Current distribution, ecological niche, and economic impact of the Asian subterranean termite in its invaded country, Taiwan

by

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Abstract

The Asian subterranean termite, *Coptotermes gestroi* (Wasmann), was first recorded in Taiwan in the early 1900s. A phylogeographic study indicated that *C. gestroi* is an invasive species and was most likely introduced from the Philippines. This tropical species has been collected from the southern tip (≈ 21.9 °N) up to central region (≈ 23.8 °N) of Taiwan. Altitude wide, *C. gestroi* was mostly found at low elevations (< 500m). Its naturalization has been confirmed by its consistently seasonal dispersal flight. The Asian subterranean termite and the Formosan subterranean termite, *Coptotermes formosanus* Shiraki, were responsible for > 87% of construction infestations on Taiwan, and control of the two species in Taiwan costs > 3 million US dollars annually. In southwestern counties, the infestation rates of the two *Coptotermes* spp. were not significantly different, but in other area, only *C. formosanus* occurs. By analyzing environmental factors of the 30 *Coptotermes* collection sites in the Kenting National Park, located at the southern tip of Taiwan, we found the ecological niches of *C. gestroi* and *C. formosanus* were significantly different. *Coptotermes gestroi* were found at warmer and drier areas than *C. formosanus*, and both species were only found together at one location. In another long-term experimental site, Xiaping Botanical Garden, located at the central Taiwan, *C. gestroi* infestation on trees was reported. An overall termite infestation survey on trees showed 12 of the 3,253 trees (≈ 0.4 %) were infested by *Coptotermes* spp. Eleven of them were caused by *C. gestroi* and only one was infested by *C. formosanus*. By using the mark-release-recapture method, population size of *C. gestroi* were estimated at 0.24-0.31 millions individuals, and linear tunnel length was up to 35 m. *Coptotermes gestroi* has already become a major termite pest in Taiwan which provided research opportunity and also raised some concerns of 1.) pest replacement between *C. formosanus* and *C. gestroi* in urban area along with environmental change and continuous urbanization; 2.) forest health threaten by *C. gestroi*; 3.) insufficient quarantine process to prevent other wood destroyed organisms invading Taiwan.

Key words: *Coptotermes gestroi*, invasive termite, Taiwan, ecological niche, economic damage

Taxonomy, distribution, and origin

The identification of *Coptotermes* spp. in Taiwan was a controversial issue in the early 1900s (Oshima 1909, Oshima 1912), and the problem was not solved until a few years ago (Li et al. 2010a). The inherent difficulties of *Coptotermes* taxonomy include its lacking distinguishing features, high degree of morphological variation among intraspecific populations, and difficulty in matching soldiers and alates of the same species. Based on detailed soldier morphology (Tsai and Cheng 2003) and analysis of mitochondrial genes sequences (Li et al. 2009), the occurrence of the Formosan subterranean termite, *Coptotermes formosanus* Shiraki (1909), and the Asian subterranean termite, *Coptotermes gestroi* (Wasmann 1896), in Taiwan was confirmed. The recent termite survey showed both species were most often found in lowland areas, < 500 m (Li et al. 2009, Yang and Li, 2012). *Coptotermes formosanus* is distributed throughout Taiwan Island, but *C. gestroi* was limited to southwestern Taiwan. Nantou (≈ 23.8 °N) is the most northern prefecture in Taiwan where an established *C. gestroi* colony has been recorded (unpublished data). Its naturalization has been confirmed by consistent seasonal dispersal flights.

Analysis mitochondrial sequences of COII, 12S rRNA, and 16S rRNA genes found that most Taiwanese *C. formosanus* populations were closely related to Japanese and some Chinese populations and that Taiwanese *C. gestroi* populations were most closely related to those from the Philippines (Li et al. 2009). In addition, high intraspecific variation was found in Taiwanese *C. formosanus* populations, but no variation was observed in Taiwanese *C. gestroi* populations, which indicated Taiwan is a center of origin for *C. formosanus*, but a recent introduction site for *C. gestroi*. *C. gestroi* was first recorded in Taiwan in 1909 (Oshima 1909), but the exact introduced time is unknown. The Taiwanese *C. gestroi* population was most likely introduced from the Philippines through frequent shipping between the two countries (Li et al. 2009).

Ecological niche

The current distribution of *C. gestroi* is limited to southwestern Taiwan that indicates temperature may be an important factor for its colonization. However, its current distribution may not reflect the range of its suitable habitat, since *C. gestroi* was a recently introduced species. The introduction point and inconsistent urbanization in Taiwan may also affect its current distribution, which has been demonstrated in a global scale by Li et al. in 2013. The further colonization of *C. gestroi* in northern and eastern Taiwan deserves close observation.

Previous behavioral bioassays showed *C. gestroi* and *C. formosanus* had strong agonistic interactions when their tunnel encountered by each other (Li et al. 2010b). We wonder if this interspecific

competition occurs in their overlapped zone, such as South Taiwan (Li et al. 2009), South Florida (Scheffrahn and Su 2005), and Hawaii (Swezey 1914, Weesner 1965) and results in niche partitioning. In order to investigate the ecological niche of these two *Coptotermes* spp., we analyzed environmental factors of *Coptotermes* collection sites in the Kenting National Park, which is located at the southern tip of Taiwan. *Coptotermes formosanus* was found in 20 locations and *C. gestroi* was collected in 11 locations. Both species were found together at only one location. The four significant different weather factors of the collection sites between *C. gestroi* and *C. formosanus* were minimum temperature in winter (16.7 and 16.2 °C), annual precipitation (2474.8 and 2782.3 mm), evapotranspiration (1099.6 and 1153.5 mm), and aridity index (1.93 and 2.18), respectively. The results showed the habitats in southern tip of Taiwan were quite similar, but *C. gestroi* was found at significantly warmer and drier areas than *C. formosanus* (unpublished data).

Economic damage and current control methods

Subterranean termites have been recorded as a severe pest of wooden construction in Taiwan for over 200 years (Su 2003, Su and Hsu 2003). Even though most modern buildings were constructed of concrete and steel in order to survive frequent earthquakes and typhoons, wood is still commonly used for furniture, wooden floor, ceiling, and other wooden decorations which were still seriously threatened. In addition, over 90% of historical buildings were made of wood which were heavily damaged by termites. *Coptotermes* spp. was responsible for > 87% of termite infestation in urban area of Taiwan (Li et al. 2011), and termite control cost in Taiwan was estimated as 4 million US dollars annually (Li 2009 dissertation). It is likely that over 3 million US dollars is the annual cost for controlling *Coptotermes* spp. In southwestern Taiwan, the infestation rate of *C. gestroi* and *C. formosanus* in construction are not much different (unpublished data).

Currently, 159 pesticide products are labeled for termite control and 19 of them (12%) were specialized for this purpose in Taiwan (Environmental Protection Administration 2014a). Nine active ingredients of the 19 specialized products include cypermethrin (1), bifenthrin (3), permethrin (1), boric acid (3), disodium octaborate tetrahydrate (2), fipronil (5), imidacloprid (1), hexaflumuron (2), noviflumuron (1). A total of 806 licensed pest control companies were registered in Taiwan (Environmental Protection Administration 2014b), and most include in their service offerings termite remedial control but not construction pretreatment.

Surveys of *Coptotermes* infestation on trees was conducted at three parks located in Taipei City (3,202 trees), Taichung City (594 trees), and Nantou County (3,253) in the past two years. The infestation rates were generally low, ranging from 1.7 to < 0.1%. In Taipei and Taichung, all *Coptotermes* samples were identified as *C. formosanus*. However, in the long-term experimental site of

Nantou, 11 of 12 *Coptotermes* infested tree were caused by *C. gestroi*. This finding raised some concerns if *C. gestroi* is more adopted in forest than *C. formosanus* in southern Taiwan, and if *C. gestroi* could cause further forest damage in Taiwan in the future. The population size of *C. gestroi* were estimated, using the mark-release-recapture method, at 0.24-0.31 millions individuals, and linear tunnel length was up to 35 m (unpublished data).

Coptotermes gestroi has already become a major termite pest in Taiwan along with the native species, *C. formosanus*, which provides us an ideal timing and location to observe pest replacement between the two species in an urban area along with environmental change and continuous urbanization. In addition to the urban environment, the potential of *C. gestroi* colonizing natural habitats such as forests should be studied. The No-Logging policy in Taiwan assures that most commercial wood will continually be imported from other countries, which also raises the concern if the current quarantine process executed at ports is sufficient to prevent other wood destroyed organisms from invading Taiwan. Examination and elimination of termite and other wood destroyed organisms in imported wood, especially logs, would require more attention in Taiwan.

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