ABSTRACTS (PH D THESIS)

Nesting Biology of the Drywood Termite, *Incisitermes minor* (Hagen)

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The invasive drywood termite, *Incisitermes minor* (Hagen) (Isoptera: Kalotermitidae) is considered to be the most destructive drywood termite in the western United States (USA). The colonies live entirely within a single piece of wood. Because of this hidden ecology, *I. minor* can be easily transported around the world within an infested piece of wood as a result of human activities. Originally from the southwestern USA and northern Mexico, infestations of this invasive species have been reported in Canada, China, and Hawaii, and more than half of the prefectures in Japan. The cryptic lifestyle of drywood termites makes it difficult to study their foraging behavior and to detect infestations in wood. In recent years, X-ray Computed Tomography (CT) has been developed as a reliable indirect method to analyze termite nests without damaging.

The present study aims to elaborate the nesting biology of *I. minor*, focusing on the observation of initial nest-founding in natural environment and X-ray computed tomographic (CT) analysis of the nest-gallery systems of *I. minor*.

Evaluation of initial nest-founding by *I. minor* reproductives

The evaluation of initial nest-founding of *I. minor* reproductives following the nuptial flight was conducted on six commercial timber species. The timbers included three Japanese timbers, hinoki (*Chamaecyparis obtusa* Endl.), karamatsu (*Larix leptolepis* Gord.), and sugi (*Cryptomeria japonica* D. Don), and three USA timbers, Douglas-fir (*Pseudotsuga menziessi* Mirbel), western red cedar (*Thuja plicata* Donn ex D. Don) and spruce (*Picea sitchensis* Bong. Carriere). The infested timbers were recorded in detail by identifying position of excavated holes on timbers (sapwood, heartwood, and border line of sapwood and heartwood), and the location of excavated holes on timber set-up (closed gap (CG) area, open gap (OG) area, cross-sectional surface (CS) area, bottom surface (BS) area, and upper surface (US) area of the timbers).

The results suggested that *I. minor* reproductives showed timber preferences in establishing the royal chamber to initiate the colony. The order of preferred timber species was as follows: hinoki, spruce, western red cedar, sugi, Douglas-fir, karamatsu. The current results showed nesting preferences among these six commercial timbers corresponded to previous report on feeding preferences. The reproductives of *I. minor* expressed nest-site selectivity on a preferred part of the timbers, i.e, on the springwood part of the annual growth rings on the sapwood part of the timbers. The reproductives of *I. minor* also showed selectivity in determining their nest-site location in response to the timber arrangement, namely by preferring the CG area. The results corresponded to previous reports which suggested that *I. minor* royal pairs like wood cracks, crevices or holes as sites at which to excavate the first royal chamber.

X-ray CT analysis of the nest-gallery systems of *I. minor*

We conducted CT scan to capture the structure of initial chambers excavated by *I. minor* as part of nest-founding activities and foraging; to observe first year development of the chambers; to monitor colonization process of foraging groups of *I. minor* in extending the nest-gallery to previously unoccupied timber; and to visualize how drywood termites establish and maintain their nest-gallery systems in response to the internal structure of fibers, growth rings and other anatomical properties of timbers. The selected timbers were imaged using an X-ray CT apparatus (Y.CT Modular320 FPD, YXLON International GmbH, Germany) maintained at Kyushu National Museum. The X-ray data obtained during the scanning process will be stored in files containing two-dimensional (2D) image stacks (*.raw image file), with each file representing a single 2D image-slice of the timbers. The 2D CT image stacks for each timber will be rendered into 3D images (each 2D image slice was 0.3 mm in thickness) by using volume graphics

software (VGStudio MAX 2.1, Volume Graphics GmbH, Germany).

The structure of initial chamber excavated by the royal pair of *I. minor* resembled European pear-shape and cashewnut-shape, in response toward timber anatomical properties. Those chambers were established in the springwood of the sapwood, and were carefully excavated beneath the surface to follow the direction of annual growth rings, and avoided the summerwood. *In situ* observation of the first year development of initial chambers suggested that royal pairs of *I. minor* can start breeding new colony members in the first six months, and by the end of the first year, an incipient colony can have 0 – 5 new members. The development of royal chambers in the first year showed a preference for the springwood part of the particular growth rings where the entrance holes were excavated.

We also evaluated the structure of initial chamber which was established by group of foragers, mediated by the foraging activities of individuals that attacked adjacent surface of a new timber. The result indicated that drywood termite has greater foraging flexibility in response of environmental conditions. In extending the nest-gallery, *I. minor* also expressed selectivity in foraging by selecting favorable excavation areas, and showed adaptability with respect to the timber environment. In the absence of primary reproductives, the colony showed dynamic change in its caste composition through the emergence of replacement reproductives. The results also suggested that replacement reproductives can emerge from the pseudergate stage. However, the sexes of the replacement reproductives, the time interval before they emerge and the suitable conditions required to facilitate the emergence of replacement reproductives are not yet fully understood.

During colonization and foraging within wood, the internal structures of fibers and growth rings and other anatomical properties influenced the way drywood termites established their nest-gallery. The nest-gallery excavations demonstrated continual adaptation by foragers to anatomical constraints in selecting favorable areas of less dense wood fiber inside the timbers. The colony also exhibited defense mechanisms with which to protect the colony, such as by sealing a tunnel leading to the outer environment using cement pellets. The sticky hydrated pellets were observed in the chambers inside the nest-gallery, even in the first six months of new nest establishment.