

RESEARCH PAPER

Redescription of Formosan subterranean termite, *Coptotermes formosanus* (Blattodea: Rhinotermitidae), with three new synonyms from China

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Abstract. The Formosan subterranean termite, *Coptotermes formosanus* Shiraki, 1909, is an important structural pest in Mainland China, Japan, Taiwan, Bahamas, and the United States. *Coptotermes formosanus* was first described in Japanese, and the morphological description was too simple for congeneric species differentiation, resulting in confusion in species identification. To date, ten junior synonyms of *C. formosanus* have been reported. To avoid further confusion, we redescribed *C. formosanus* based on the type specimen and the specimens from the type locality, Taiwan. Most of the *Coptotermes* Wasmann, 1896 taxonomy has been clarified worldwide and the Chinese case remains an outlier, with many species that need to be revised. We further examined the taxonomic statuses of four Chinese species, *C. changtaiensis* Xia & He, 1986, *C. hekouensis* Xia & He, 1986, *C. shanghaiensis* Xia & He, 1986, and *C. suzhouensis* Xia & He, 1986. We proposed that *C. changtaiensis*, *C. hekouensis*, and *C. suzhouensis* are the junior synonyms of *C. formosanus*. Even though the morphological characters of *C. shanghaiensis* are similar to *C. formosanus*, the body size of the former is significantly smaller. Additional *Coptotermes* samples collected from the Shanghai area would be required for the taxonomic status of *C. shanghaiensis* to be confirmed.

Key words. Blattodea, Isoptera, Rhinotermitidae, taxonomy, synonym, China, Taiwan

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Introduction

Termite control and construction repair cost tens of billions of US dollars worldwide annually (RUST & SU 2012, SU 2002). The termite genus, *Coptotermes* Wasmann, 1896, contains the highest proportion of pest species and is considered the most economically important termite group (SU & SCHEFFRAHN 2000, LI et al. 2010, RUST & SU 2012, SCHEFFRAHN et al. 2015). *Coptotermes formosanus* Shiraki, 1909 and *Coptotermes gestroi* (Wasmann, 1896), are more notorious than the other congeners because of their invasiveness tendencies (GAY 1969, EVANS 2010). Even though *Coptotermes* is such an important pest genus, the taxonomic status of many *Coptotermes* species is still not clarified (CHOUVENC et al. 2016).

EGGLETON (1999) reviewed the description and synonymy rates of termite species among the biogeographic

realms between 1949 and 1996. In this period of time, over one hundred termite taxonomic papers were published in China and Chinese termite taxonomists increased dramatically. However, not a single termite revisionary study regarding Chinese termite species was conducted in this period of time. EGGLETON (1999) pointed out that these studies are parochial in status and need to be revised. Recent termite taxonomic reviews of several termite genera including, *Prorhinotermes* Silvestri, 1909 (LI H.-F. et al. 2011), *Coptotermes* (CHOUVENC et al. 2016), *Sinocapritermes* Ping & Xu, 1986 (CHIU et al. 2016) and *Stylotermes* Holmgren & Holmgren, 1917 (LIANG et al. 2017) also support Eggleton's doubt on the validity of Chinese termite species. The misclassifications of *Coptotermes* species are likely due to underestimation of intraspecific morphological variation and the selection of too few numbers of indivi-



duals for morphometric analysis of both soldier and winged imago castes (KIRTON & BROWN 2003; LI Z. Q. et al. 2011, 2012; CHOUVENC et al. 2016), which was commonly found in the taxonomic studies of Chinese *Coptotermes* species in 1980s–1990s (ZHU et al. 1984, PING 1985, TSAI et al. 1985, LI & HUANG 1986, XIA & HE 1986, HE & QIU 1992, GAO et al. 1995). Twenty *Coptotermes* species in China were suspected as the synonyms of *C. formosanus* or *C. gestroi* (CHOUVENC et al. 2016), as all publicly available genetic sequences from Chinese *Coptotermes* samples currently match either of the two species. Unfortunately, the type material of these questionable species is not available for genetic characterization, sending the confirmation of their validity or their junior synonymy into a taxonomic limbo.

Among the 21 Chinese *Coptotermes* species, *C. formosanus* was first described in 1909. The original morphological description of *C. formosanus* was too simple for congeneric species differentiation, resulting in confusion in species identification. Ten junior synonyms of *C. formosanus* have been reported (KRISHNA et al. 2013, Li et al. 2012). To avoid further confusion and to clarify the taxonomic status of *Coptotermes* species in China, in this study, we first redescribed *C. formosanus*, based on the neotype specimen designated by LI et al. (2010) and many samples collected from the type locality, Taiwan. We provided comprehensive morphological data of *C. formosanus*, and further compared its morphometric data with that of the type specimens of the other four Chinese species, *C. changtaiensis*, *C. hekouensis*, *C. shanghaiensis*, and *C. suzhouensis*, described by XIA & HE (1986). The results support *C. changtaiensis*, *C. hekouensis*, and *C. suzhouensis* are the junior synonyms of *C. formosanus*. More samples collected from Shanghai area are needed for further confirmation of the taxonomic status of *C. shanghaiensis*.

Material and methods

The neotype of *C. formosanus* deposited in the National Museum of Natural Science, Taichung City, Taiwan (NMNS) and 24 *C. formosanus* specimens preserved in the National Chung Hsing University Termite Collection, Taichung City, Taiwan (NCHU) were used for morphometric measurements and species re-description. All the specimens are preserved in 95% ethanol. Measurements were acquired by using a Leica M205 C stereomicroscope with a Leica MC170 HD digital camera. Morphometric data were measured with LAS software (version 4.4.0, Leica Application Suite, Wetzlar, Germany) using the standard characters of ROONWAL (1969). The colors of sample were described by comparing with the Munsell color system (Munsell Color Company 1975) to determine hue, value, and chroma of each target character.

We examined the type specimens of the winged imagos of *C. hekouensis* (n = 1), *C. shanghaiensis* (n = 17), and *C. suzhouensis* (n = 8), the soldiers of *C. changtaiensis* (n = 6), *C. hekouensis* (n = 3) and *C. suzhouensis* (n = 7). The specimens are deposited in the Shanghai Entomological Museum (SEM), Institute of Plant Physiology and Ecology, Chinese Academy of Science, Shanghai, China. Due to the Chinese conservation policy, DNA extraction from

type specimens is not permitted. Hence, we only examined the morphology of the type specimens. The measurements of the four species, *C. changtaiensis*, *C. hekouensis*, *C. shanghaiensis*, and *C. suzhouensis* were taken onsite under a stereomicroscope with an ocular micrometer. We re-examined the characters used to differentiate these four species from *C. formosanus* in XIA & HE (1986). The termite castes of type specimens and additional material examined in this study are abbreviated as A, alate (winged imago); N, nymph; S, soldier; W, worker.

Systematics

Coptotermes formosanus Shiraki, 1909

(Figs 1–3; Tables 1–2)

- Coptotermes formosanus* Shiraki, 1909: 229, 239–241 (imago, soldier)
Termes (Coptotermes) formosanus: OSHIMA (1909: 33, pl. 11, figs 2, 3, 11, 12).
Coptotermes formosanus: OSHIMA (1912: 75–80, pl. 1: fig. 1, pl. 2: figs. 3, 21).
Coptotermes formosae Holmgren, 1911c: 192 (imago)
Coptotermes hongkonensis Oshima, 1914: 7–10 (imago, soldier) pl. 1, fig. 6.
Coptotermes intrudens Oshima, 1920: 262–264 (imago, soldier, worker), pl. 7.
Coptotermes eucalyptus Ping, 1984: 186–187, 189 (soldier), fig. 2.
Coptotermes xiaoliangensis Ping, 1984: 184–185, 188 (soldier), fig. 1.
Coptotermes guangzhouensis Ping, 1985: 317–318, 326–327 (soldier), fig. 1.
Coptotermes heteromorphus Ping, 1985: 320–321, 327 (soldier), fig. 4.
Coptotermes communis Xia & He, 1986: 166–167, 179 (imago, soldier), figs 48–56.
Coptotermes rectangularis Ping & Gong, 1986: 157–158, 160 (soldier), fig. 5.
Coptotermes guizhouensis He & Qiu, 1992: 721–723 (imago, soldier), figs 1–6.
Coptotermes changtaiensis Xia & He, 1986: 164–165 (soldier), figs 31–41, **syn. nov.**
Coptotermes hekouensis Xia & He, 1986: 162–164 (imago, soldier), figs 16–30, **syn. nov.**
Coptotermes suzhouensis Xia & He, 1986: 167–169 (imago, soldier), figs 57–65, **syn. nov.**

Type locality. Taiwan (original description: SHIRAKI 1909), Taiwan: Taoyuan (neotype designed by LI et al. (2010)).

Type material studied. NEOTYPE: 'TW49, Taoyuan Co. / Taoyuan City [桃園], 150m / 24.99033/121.30314 / 6/20/2006 col. H.-F. Li / *Coptotermes formosanus*', 1A, male. Worker caste from the same colony of the neotype was designated to gene analysis in the previous study (LI et al. 2009). Partial mitochondrial sequences of COII, 12S rRNA, and 16S rRNA are available in GenBank with accession number EU805758, EU805712, and EU805735, respectively.

Additional material studied. TAIWAN: CHIAYI CO.: Chiayi City: 23.48°N, 120.44°E, 4-VI-2007, H.-F. Li, 3S (TW38); 23.48°N, 120.44°E, 4-VI-2007, H.-F. Li, 3A (TW37). HUALIEN CO.: Hualien City: 24.00°N, 121.64°E, 29-IV-2013, G.-R. Wang, 3A (TW4174); 23.97°N, 121.60°E, 17-IV-2013, G.-R. Wang, 3A (TW4139); 23.98°N, 121.60°E, 20-IV-2013, G.-R. Wang, 1A (TW4140). Shoufeng Township [壽豐]: 23.87°N, 121.60°E, 29-V-2012, G.-R. Wang, 3A, 3S (TW4069). LIANJIANG CO.: Nangan Township [南竿]: 26.15°N, 119.93°E, 8-VI-2012, J.-F. Tsai, 3A (TW4070). NANTOU CO.: Huisun [惠蓀林場]: 24.09°N, 121.03°E, 2-IV-2015, W.-R. Liang, 1A (TW4304). Shuili Township [水里]: 23.80°N, 120.84°E, 26-V-2014, H.-T. Yeh, 2A (TW4258). PINGTUNG CO.: Nanrenshan [南仁山]: 22.08°N, 120.86°E, 20-X-2008, N. Kanza-ki, Y.-C. Lan, H.-F. Li, and J.-F. Tsai, 3S (TW76); 22.08°N, 120.84°E, 30-V-2010, Y.-C. Lan, 3A (TW4185). TAICHUNG CO.: NCHU [國立中興大學]: 24.12°N, 120.67°E, 31-V-2014, W.-R. Liang, 3S (TW4257). Taichung City: 24.18°N, 120.68°E, 8-V-2009, M.-J. Chen, 3S (TW123);

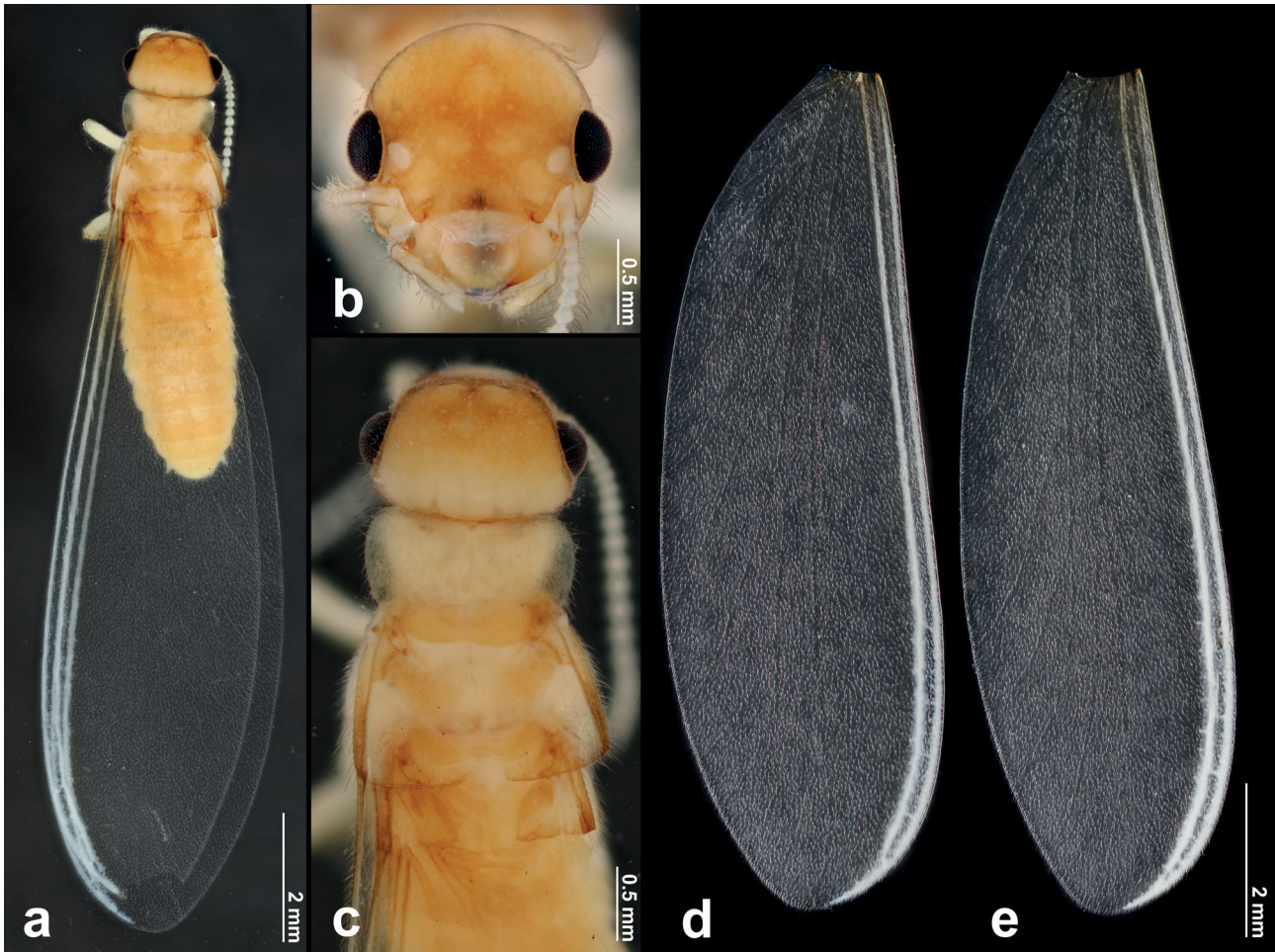


Fig. 1. Neotype of *Coptotermes formosanus* Shiraki, 1909. a – dorsal view of body; b – anterior view of head; c – dorsal view of anterior body; d – hind wing; e – fore wing. The color of neotype became pale after preserving in ethanol for more than 10 years.

24.13°N, 121.69°E, 12-VI-2006, H.-F. Li, 3A (TW103). **TAINAN CO.:** Tainan City: 22.96°N, 120.86°E, 22-V-2006, H.-F. Li, 3S (TW51). **TAIPEI CO.:** Taipei City: 25.05°N, 121.56°E, 18-V-2009, M.-J. Chen, 3A, 3S (TW120); Jioufen [九份]: 25.10°N, 121.84°E, 14-VI-2009, H.-F. Li, 3A (TW88). **TAITUNG CO.:** Lanyu island: 22.02°N, 121.54°E, 26-V-2010, N. Kanzaki, Y.-C. Lan and S.-H. Tzeng, 3A (TW168). Taitung County: 22.87°N, 121.21°E, 22-V-2010, Y.-C. Lan, H.-F. Li and S.-H. Tzeng, 3S (TW163). Pingzhen City [平鎮]: 24.90°N, 121.20°E, 3-XII-2011, H.-F. Li., 1S (TW4020); 24.90°N, 121.20°E, 20-XII-2011, X.-P. Shih, 1S (TW4021). **TAOYUAN CO.:** Taoyuan City: 23.99°N, 121.30°E, 20-VI-2006, H.-F. Li, 3A, 3S (TW49). **YILAN CO.:** Nanao Township [南澳]: 24.42°N, 121.79°E, 7-VI-2006, H.-F. Li, 3S (TW18).

Redescription. Winged imago (Fig. 1; Table 1). Head capsule moderate dark goldenrod (10YR 5/10). Head (Fig. 1b) subcircular, length of head similar to width. Capsule covered with several setae. Antenna with 19–21 segments; 1st and 2nd sparsely hairy, the others hairy; 1st cylindrical, the longest; 2nd cylindrical, shorter and narrower than 1st; 3rd the shortest; 3rd to 20th moniliform, the last antennomere elongate elliptic. Labrum, anterior margin broadly rounded, broadest at middle, sides slightly converging posteriorly; central area convex; anterior border transparent; anterior with 6 long setae, central area with several long setae (<8 setae) and some short setae. Eye circular to subcircular. Ocellus elliptical. Pronotum (Fig. 1c) dark goldenrod (10YR), trapezoidal, width narrower than head; anterior margin concave, posterior

margin middle notched, broadest at anterior, lateral margin converging posteriorly; hairs dense, with a yellow Y-shaped marking glabrous. Abdomen (Fig. 1a) oblong, hairy. Legs pale yellow (5Y 9/6), femur sturdy, shorter than tibia. Tibia slender, tibial spurs formula 3:2:2; tarsi 4-jointed. Fore wing scale, with over 100 long setae, margin hairier than central area; forewing membrane hairy, veins near the base of wing have a faint brownish coloration (Fig. 1e); fore wing scale wider than hindwing stump, fore wing scale overlapping the base of hind wing scale (Fig. 1c); costal margin and radial sector veins sclerotized, run through the wing and merge at the end, media vein faint, simple or bifurcates once to twice, cubitus vein with 7–11 branches. Hind wing (Fig. 1d) similar to fore wing.

Soldier (Figs 2–3; Table 2). Head capsule (Fig. 2a) color amber (2.5Y 8.5/10), rounded (Fig. 3a), elliptical (Fig. 3b), oval (Fig. 3c), rounded rectangle (Fig. 3e), rounded trapezoid (Figs 3f and g) but typically pear-shaped (Figs 3d and h), the sides curved or nearly straight. Capsule covered with scattered setae (0.2–0.17 mm). Postmentum (Fig. 2b) long, dilated in anterior one third and having a waist at posterior one third. Labrum acuminate, broadest near the base, four long setae at the tip, distal two longer than 0.13 mm followed by two less than 0.1 mm, central area with two long

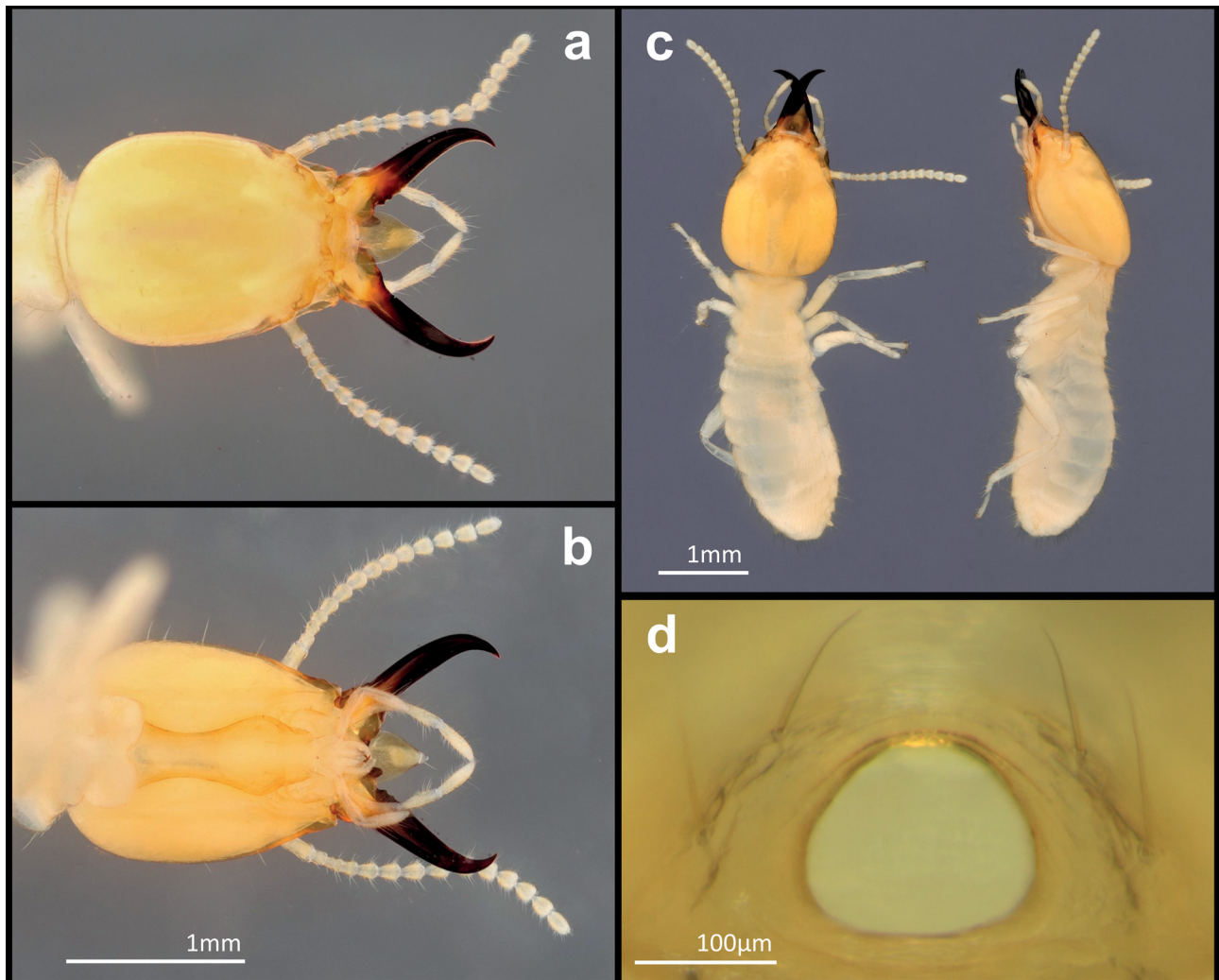


Fig. 2. Soldiers of *Coptotermes formosanus* Shiraki, 1909 from the same colony of the neotype. a – dorsal view of head; b – ventral view of head; c – dorsal view and lateral view of body; d – anterior view of fontanelle with four setae.

setae. Fontanelle opening frontally, with four setae, shaped from nearly triangular to arched (Figs 3i–l), arched in most specimens in a matured colony (antenna with 16 segments or more), located at anterior to middle of capsule. Mandible (Fig. 2a) incurved apically, inner margin of left mandible with three tiny denticles and one big apophysis near the base. Right mandible with three little crenate knurls near the base. Antenna with 14–17 segments, a soldier in a mature colony has 16 joints antenna in general, when 16 joints, 1st and 2nd sparsely hairy, the others hairy; 1st cylindrical, the longest; 2nd–15th moniliform; 2nd the shortest, gradually increasing in length till 6th; the last antennomere elliptical. Pronotum trapezoid, width narrower than head. Anterior and posterior margin slightly bilobed, broadest at anterior, lateral margin converging posteriorly. Mesonotum as broad as pronotum, lateral margin rounded. Metanotum similar in shape with mesonotum but broader than pronotum and mesonotum. Pilosity, in pronotum, central area sparsely hairy with 6–15 long setae, entire margin fringe hairy, with 20–40 long setae; in mesonotum and metanotum, similar pilosity with pronotum, sparsely at central area while hairy at entire margin fringe. Abdomen narrowly elliptical, hairy.

Legs, femur stout. Tibia slender. Tibial spurs formula 3:2:2, tarsi 3-jointed.

Remarks on *Coptotermes formosanus* in XIA & HE (1986). XIA & HE (1986) did not mention how they got the morphological data of *C. formosanus*. In XIA & HE (1986), the morphology of winged imagos of *C. formosanus* is described as follows: head circular from dorsal view, eye circular, ocellus oval (maximum diameter: 0.20–0.23 mm; minimum diameter: 0.15–0.16 mm), compound eye oval (maximum diameter: 0.40–0.43 mm; minimum diameter: 0.40–0.43 mm). The morphology of soldiers of *C. formosanus* as follows: head pear-shape, the fontanelle shape triangle, pronotum broader than length (maximum width: 0.80–0.87 mm; maximum length: 0.38–0.42 mm), and antenna 14–15 segments.

Measurements of each *C. formosanus* characteristics of Taiwanese samples (Table 1, 2) present a larger variation than those in XIA & HE (1986). Especially in soldier caste, the head shapes of Taiwanese samples are variable, showing a high level of intraspecific variation continuum (Figs 3a–h) and their fontanelle shape can be triangular or arched (Figs 3i–l).

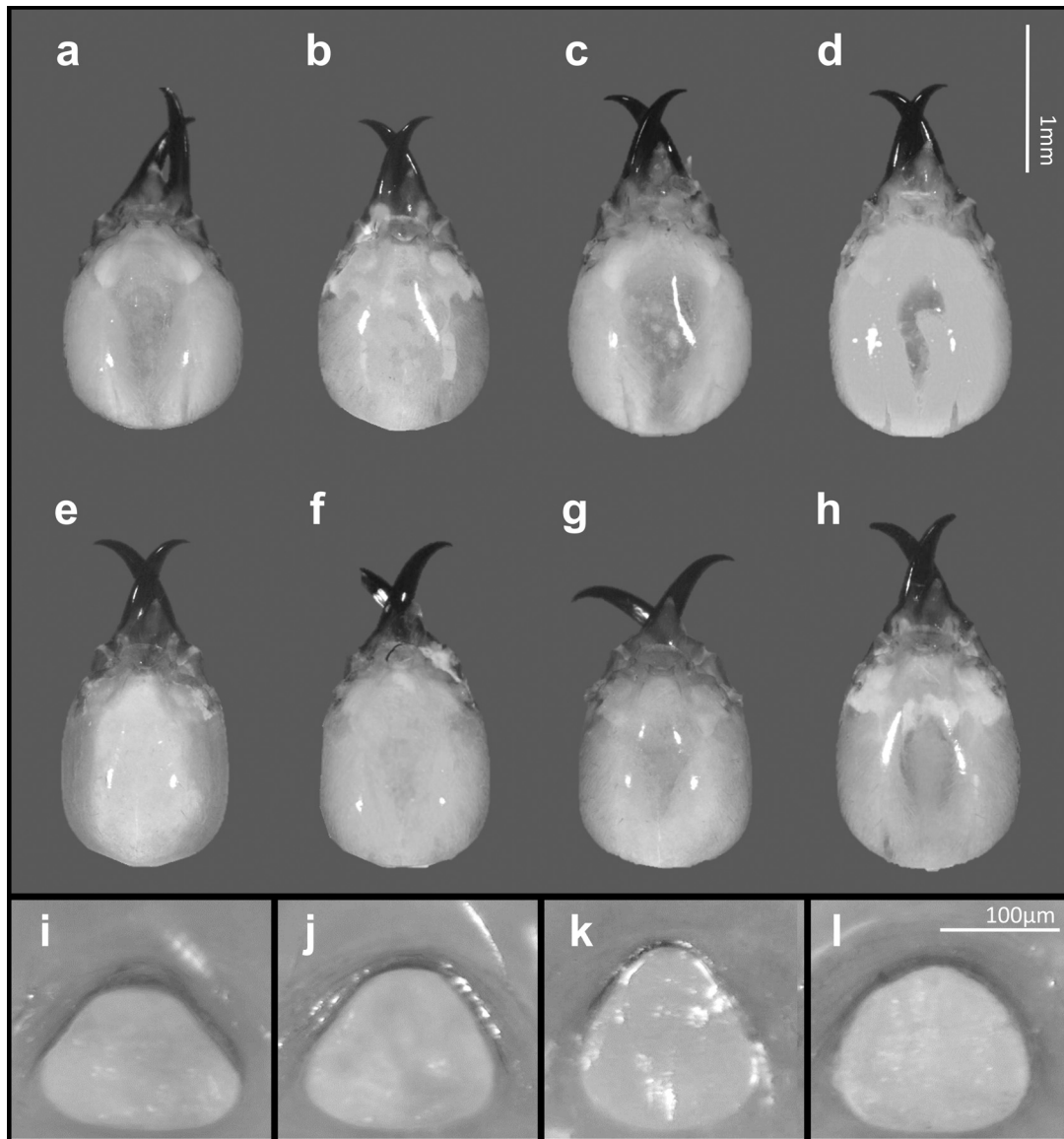


Fig. 3. Morphological variation of fontanelle shape and head shape of *Coptotermes formosanus* Shiraki, 1909. a–h – variability of head shapes: a–d – gradual shape change from rounded to pear-shape; e–h – gradual shape change from rounded rectangle to pear-shape. i–l – variability of fontanelle shapes: i–k – triangle; l – arched.

Table 1. Measurements of winged imago of *Coptotermes formosanus* Shiraki, 1909.

Measurement (mm)	range (mean \pm SD)
	<i>Coptotermes formosanus</i>
Length of head to tip of labrum	1.46–1.83 (1.69 \pm 0.09)
Maximum width of head with eyes	1.27–1.67 (1.57 \pm 0.09)
Maximum length of labrum	0.43–0.54 (0.50 \pm 0.02)
Maximum width of labrum	0.46–0.54 (0.51 \pm 0.02)
Maximum diameter of compound eye	0.36–0.45 (0.41 \pm 0.02)
Minimum diameter of compound eye	0.33–0.42 (0.38 \pm 0.02)
Maximum diameter of ocellus	0.14–0.22 (0.20 \pm 0.02)
Minimum diameter of ocellus	0.09–0.16 (0.13 \pm 0.02)
Maximum length of pronotum	0.76–0.99 (0.91 \pm 0.06)
Maximum width of pronotum	1.16–1.48 (1.39 \pm 0.08)
Pronotum middle length	0.69–0.86 (0.81 \pm 0.04)
Length of hind femur	1.09–1.33 (1.23 \pm 0.06)
Width of hind femur	0.36–0.46 (0.40 \pm 0.02)
Length of hind tibia	1.33–1.60 (1.50 \pm 0.06)
Segments of antenna	19–21

n = 35, 14 colonies.

Table 2. Measurements of soldier of *Coptotermes formosanus*

Measurement (mm)	range (mean \pm SD)
	<i>Coptotermes formosanus</i>
Length of head to lateral base of mandible	1.34–1.81 (1.54 \pm 0.14)
Maximum width of head	1.08–1.40 (1.22 \pm 0.10)
Width of fontanelle	0.15–0.22 (0.18 \pm 0.01)
Length of left mandible	0.77–1.19 (1.00 \pm 0.12)
Maximum length of postmentum	0.88–1.24 (1.00 \pm 0.09)
Maximum width of postmentum	0.37–0.49 (0.42 \pm 0.03)
Minimum width of postmentum	0.21–0.29 (0.25 \pm 0.02)
Maximum length of labrum	0.35–0.55 (0.42 \pm 0.05)
Maximum width of labrum	0.25–0.37 (0.30 \pm 0.03)
Maximum width of pronotum	0.76–1.07 (0.87 \pm 0.09)
Maximum length of pronotum	0.40–0.63 (0.49 \pm 0.07)
Maximum width of mesonotum	0.72–1.03 (0.83 \pm 0.09)
Maximum width of metanotum	0.84–1.16 (0.94 \pm 0.08)
Length of hind femur	0.83–1.12 (0.96 \pm 0.08)
Width of hind femur	0.19–0.36 (0.26 \pm 0.04)
Segments of antenna	14–17

n = 34, 12 colonies.

Remarks on three new synonyms of *C. formosanus*

Coptotermes changtaiensis Xia & He, 1986, syn. nov.

Type locality. China: Fujian Province: Changtai County [福建長泰].

Type material examined. SYNTYPE: China: Fujian: Changtai County [福建長泰], 16-V-1965, S.-D. FAN, S.-W. PENG, P.-F. GUO leg. [范树德, 彭辛午, 郭培福], 17S, 1W, No. 3760.

Additional material examined. CHINA: Shanghai [上海], 2-VII-1969, >10S, >10W, No. 1839. FUJIAN: Changtai County [福建長泰], 10-V-1965, >10S, >10W, No. 3758. ZHEJIANG: Jiande City [浙江建德], 22-XI-1962, >10S, >10W, No. 2894. Hangzhou City [浙江杭州], 3-III-1975, >10S, >10W, No. 4163. Haining City [浙江海宁], 24-XI-1976, >10S, >10W, No. 4429.

Remarks. The original description of *C. changtaiensis* is only based on the soldier caste. According to XIA & HE (1986), *C. changtaiensis* can be differentiated from *C. formosanus* by the shape of the soldier head: *C. changtaiensis* has an elliptical or rounded head while *C. formosanus* has a pear-shaped head. However, we found that the head shapes of *C. formosanus* soldiers are variable (Fig. 3). The head shapes of the *C. changtaiensis* soldiers (Fig. 4a) are overlapping with the shape series of *C. formosanus* (Figs 3e–h). No differences were found between *C. changtaiensis* and *C. formosanus* in the setae distribution and other characters examined by us. The morphometric

measurements of these two species are highly overlapping and their differences proposed by XIA & HE (1986) are not detected in the present study (Table 3).

Coptotermes hekouensis Xia & He, 1986 syn. nov.

Type locality. China: Yunnan Province: Hekou County [云南河口].

Type material examined. SYNTYPE: China: Yunnan Province: Hekou County [云南河口], 11-V-1962, W.-L. XU [徐维良], 2A, 4S, No. 1282.

Additional material examined. CHINA: YUNNAN: Hekou County [云南河口], IV-1962, 2N, >10S, >10W, No. 1270. Hekou County [云南河口], 11-V-1962, 1A, 7S, >10W, No. 1269.

Remarks. According to XIA & HE (1986), *C. hekouensis* can be differentiated from *C. formosanus* by three characters of the winged imagos: color of head capsule yellow brown in *C. hekouensis*, in contrast to reddish brown in *C. formosanus*, and *C. hekouensis* with narrower pronotum and shorter hind tibia than *C. formosanus*. One diagnostic character of soldiers was mentioned: head capsule elliptical or rounded in *C. hekouensis*, in contrast to pear-shaped head in *C. formosanus*. The type specimens of *C. hekouensis* examined in this study have been preserved for more than 50 years and their coloration likely faded (Fig. 4). We do not consider color as a valid reference because the preserving condition of the specimen may affect the color. The head shapes of the soldiers of *C. hekouensis* (Fig. 4c)

Table 3. Measurements of soldiers of *Coptotermes* spp.

Measurement (mm)	range (mean ± SD)			
	<i>C. formosanus</i> ^a	<i>C. suzhouensis</i> ^b	<i>C. hekouensis</i> ^c	<i>C. changtaiensis</i> ^d
Length of head to lateral base of mandible	1.34–1.81 (1.54 ± 0.14)	1.69–1.75 (1.73 ± 0.02)	1.55–1.67 (1.62 ± 0.06)	1.65–1.75 (1.72 ± 0.01)
Maximum width of head	1.08–1.40 (1.22 ± 0.10)	1.31–1.39 (1.38 ± 0.03)	1.27–1.39 (1.33 ± 0.06)	1.29–1.35 (1.34 ± 0.01)
Maximum width of fontanelle	0.15–0.22 (0.18 ± 0.01)	0.18–0.20 (0.18 ± 0.01)	0.16–0.20 (0.18 ± 0.02)	0.16–0.18 (0.16 ± 0.01)
Maximum length of left mandible	0.77–1.19 (1.00 ± 0.12)	1.04–1.08 (1.06 ± 0.01)	1.04–1.06 (1.05 ± 0.01)	1.02–1.04 (1.03 ± 0.01)
Maximum length of postmentum	0.88–1.24 (1.00 ± 0.09)	1.06–1.16 (1.13 ± 0.03)	0.88–1.04 (0.94 ± 0.09)	1.08–1.10 (1.09 ± 0.01)
Maximum width of postmentum	0.37–0.49 (0.42 ± 0.03)	0.43–0.50 (0.49 ± 0.03)	0.43–0.45 (0.44 ± 0.01)	0.43–0.47 (0.44 ± 0.01)
Minimum width of postmentum	0.21–0.29 (0.25 ± 0.02)	0.24–0.33 (0.31 ± 0.04)	0.24–0.25 (0.25 ± 0.01)	0.27–0.29 (0.28 ± 0.01)
Maximum length of labrum	0.35–0.55 (0.42 ± 0.05)	0.43–0.49 (0.46 ± 0.02)	0.37–0.43 (0.41 ± 0.03)	0.43–0.47 (0.45 ± 0.01)
Maximum width of labrum	0.25–0.37 (0.30 ± 0.03)	0.31–0.35 (0.34 ± 0.01)	0.29–0.31 (0.31 ± 0.01)	0.31–0.33 (0.33 ± 0.01)
Maximum length of pronotum	0.40–0.63 (0.49 ± 0.07)	0.55–0.59 (0.58 ± 0.02)	0.57–0.57*	0.51–0.57 (0.54 ± 0.02)
Maximum width of pronotum	0.76–1.07 (0.87 ± 0.09)	0.92–1.00 (0.97 ± 0.02)	0.90–0.96*	0.92–0.98 (0.95 ± 0.02)

^an = 34, 12 colonies.

^bn = 7, 1 colony.

^cn = 3, 1 colony.

^dn = 6, 1 colony.

*An individual of *C. hekouensis* is incomplete and the measurement is not available.

Table 4. Measurements of winged imagos of *Coptotermes* spp.

Measurement (mm)	range (mean ± SD)			
	<i>C. formosanus</i> ^a	<i>C. suzhouensis</i> ^b	<i>C. hekouensis</i> ^c	<i>C. shanghaiensis</i> ^d
Maximum width of head with eyes	1.27–1.67 (1.57 ± 0.09)	1.53–1.58 (1.55 ± 0.01)	1.50	1.26–1.42 (1.34 ± 0.04)
Maximum length of pronotum	0.76–0.99 (0.91 ± 0.06)	0.73–0.95 (0.88 ± 0.07)	0.85	0.65–0.76 (0.71 ± 0.03)
Maximum width of pronotum	1.16–1.48 (1.39 ± 0.08)	1.25–1.48 (1.42 ± 0.09)	1.35	1.08–1.20 (1.15 ± 0.04)
Maximum diameter of ocellus	0.14–0.22 (0.20 ± 0.02)	0.16–0.23 (0.21 ± 0.02)	0.21	0.16–0.21 (0.19 ± 0.02)
Minimum diameter of ocellus	0.09–0.16 (0.13 ± 0.02)	0.12–0.17 (0.14 ± 0.02)	0.14	0.10–0.16 (0.13 ± 0.01)
Maximum diameter of compound eye	0.36–0.45 (0.41 ± 0.02)	0.40–0.48 (0.44 ± 0.03)	0.42	0.36–0.42 (0.38 ± 0.02)

^an = 35, 14 colonies.

^bn = 8, 1 colony.

^cn = 1, 1 colony.

^dn = 17, 1 colony.

are overlapping with the shape series of *C. formosanus* (Figs 3a–d). In addition, no differences were found between *C. hekouensis* and *C. formosanus* in the setae distribution and other characters examined by us. The morphometric measurements of these two species highly overlapped and the differences proposed by XIA & HE (1986) were not detected in the present study (Table 3 and 4).

Coptotermes suzhouensis Xia & He, 1986 syn. nov.

Type locality. China: Jiangsu Province: Suzhou City [江苏苏州].

Type material examined. SYNTYPE: China: Jiangsu Province: Suzhou City [江苏苏州], 25-V-1959, K.-L. XIA, X.-S. HE & Y.-Q. YE [夏凯龄, 何秀松, 叶宜秋], 8A, 20S, 3W, No. 1853.

Additional material examined. CHINA: JIANGSU: Suzhou City [江苏苏州], 25-V-1959, >10W, No. 3836. Suzhou City [江苏苏州], 25-V-1959,

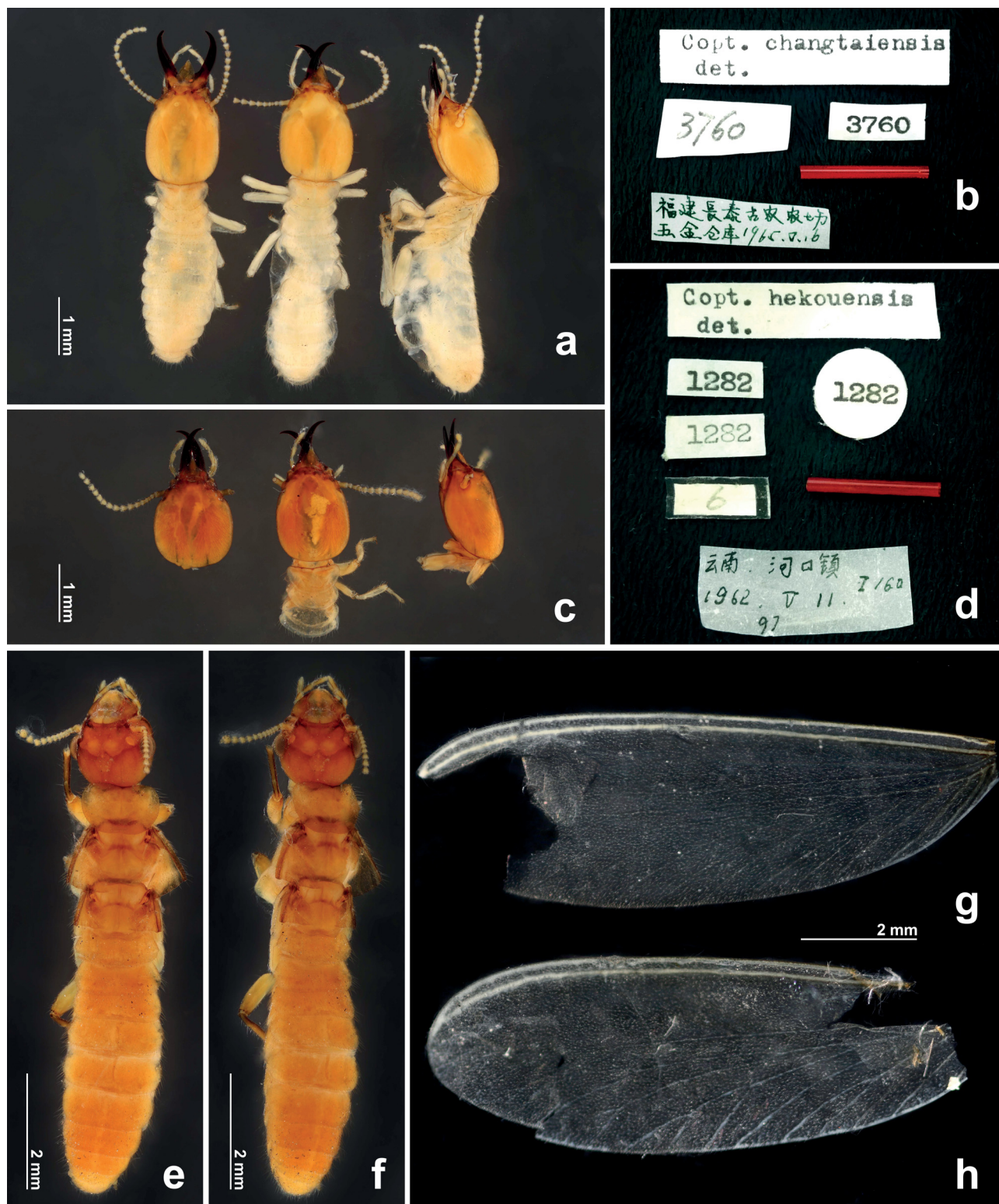


Fig. 4. The type specimens of *Coptotermes changtaiensis* Xia & He, 1986 and *C. hekouensis* Xia & He, 1986. a–b – *C. changtaiensis*: a – soldiers; b – labels. c–h – *C. hekouensis*: c – soldiers; d – labels; e–f – alate in dorsal view (e – pronotum facing up; f – head facing up); g – forewing; h – hind wing.

10S, No. 3831. Suzhou City [江苏苏州], 25-V-1959, >10S, No. 3837. Suzhou City [江苏苏州], 1959.V.25, >10W, No. 3842. Suzhou City [江苏苏州], 25-V-1959, 9A, 1S, >10W, No. 3302. Suzhou City [江苏苏州], 25-V-1959, >10S, No. 3841. Suzhou City [江苏苏州], 25-V-1959, 3S, 2W, No. 3835.

Remarks. LI et al. (2018) collected termite samples from Feixi County in Hefei, Anhui Province and identified them

as *C. suzhouensis*. The mitochondrial genome of their samples is almost identical to that of *C. formosanus*, and they further suggested that *C. suzhouensis* is the junior synonym of *C. formosanus*. However, no evidence supported the samples they used represented *C. suzhouensis*. LI et al. (2018) did not use the type specimens for sequencing, and the samples were not collected from the type locality,



Fig. 5. The type specimens of *Coptotermes suzhouensis* Xia & He, 1986. a – habitus of winged imago; b – imago in dorsal view; c – soldiers; d – labels.

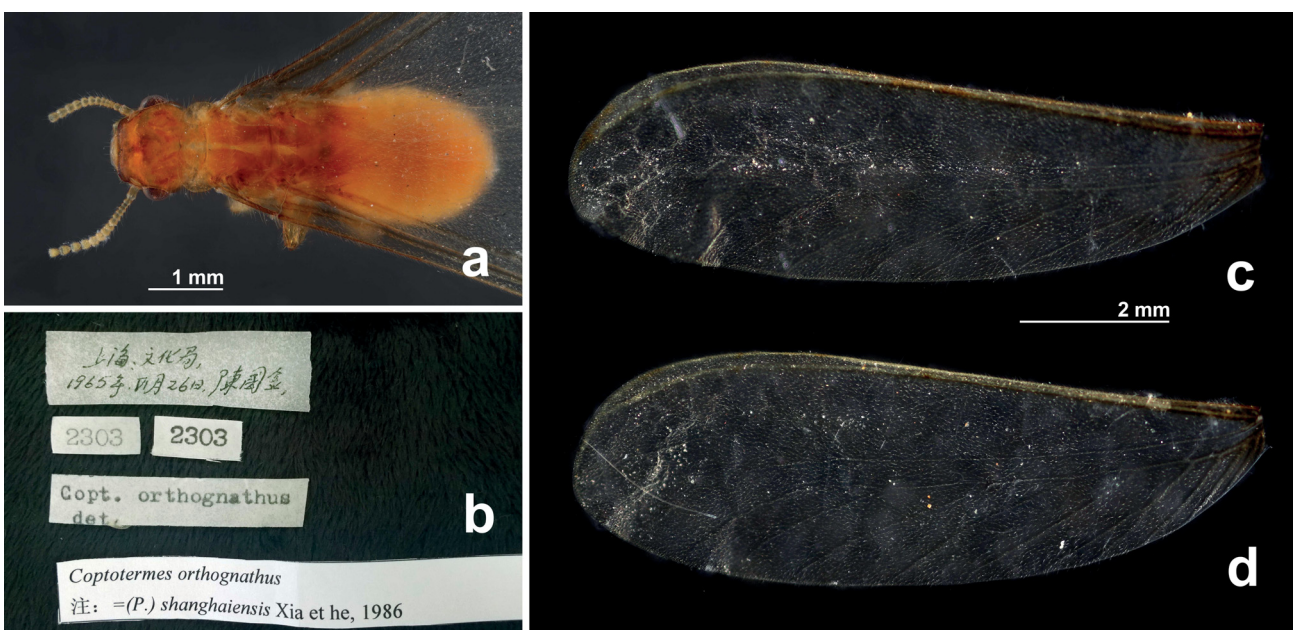


Fig. 6. The specimens of *Coptotermes shanghaiensis* Xia & He, 1986. a – winged imago; b – labels; c – forewing; d – hind wing.

Suzhou, Jiangsu, either. The mitochondrial genome provided by LI et al. (2018) simply proved they misidentified *C. formosanus* as *C. suzhouensis*.

According to the key provided by XIA & HE (1986), *C. suzhouensis* can be differentiated from *C. formosanus* by five characters of the winged imago: (1) head shape: *C. suzhouensis* subcircular, *C. formosanus* rounded; (2) compound eye: *C. suzhouensis* subcircular, *C. formosanus* rounded; (3) ocellus: narrower in *C. suzhouensis* than in *C. formosanus*; (4) anterior and posterior margin of pronotum: more concave in *C. suzhouensis* than in *C. formosanus*; and (5) wings: wider in *C. suzhouensis* than in *C. formosanus*. In addition to winged imago, XIA & HE (1986) mentioned the soldier head capsule of *C. suzhouensis* was elliptical or rounded and that of *C. formosanus* was pear-shaped. However, in this study, we found the winged imagos of *C. suzhouensis* and *C. formosanus* were similar in the shape of head, compound eye, and pronotum. The measurements of the minimum length of ocellus were not significantly different (Table 4). The head shape of *C. suzhouensis* soldiers we examined (Fig. 5c) overlap with the shape series of *C. formosanus* (Figs 3e–h). Apart from that, no differences between *C. suzhouensis* and *C. formosanus* were found in the setae distribution and other characters examined by us. The morphometric measurements of these two species highly overlapped and the differences proposed by XIA & HE (1986) are not detected in the present study (Tables 3–4).

Remarks on the taxonomic status of *Coptotermes shanghaiensis*

Coptotermes shanghaiensis Xia & He, 1986

Type locality. China: Shanghai [中國上海].

Type material examined. In the original description, the collection information of type specimens is: China: Shanghai [上海], (soldier, alate, and worker), No: 09003454, 26-VI-1965, G.-J. CHEN [陈国金]. We did not find this type specimen at SEM, but find a specimen with the same collection locality, date, and collector as following: China: Shanghai [上海文化局], 26-VI-1965, G.-J. CHEN [陈国金], No. 2303, *Cop. Orthognathus*, *Coptotermes orthognathus* = (*P.*) *shanghaiensis* Xia et He, 1986 [new label], 37A. We suggest this specimen was derived from the type specimens.

Additional material examined. CHINA: Shanghai [上海], 26-VI-1965, G.-J. CHEN, 8A, 1N, >10W, No: 3855; Shanghai [上海], 30-VII-1965, >10S, >10W, No: 3683; Shanghai [上海], 9-V-1957, 7S, >10W, No: 1845.

Remarks. According to XIA & HE (1986), *C. shanghaiensis* could be differentiated from *C. formosanus* based on three characters of winged imagos: smaller wing length than that of *C. formosanus*; narrower pronotum width than that of *C. formosanus*; and narrower head width than that of *C. formosanus*. One diagnostic character of soldier caste was mentioned: elliptical or rounded head, in contrast to the pear-shaped head of *C. formosanus*. No soldier specimen of *C. shanghaiensis* from the type location was available for this study. The winged imagos of *C. shanghaiensis* can be distinguished from *C. formosanus* by the morphometric variation of pronotum (Table 4). Although no difference between *C. shanghaiensis* and *C. formosanus* was found in the setae distribution and other characters examined by

us, the taxonomic status of *C. shanghaiensis* needs further investigation. Soldier and winged imagos collected from multiple colonies in the type locality and their molecular sequences are required.

Conclusion

Winged imago and soldier caste of *C. formosanus* were redescribed based on the type specimen and additional specimens from the type locality, Taiwan. The three Chinese *Coptotermes* species, *C. changtaiensis*, *C. suzhouensis*, and *C. hekouensis*, are all morphologically similar to *C. formosanus*. The morphometric comparison supports that the three *Coptotermes* species are junior synonyms of *C. formosanus*. Even though *C. shanghaiensis* is similar to *C. formosanus* in setae distribution and other characters examined, its measurements of pronotum size are smaller than those of *C. formosanus*. In the absence of a soldier description, the current observations do not allow for the validation of *C. shanghaiensis* as a species or as another junior synonym to *C. formosanus*. The taxonomic status of *C. shanghaiensis* needs a further investigation with more samples collected from the type locality.

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