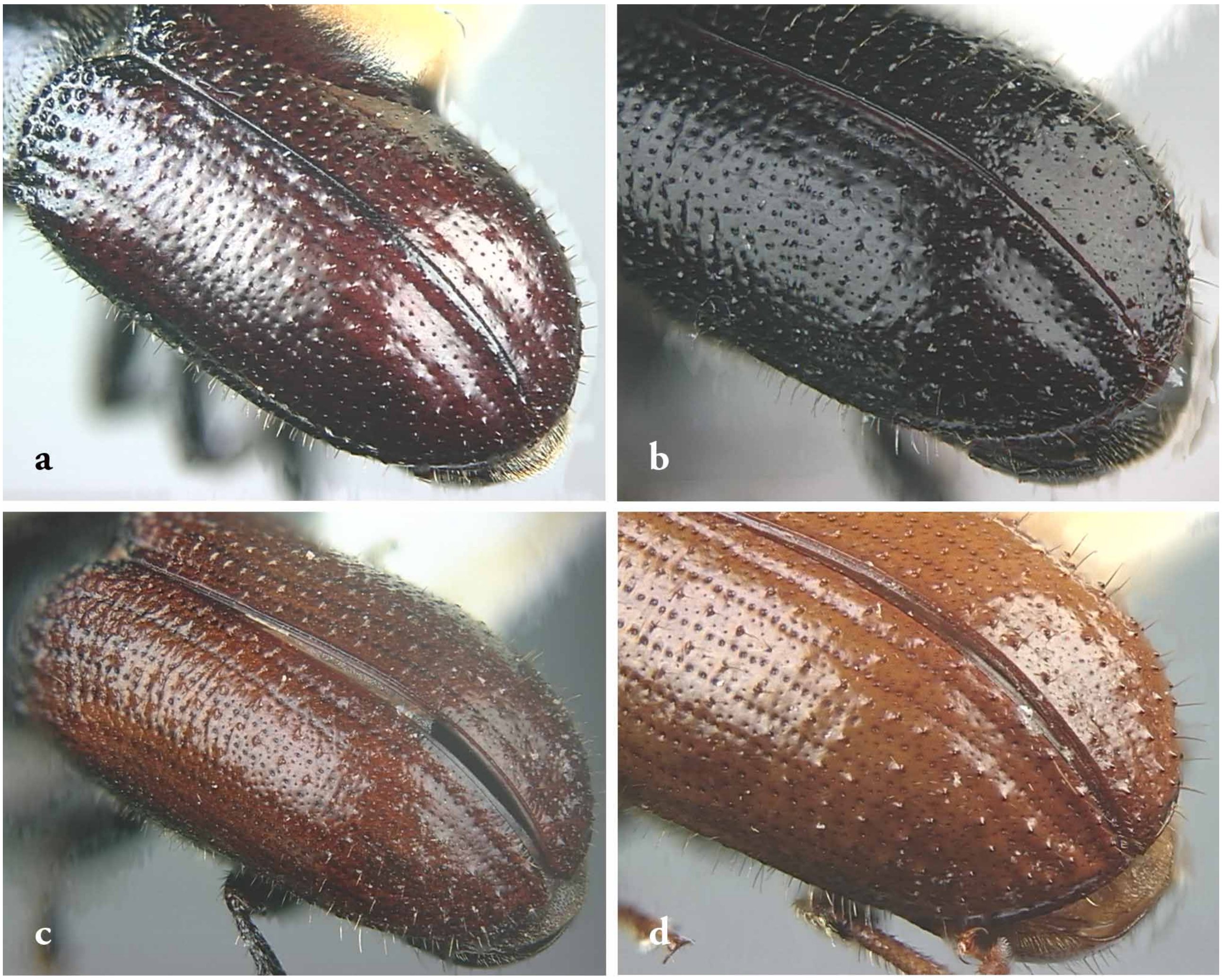

FIGURE 2. Eytral declivity of *Tomicus* species: (a) *brevipilosus* (Eggers), (b) *T. piniperda* (Linnaeus), (c) *T. destruens (Wollaston)*, (d) *T. yunnanensis* **sp. n.** (holotype).

5(4). **Erect elytral hairs on disc longer**, about as long as distance between striae; erect hairs on declivity distinctly longer than those on disc (Fig. 2b). Antennal club brown, antenna uniformly colored (Fig. 4c). Interstria 2 on declivity strongly impressed and concave, with uniseriate, regularly spaced fine punctures (Fig. 2b). More slender, elytra 1.7–1.8x longer than wide; larger, length 3.5–5.2 mm (Jilin: 4.4–5.2 mm). Elytra usually longer than twice width of pronotum. Maternal gallery monoramous, longitudinal. Distribution: Eurasia including Japan but not known from Yunnan. Hosts: continental *Pinus* spp. and *Pinus pinaster*, not known from *P. yunnanensis*.................................... *T. piniperda* (Linnaeus)
- **Erect elytral hairs on disc shorter**, about 0.5x as long as distance between striae; erect hairs on declivity as long as those on disc (Fig. 2a). Antennal club brown to dark brown, usually noticeably darker than funicle (Fig. 3a). Interstria 2 on declivity weakly impressed, with punctures very fine, uniseriate, sparse, often widely spaced or even absent on much of declivity (Fig. 2a). Stouter, elytra 1.6x longer than wide; smaller, length 3.2–4.4 mm (Yunnan: 4.0–4.4 mm). Elytra shorter than twice width of pronotum. Maternal gallery unknown, but probably monoramous and longitudinal. Distribution: Fukien,

Fujian and Yunnan (China), Assam (India), Korea, Japan. Hosts: *Pinus koraiensis*, *P. insularis*, *P. parvifolia*, *P. yunnanensis* .... *T. brevipilosus* (Eggers)

FIGURE 3. Antenna of *Tomicus* species: (a) *T. brevipilosus* (Eggers), (b) *T. minor* (Hartig), (c) *T. puellus* (Reitter), (d) *T. pilifer* (Spessivtsew).

6(4). **Mediterranean species.** Interstria 2 on declivity weakly impressed, punctures dense, confused (Fig. 2c). Granules of interstriae 2 and 3 on disc closely spaced, most by a distance equal to 1.5–2.5 punctures of adjacent striae; granules of interstriae 1 and 3 on declivity widely spaced, the distance between adjacent granules within a row equal to ca. 2/3 the distance between rows of granules on interstriae 1 and 3. Only base of elytra dark. Protibia with five or six teeth, usually evenly spaced in one cluster (Fig. 5). Length 4.1–4.9 mm. Maternal gallery monoramous, longitudinal. Distribution: Mediterranean basin and Atlantic coastal regions of Spain, Portugal and North Africa. Hosts: Mediterranean *Pinus* species .. ..*T. destruens* (Wollaston)

\- **Asian species**. Interstria 2 on declivity strongly impressed but broadly convex to flat, punctures more evenly spaced, appearing biseriate or irregularly uniseriate (appearing to zig-zag down declivity) (Figs.

2d, 7). Granules of interstriae 2 and 3 on disc widely spaced, many by about the distance between three to five punctures of adjacent striae; granules of interstriae 1 and 3 near base of declivity closely spaced, distance between pairs of granules =1/2 distance separating rows of granules of interstria 1 from those of interstria 3. Basal 1/6th to 1/5th of elytral disc darker, often black (easily seen in paler specimens). Protibiae usually with six (five to seven) marginal teeth, the first (closest to body) often separated from the remaining teeth (>2/3 of individuals) (Fig. 5). Length 4.3–5.3 mm. Maternal gallery monoramous, longitudinal. Distribution: Yunnan (China). Host: *Pinus yunnanensis*.....................*T. yunnanensis* **sp. n.**

FIGURE 4. Antenna of *Tomicus* species: (a, b) *T. yunnanensis*, (c) *T. piniperda* (Linnaeus), (d) *T. destruens* (Wollaston).

Description of new species

Tomicus yunnanensis **Kirkendall & Faccoli, sp. n.**

Figs. 2d, 4a, b, 5, 7

Description

Males and females not readily distinguishable. Total length of specimens of both sexes 4.3–5.4 mm (holotype 5.2; mean = 4.8, N= 20 for means, ranges and ratios), sum of pronotal and elytral (P+E) lengths 4.2–5.4 (mean = 4.9); P+E lengths 2.3–2.6 times wider than elytra (mean = 2.4). Mature color dark reddish brown. Frons shining, weakly to moderately impressed, upper margin more strongly so; a fine median carina from middle of frons to just above epistoma. Lower frons bordered laterally by narrow carinae from epistoma to level of middle of eye. Surface smooth centrally, outer fourths with fine vertical crenulations, with scattered deep setiferous punctures. Antennal funicle with 6 segments; club and funicle uniformly brown; club ovate, narrowly rounded, tip with abundant vestiture of short pale hair-like setae, suture of first segment with a row of fairly uniformly short setae (Figs. 4a, b). Pronotum in mature individuals very dark reddish brown (almost black), stout, 0.8x longer than wide, strongly constricted in anterior third. Dorsal surface shining, finely, fairly densely punctured (Fig. 7). Vestiture of moderately abundant, fine, pale setae, denser along lateral areas of pronotum. Legs almost black, same color as rest of body and pronotum. Protibia usually with six (five to seven) marginal teeth (15/20 with 6), the first (tooth closest to body) often separated from the remaining teeth (Fig. 5). Colour of elytra dark reddish brown in mature specimens, paler than pronotum and body, basal 1/6th to 1/5th darker. Elytra 1.6–1.8x longer than wide (mean and holotype = 1.7), 2.3–2.5x longer than pronotum (mean = 2.4). Sides subparallel, broadly rounded in posterior fourth. Disc shining, with weak traverse crenulations, these most dense and most pronounced basally. Striae with punctures spaced by approximately their diameter. Interstriae approximately 3–4x wider than striae, with uniseriate rows of widely spaced granules, these more closely spaced on declivity than on disc, generally spaced by about 3–5 punctures of adjacent striae. Interstriae with erect hair-like setae, scattered on disc but denser on declivity, about as long as distance between striae. Declivity (Fig. 2d, see also Fig. 7) broadly rounded, beginning at distal fourth of elytra; interstriae similarly sculptured, all but interstria 2 with a row of small conical setiferous tubercles. Interstria 2 strongly impressed but broadly convex to flat, punctures evenly spaced, irregularly uniseriate (appearing to zig-zag down declivity). Punctures of striae 1 to 3 less than or equal to twice as large as interstrial punctures. Interstriae 1 and 3 weakly elevated. Granules on interstriae 1 and 3 near base of declivity closely spaced, distance between pairs of granules = 1/2 distance separating rows of granules of interstria 1 from those of interstria 3. *T. yunnanensis* can also be identified by comparing DNA sequences to those in GenBank, for nuclear genes ITS-2 and 28S (sequences AY570812-AY570813, AY570826-AY570827, respectively) or mitochondrial gene COI (sequences AY570844-AY570892) (Duan *et al*., 2004).

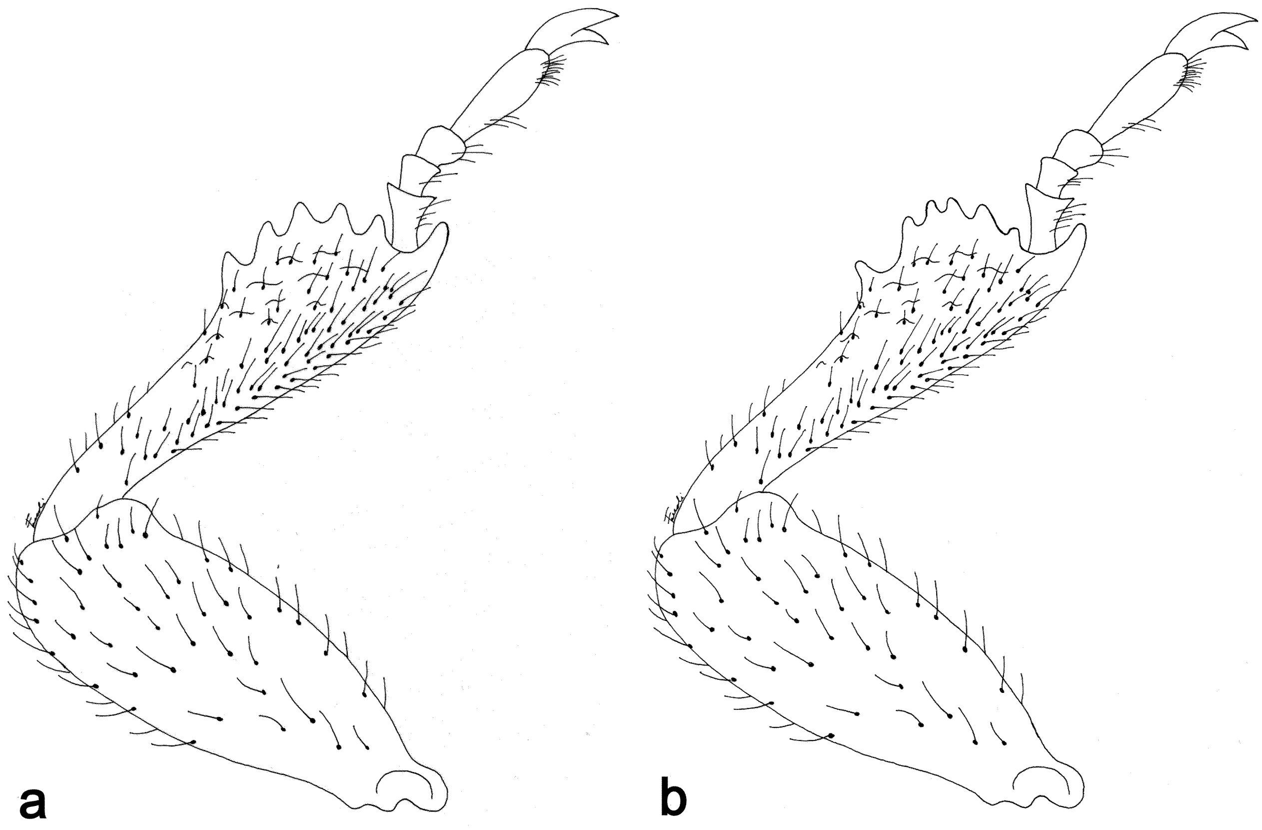

FIGURE 5. Protibiae of *Tomicus* species: *T. destruens* (Wollaston) (left), *T. yunnanensis* **sp. n.** (right).

FIGURE 6. Pronotum of *Tomicus* species: (a) *T. minor* (Hartig), (b) *T. pilifer* (Spessivtsew) (note difference in density of punctures).

FIGURE 7. *Tomicus yunnanensis* **sp. n.**, dorsal and lateral habitus of holotype.

Type material

All from Yunnan Province in China. Holotype (slightly immature; sex not determined) and 1 paratype, Xiundian, 22 April 2003; 4 paratypes, Zhanyi, 22 April 2003; 1 paratype, Zhanyi, 6 May 2004; 5 paratypes, Shilin (Shilin Stone Forest), 2 April 2003; 7 paratypes, Gejiu, 2 April 2003; 4 paratypes, Midu, 12 April 2003; 3 paratypes, Xiangyun, 11 April 2003; 6 paratypes, Shizong, 23 April 2003; 2 paratypes, Lufeng, 6 May 2004; 2 paratypes, Shilin, Chonghu, N 24º 43.3' E 103º 24.5', L. R. Kirkendall,Ye Hui & Chen Peng, from *Tomicus*-killed *P. yunnanensis*. The holotype is deposited in the Natural History Museum, London. Paratypes will be distributed to the collections of the Chinese Academy of Sciences (Beijing), Kunming University (Yunnan), National Museum of Natural History (Washington, D. C., USA), The Natural History Museum (London, England), Naturhistorisches Museum Wien (Vienna, Austria), Milos Knizek (Prague, Czech Republic), Mikael Mandelshtam (Moscow, Russia) and the collections of LRK and MF.

Etymology

The Latin epithet for the new species was chosen to reflect to the Chinese province where research on the new species has focussed (Yunnan) as well as the only host tree known, Yunnan pine. We suggest "Yunnan shoot borer" be used as a common name.

Differential diagnosis for Tomicus *species in southern China*

Foresters have assumed that the *Tomicus* species making longitudinal galleries in *P. yunnanensis* was *T. piniperda*. In fact, the latter species has not yet been collected from Yunnan; the *Tomicus* samples sequenced by Duan *et al*. (2004) and those identified in this study include only *T. yunnanensis*, *T. minor* and *T. brevipilosus*. In southwestern China and northern Burma, *T. minor* can easily be distinguished from the other species by the presence of setiferous (hair-bearing) granules on interstria 2 on the declivity, which are absent in the other two species. Most Yunnan *Tomicus* specimens we have seen are *T. yunnanensis* (Table 1). If a specimen is encountered that seems to differ (and is not *T. minor*), the equal elytral setae characteristic of *T. brevipilosus* are best be viewed from the side: in *T. brevipilosus* the erect interstrial setae do not noticeably increase in length from the elytra to the declivity, as they do in *T. yunnanensis*. The declivities of *T. brevipilosus* and *T. yunnanensis* also differ in many details (see key and Fig. 2); for example, when material of both species is available, interstria 2 of *T. brevipilosus* appears distinctly narrower and less impressed on the declivity and the punctures of the adjacent striae 1 and 3 are more clearly impressed.

Discussion

The morphological differences that distinguish *T. yunnanensis* from *T. piniperda* fully support the molecular results of Duan *et al*. (2004). Similarly, DNA-based studies have recently confirmed the specific status of *T. destruens* (Gallego & Galian, 2001; Kerdelhue *et al*., 2002; Kohlmayr, 2002). *Tomicus destruens* had earlier been considered (by some workers, but not all) to be a junior synonym of *T. piniperda* (e.g. Schedl, 1946; Balachowsky, 1949; Gil & Pajares, 1986), but, like T. *yunnanensis*, it shows small but consistent morphological differences as well as important differences in the timing of reproduction and in general aggressiveness (Lekander, 1971; Pfeffer, 1995; Monleón *et al*., 1996; Kohlmayr, 2002; Gallego *et al*., 2004; Faccoli *et al*., 2005; Faccoli, 2006).

Tomicus yunnanensis has been collected in many localities in Yunnan, southwestern China (Table 1). The species had been primarily collected from (and apparently only kills) Yunnan pine, *P. yunnanensis*. For their molecular study, Duan *et al*. (2004) did not find *T. yunnanensis* in stands of *Pinus semaonensis* and *P. armandi* in Yunnan. It is thus possible that the distribution of the species follows the restricted distribution of *P. yun-*

nanensis. Yunnan pine growths in the provinces of Guangxi, Guizhou, southwest Sichuan, southeast Xizang and Yunnan, at 400–3100 m elevation, and its range extends southwards into northern Burma, where it intergrades with *P. kesiya* (Fu *et al*., 1999).

Yunnan populations of *Tomicus* have been intensely studied because of ongoing outbreaks on Yunnan pine. Previously published articles discussing *piniperda*-like *Tomicus* from southwestern China (Ye, 1991, 1994; Ye & Li, 1995; Ye & Zhao, 1995; Ye, 1997; Ye & Lieutier, 1997; Ye & Ding, 1999; Långström *et al*., 2002; Lieutier *et al*., 2003; Duan *et al*., 2004; Ye & Lieutier, 2004; Sun *et al*., 2005) apparently refer to *T. yunnanensis*, since no specimens of *T. piniperda* have yet been recorded from Yunnan (Duan *et al*., 2004; this study).

In a general overview of *Tomicus* biology in Yunnan pine forests, Ye (1991) found important differences between the life cycles of populations from this part of China and those from elsewhere. Elsewhere in Europe and Asia, *T. piniperda* breeds in early spring, whereas reproduction by the Yunnan shoot borer occurs in winter (Ye, 1991; Ye & Zhao, 1995). Maternal galleries are longitudinal and monoramous in both species, but *T. yunnanensis* attacks are located mostly in the middle to upper part of the bole (Ye & Li, 1995; Ye & Ding, 1999), whereas *T. piniperda* mainly attacks the lower part of trunks (Långström, 1983). After emerging from the bark, callow adults fly toward the crown for maturation feeding, *T. yunnanensis* in early spring but *T. piniperda* in mid- to late summer. The longer period of shoot feeding by the Yunnan shoot borer results in considerably more damage, four to five shoots bored compared with only one to two by *T. piniperda* (Ye, 1991). The most important difference, however, is that the Yunnan shoot borer aggregates in large numbers in the canopy of certain individual trees, followed by trunk attack of these hosts during the same year (Ye & Lieutier, 1997; Lieutier *et al*., 2003). Such regular mass attacks of trunks are unknown in other *Tomicus* species, where individuals are usually highly dispersed during the maturation feeding phase in shoots. Aggregation in *T. piniperda* is facilitated by a common attraction to certain host odours, but small-scale attempts to trap *T. yunnanensis* in Yunnan with standard baits used to monitor *T. piniperda* in North America failed (Ye & Haack, unpublished data), and Sun *et al*. (2005) could not find combinations of host volatiles that were attractive to the new species. Finally, the fungal associates of Yunnan pine borers are quite different from those of other *Tomicus*, including *T. piniperda*. The primary blue-stain fungus associated with *T. yunnanensis* is *Leptographium yunnanense* (Zhou *et al*., 2000), whereas the main fungi associated with *T. piniperda* are *Leptographium wingfieldii* and *Ophiostoma minus*, phytopathogenic blue-stain fungi that assist the beetles in overcoming the resistance of their host trees (Wingfield & Gibbs, 1991; Solheim *et al*., 2001; Solheim & Långström, 2001; Jacobs *et al*., 2004). It is believed that *Leptographium yunnanense* is similarly important to *T. yunnanensis* and critical to its ability to kill trees (Liao & Ye, 2004).

Although all specimens examined for this paper were taken from *Pinus yunnanensis*, the new species has been found shoot feeding in *P. kesiya* var. *langvianensis* (in southern Yunnan), *P. armandi* (central Yunnan) and *P. densata* (northern Yunnan). It apparently does not complete its lifecycle in these pine species in nature, though it can reproduce in *P. kesiya* logs in the laboratory (Ye, unpublished observations).

Concluding remarks

Tomicus populations in Yunnan were consistently misidentified until a few years ago, despite showing quite a different ecology and behavior from *T. piniperda*. The morphological differences between the new species and *T. piniperda* (or *T. brevipilosus*) may be slight, but to an experienced bark beetle taxonomist they are no more so than the differences between closely related species in many other bark beetle genera. Exactly the same situation has occurred with Mediterranean *Tomicus piniperda vs. T. destruens*. The distinctiveness of the latter was long in question, despite evident differences in both adult and larval morphology and in life history (Wollaston, 1865; Lekander, 1971; Halperin, 1978), and consequently many ecological and behavioral studies confused the two species (Faccoli, 2006). Apparently there are deficiencies in the quality of taxonomic training being received by forest entomologists, but there also seems to be a worrisome lack of communication between forest entomologists and appropriate taxonomic specialists. At worst, incorrect assumptions about species identification can lead to the application of incorrect control measures, and hence to considerable waste of resources. This problem is exacerbated by failure to deposit voucher specimens in public research collections (Wheeler, 2003), as a result of which it is often impossible to verify or correct identifications underlying previous published research. The fact that *T. yunnanensis* has been unrecognized until very recently, despite important ecological and behavioral differences between it and *T. piniperda* being known for some time, emphasizes the importance of improving integration of forest entomology and taxonomy.

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