Current Status of *Coptotermes* Wasmann (Isoptera: Rhinotermitidae) in China, Japan, Australia and the American Pacific

by

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ABSTRACT

This paper presents a brief review of the current taxonomic status, distribution and recent biological research on *Coptotermes* Wasmann in China and Japan; and of the taxonomic status and distribution of the genus in Australia and the United States. It is hoped that this update will serve as a guide to lead interested researchers into the relevant regional literature.

INTRODUCTION

The genus *Coptotermes* Wasmann (Isoptera: Rhinotermitidae, type is *Coptotermes gestroi* [Wasmann]) is widely distributed around the globe. Snyder (1949) listed forty-four species in the genus; while Roonwal (1970) reported that the genus *Coptotermes* contained 48 species, of which 23 were oriental. All *Coptotermes* spp. attack wooden structures and/or trees. On a worldwide basis, the most notorious pest in the genus is *Coptotermes formosanus* Shiraki, which is believed to have originated in China (Kistner 1985) but has spread worldwide (Su & Tamashiro 1987). Most species nest underground, but some species are mound-builders, such as *Coptotermes acinaciformis* (Froggatt) and *Coptotermes lacteus* (Froggatt) in Australia (Gay & Calaby 1970). Others, such as *Coptotermes curvignathus* Holmgren in southeastern Asia, Vietnam and southern China, nest in dead trees (Roonwal 1970).

In this paper, we review the current taxonomic status, distribution, and biology of *Coptotermes* in China and Japan, with brief mention also of Australia and the United States. This is intended as a topical review and synthesis, particularly of research that might not be familiar to scientists outside of the regions of interest, rather than a comprehensive bibliography. The references cited here should lead the interested reader deeper into the relevant scientific literature.

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CHINA

Distribution: The distribution of termites in China covers 25 provinces and autonomous regions, except for the provinces of Heilongjiang, Jilin, and Qinghai, and the autonomous regions of Inner Mongolia, Ningxia and Xingjiang. The northern distribution limit of *Coptotermes* is 33.5°N (Li *et al.* 1994).

According to Huang *et al.* (1989), there are four families, 42 genera and 361 species of termites in China; with the family Rhinotermitidae consisting of eight Chinese genera and 169 species. Li *et al.* (1994) reported that China has four termite families, representing 44 genera and 435 species of termites, but did not list any names. Gao *et al.* (1990) listed four families, 42 genera and 379 species, including 33 *Coptotermes* spp. In contrast, before revision, four species of *Coptotermes* were

Table 1. Species of *Coptotermes* in mainland China, after Huang et al. (1989).

Before revision	After revision	
	Subgenus: *Oligocrinitermes* Xia et He (New)	Subgenus: *Polycrinitermes* Xia et He (New)
C. ceylonicus Holmgren[a]	*C. bannaensis* Xia et He	*C. changtaiensis* Xia et He
C. curvignathus Holmgren[b]	*C. cochlearus* Xia et He	*C. chaoxianensis* Huang et Li
C. emersoni Ahmad	*C. dimorphus* Xia et He	*C. communis* Xia et He
C. formosanus Shiraki	*C. gestroi* (Wasmann)	*C. crassus* Ping
	C. longignathus Xia et He	*C. cyclocoryphus* Zhu, Li et Ma
	C. menglunensis Tsai et Huang	*C. eucalyptus* Ping
	C. monosetosus Tsai et Li	*C. formosanus* Shiraki
	C. obliquus Xia et He	*C. grandis* Li et Huang
	C. yaxianensis Li	*C. guangdongensis* Ping
		C. guangzhouensis Ping
		C. gulangyuensis Li et Huang
		C. hainanensis Li et Tsai
		C. hekouensis Xia et He
		C. heteromorphus Ping
		C. jiaxingensis Xia et He
		C. longistriatus Li et Huang
		C. minutus Li et Huang
		C. ochraceus Ping et Xu
		C. rectangularis Ping et Xu
		C. setosus Li
		C. shanghaiensis Xia et He
		C. suzhouensis Xia et He
		C. varicapitatus Tsai et Li
		C. xiaoliangensis Ping
Total: 4		33

[a] *C. ceylonicus* Holmgren is not considered to be present in China.
[b] *C. curvignathus* Holmgren should be replaced by *C. hainanensis* Li et Tsai.

recognized: *C. curvignathus* Holmgren, *C. formosanus* Shiraki, *C. ceylonicus* Holmgren and *C. emersoni* Ahmad (Huang *et al.* 1989). Current revision (Table 1), based on larger comparisons of Chinese collections, holds that *C. ceylonicus* Holmgren is not present in China and that *C. curvignathus* Holmgren should be replaced by *C. hainanensis* Li et Tsai.

The territory of Hong Kong, located at 22° 10'-22° 35' N and 113° 50'-114° 24' E in southeast Guangdong province, represents an area of ca. 1093 km^2 (Gao *et al.* 1996). Oshima (1914) conducted the earliest study of *Coptotermes* in Hong Kong and described only one species, *C. hongkongensis* Oshima (Snyder 1949). However Snyder (1949) considered this a junior synonym of *C. formosanus* Shiraki. After an extensive survey during 1992-1995, Gao *et al.* (1995, 1996) suggested that *C. hongkongensis* Oshima should be resurrected, because some specimens appeared identical to *C. hongkongensis* rather than to *C. formosanus*. Before this survey, there were only two *Coptotermes* species described in Hong Kong (Table 2). Recent allozyme electrophoresis (Wang 1998) has confirmed the presence of *C. formosanus*, but the other species reported in Hong Kong have not yet been investigated in this fashion.

Biology: Although Li *et al.* (1994) reported more than 30 *Coptotermes* species in China and nine *Coptotermes* species are reported in Hong Kong (Gao *et al.* 1996), only the biology of *C. formosanus* has been studied in detail (Li *et al.* 1994). Chinese investigations of *C. formosanus* biology have focused on swarming and nesting behavior, as well as colony establishment, development and longevity. The use of radioac-

Table 2. Species of *Coptotermes* in Hong Kong, after Gao et al. (1996).

Before revision[a]	After revision
C. communis Xia et He	*C. anglefontanalis* Gao, Lau et He
C. formosanus Shiraki	*C. communis* Xia et He
	C. cyclocorypus Zhu, Li et Ma
	C. eucalyptus Ping
	C. formosanus Shiraki[b]
	C. guangzhouensis Ping
	C. hainanensis Li et Tsai
	C. hongkongensis Oshima[b]
	C. melanoistriatus Gao, Lau et He
Total: 2	9

[a]Refer to Harris (1963), Hill et al. 1982, and Gao & Lam (1986).
[b]According to Gao et al. (1995, 1996), *C. formosanus* and *C. hongkongensis* are two different species and *C. hongkongensis* should be resurrected.

tive isotopes as markers to trace termite movement has been a popular technique (Li *et al.* 1994, Gao *et al.* 1996). Li *et al.* (1994) summarized laboratory studies on colony growth and development, and estimated average *C. formosanus* colony life as about 50 years, in the same range as the minimum 35 year estimate of Grace *et al.* (1995).

As in other lower termites, the hindgut of *Coptotermes* spp. harbor symbionts which aid in cellulose digestion (Cleveland 1924). Different species of termites posses their own symbionts (Koidzumi 1921), and differentiation of protozoan fauna has been used to trace termite geographic distributions and the relationships of sympatric colonies and species in *Reticulitermes* spp. in Japan (Kitade & Matsumoto 1994). Koidzumi (1921) described three species of flagellates found in the intestines of *C. formosanus* from Japan: *Holomastigotoides hartmanni* Koidzumi, *Spirotrichoympha leidy* Koidzumi and *Pseudotrichonympha grassii* Koidzumi. These same flagellates were studied in *C. formosanus* in China (Gao *et al.* 1996) and in Hawaii (Lai *et al.* 1983). However, no reports exist on protozoan fauna from other *Coptotermes* species in China.

Economic importance: Although over 30 *Coptotermes* species are found in 25 provinces of China and Hong Kong, estimates of building and household damage are based largely upon that attributable to *C. formosanus*. The annual cost of control has been estimated at US$ 120 million in mainland China (Su & Tamashiro 1987), but estimates of control costs in Hong Kong are not available.

Subterranean termite control in China and Hong Kong depends largely upon trapping methods, chemical soil barriers and nest excavation (Gao 1987, Gao *et al.* 1996, Lin 1987, Li *et al.* 1994). Given the numerous *Coptotermes* species in China, extension of new control techniques (such as baiting systems) for subterranean termites may prove challenging since different species may exhibit different biological responses and foraging behaviors.

JAPAN

Distribution: Matsumoto (1981) listed seventeen termite species in Japan, based largely upon the research of Morimoto (1975). Of these, *Incisitermes minor* (Hagen) and *Zootermopsis angusticollis* (Hagen) were introduced to Japan in imported timbers from North America but were not thought to have become established. However, with the addition of *Procapritermes* sp., Abe (1989) subsequently listed four termite families, ten genera, and sixteen species in Japan. *Coptotermes* is represented only by *C. formosanus* (Morimoto 1975). This species was probably introduced to Japan before the 17th century from China and

was found along the coast of Shikoku, Kyushu, and the western part of Shizuoka prefecture in central Honshu (Mori 1987).

Morimoto (1994) reported that several unknown termite specimens were found in Fukuoka City and Yonakunijima Island in 1985 following termite surveys in those areas. The specimens were morphologically similar to *C. formosanus* but were smaller and did not match specimens previously described in Japan. In 1993, Morimoto and his graduate student Ms. Takematsu (unpublished) found that the characteristics of these specimens were identical to *C. guangzhouensis* Ping, described in 1985 from Guangzhou (Gao *et al.* 1990). Based on this study, Morimoto (1994) concluded that Japanese *C. formosanus* may form a species complex. Although there may be at least two species of *Coptotermes* in Japan, the biology of *C. guangzhouensis* is not yet known and alates have not been collected. The unavailability of alates may indicate that the species was recently introduced to Japan.

Biology: Yoshimura *et al.* (1993) and Yoshimura (1995) studied the protozoan fauna of *C. formosanus* from Japan relative to nutritional physiology. These authors developed a method to defaunate protozoan fauna selectively and reported that *P. grassii* was the most critical of the three protozoans for wood digestion.

Economic importance: The majority of Japanese homes are constructed of brick, with wooden framing. Most structural damage in Japan is caused by the native termite *Reticulitermes speratus* (Kolbe), with *C. formosanus* only accounting for 5.8% of termite damage (Mori 1987) but responsible for an estimated annual cost of US$ 400 million for control (Su & Tamashiro 1987).

AUSTRALIA

Hill (1942) presented a comprehensive treatment of the Australian termite fauna, and Gay & Calaby (1970) described the region (including Tasmania and New Zealand) as containing five families, 27 genera, 175 described species and about 20 undescribed species. The genus *Coptotermes* is represented by at least six species: C. *acinaciformis* (Froggatt), *C. brunneus* Gay, *C. dreghorni* Hill, *C. frenchi* Hill, *C. lacteus* (Froggatt) and *C. michealseni* Silvestri. *C. acinaciformis*, *C. frenchi* and *C. lacteus* are similar in morphology and behavior (Creffield (1991); and *C. acinaciformis* is comprised of two subspecies, *C. acinaciformis acinaciformis* (Froggatt) and *C. acinaciformis raffrayi* Wasmann (Gay & Calaby 1970).

Coptotermes acinaciformis acinaciformis is widely distributed and tolerant of widely varying climatic conditions. It demonstrates considerable variability in nesting behavior. Populations dwelling in the

northern and southwestern parts of Australia are mound-builders while the populations occurring elsewhere make their nests underground, in stumps, in poles and in trunks of living or dead trees. Gay & Calaby (1970) reasoned that these different nesting behaviors were food or microenvironment dependent, but analyses of cuticular hydrocarbon (Brown *et al.* 1990) and allozyme (Wang 1998) profiles indicate a genetic basis.

Coptotermes acinaciformis raffrayi occurs only in southwestern Australia, where it attacks wooden frames of houses, and living trees (Gay & Calaby 1970). It does not make mounds. *Coptotermes michaelseni* also occurs in southwestern Australia and never builds mounds. In contrast, *Coptotermes brunneus*, which occurs along the lower lands of the Murchison River in western Australia, builds mounds up to eight feet high and six feet in diameter. *Coptotermes dreghorni* is usually found in the rain forest of northern Queensland and nests in stumps or logs (Gay & Calaby 1970). *Coptotermes frenchi* is distributed from northern Queensland to western Australia. It both builds mounds and nests underground and is a major destroyer of *Eucalyptus* forests. It is similar to *C. acinaciformis* in habitat and soldiers of the two species are similar in appearance (Gay & Calaby 1970). *Coptotermes lacteus* is another mound-building species that is found in eastern Australia. It is morphologically similar to *C. acinaciformis* and *C. frenchi*. The structure of its mounds, with numerous galleries and high moisture saturation, is used to distinguish it from other species (Gay & Calaby 1970).

Brown *et al.* (1990) collected three morphologically similar species: *C. acinaciformis*, *C. frenchi*, *C. lacteus*, plus *Coptotermes* sp. P. (sensu Brown *et al.* 1990) from different localities. Of these, C. *acinaciformis* and *C. frenchi* both contain mound-building and non-mound-building populations. Cuticular hydrocarbon analyses demonstrated that all four species possess unique cuticular hydrocarbon profiles which distinguish them from with one another (Brown *et al.* 1990, 1994). In addition, the cuticular hydrocarbon profiles of mound-building and non-mound-building populations of *C. acinaciformis* and *C. frenchi*, were qualitatively different. Thus, both *C. acinaciformis* and *C. frenchi* represent species complexes (Brown *et al.* 1990, Watson & Abbey 1993, Wang 1998). Perry *et al.* (1985) also reported that *C. michaelseni* from southwestern Australia may also include another species.

Coptotermes acinaciformis contains the same genera of flagellate protozoans as *C. formosanus*, but different species: *Holomastigotoides mirabile* Grassi, *Pseudotrichonympha hertwigi* (Hartmann) and *Spirotrichonympha flagellata* (Grassi) (Yamin 1979). No descriptions of

flagellates at the subspecies level of have been published. *Holomastigotoides hemigymnum* Grassi, *Pseudotrichonympha hertwigi* var. *major* Grassi, and *Spirotrichonympha flagellata* var. *coptotermitis* are found in *C. lacteus* (Yamin 1979). Neither differences in symbionts at the subspecific level of *C. a. acinaciformis* and *C. a. raffrayi*, nor the symbionts of *C. frenchi*, *C. brunneus*, *C. dreghorni* and *C. michaelseni* have been reported.

Coptotermes acinaciformis is considered to be the most destructive Australian termite (Verkerk 1990), and Gay and Calaby (1970) reported the annual loss caused by *C. a. acinaciformis* to be four million Australian dollars.

AMERICAN PACIFIC AND UNITED STATES

Certainly, fewer termites have been described in the United States than in China or Australia. Su and Scheffrahn (1990) reported that there were four families: Hodotermitidae (including the Termopsidae), Kalotermitidae, Rhinotermitidae and Termitidae, that included 17 genera and 45 species in the United States. In North America, 95% of the damage to wood products is caused by subterranean termites, comprised of *Reticulitermes* spp., *Heterotermes* spp. and *Coptotermes* spp. (Mauldin 1986). *Coptotermes formosanus* occurs in Hawaii, the southeastern United States as far west as Texas, and in one locality in California. In Hawaii alone, the annual costs of *C. formosanus* control exceed 100 million dollars (Tamashiro *et al.* 1990). *Coptotermes havilandi* Holmgren was recently identified in Florida (Su & Scheffrahn 1997). *Coptotermes vastator* Light occurs in the territory of Guam (Su 1994, Su & Scheffrahn 1998) and has been collected at least once in Hawaii (Bess 1970).

It is believed that *C. formosanus* was introduced to Hawaii about a century ago by immigrants or trade with Asia (Swezey 1914, Tamashiro *et al.* 1987). The three flagellate species found in *C. formosanus* in Hawaii are identical to those reported in Japan and China (Lai 1977, Lai *et al.* 1983). In the mainland United States, *C. formosanus* was introduced to Lake Charles, Louisiana, prior to 1966 (Spink 1967, LaFage 1987), New Orleans prior to 1968 (King & Spink 1969), Florida about 1980 (Koehler 1980, Su & Scheffrahn 1987) and recently was found near San Diego, California (Atkinson *et al.* 1993). These geographic populations show quantitative variations in their cuticular hydrocarbon and allozyme profiles (Haverty *et al.* 1990, Wang 1998), and this has also been shown to be true of subpopulations (colonies) within Hawaii when a sufficiently large number of samples are available (Haverty *et al.* 1996, Wang & Grace 1995).

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