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# Identification of subterranean termites and their attack characteristics on settlements in Jakarta Province, Indonesia

**ARINANA ARINANA[1,♥], FIRMAN ARDIANSYAH[1], RIKI ANDIKA[2], DIDI TARMADI[3], SATIMO[4]**

[1]Forest Product Department, Faculty of Forestry and Environment, Institut Pertanian Bogor. Jl. Ulin, Kampus IPB Darmaga, Bogor 16680, West Java, Indonesia. Tel./fax.: +62-862-1285, ♥email: arinana@apps.ipb.ac.id

[2]Faculty of Forestry, Universitas Mulawarman. Jl. Penajam, Kampus Gn. Kelua, Samarinda 75123, East Kalimantan, Indonesia

[3]Research Center for Applied Zoology, National Research and Innovation Agency. Jl. Raya Jakarta-Bogor Km 46, Cibinong, Bogor 16911, West Java, Indonesia

[4]PT. Larusa Adi Sumindi, Pembina Graha Building. Jl. DI Panjaitan Kav 45 Blok 2 Suite 201A, East Jakarta 13350, Jakarta, Indonesia

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**Abstract.** *Arinana A, Ardiansyah F, Andika R, Tarmadi D, Satimo. 2025. Identification of subterranean termites and their attack characteristics on settlements in Jakarta Province, Indonesia. Biodiversitas 26: 22-35.* The increase in termite attacks on buildings in Jakarta, Indonesia coinciding with the city's construction boom, is reshaping environmental dynamics. This study aims to identify the subterranean termite species responsible for damaging residential structures and to analyze the patterns of these infestations throughout Jakarta. The research was conducted across 57 settlement sites within the city, guided by a comprehensive survey of termite-induced damage and a four-month monitoring period from September to December 2021, during which Perseroan Terbatas (PT) Larusa Adi Sumindo, Jakarta implemented a baiting system. Morphometric identification of the termites revealed at least four species associated with building infestations: *Coptotermes curvignathus*, *C. gestroi*, *Macrotermes gilvus*, and *Microtermes insperatus*. *Coptotermes gestroi* was the most prevalent among these, found at 39 sites. The findings indicate that termite damage was most severe in window and door frames (49.1%), while the foundation exhibited the least damage (3.5%). This research highlights not only the diversity of termite species infesting urban areas but also the specific structural components vulnerable to their attacks, including frames, foundations, floors, walls, ceilings, archives, and garden trees. These insights are crucial for developing targeted mitigation strategies and building resilience against these pervasive subterranean termites, supporting sustainable urban development in Jakarta and beyond.

**Keywords:** Building damage, morphometry, residential termite, termite infestation, urban termite

## INTRODUCTION

The Indonesian capital, Jakarta, is home to a considerable population density, with a population of 11 million spread across an area of only 664 km². As indicated by data from the Central Statistics Agency (BPS), the population density of Jakarta reached 16,937 individuals/ $km^2$ in 2021 (BPS 2021). As the political and economic centre of the country, the Special Capital Region of Jakarta, with its high economic turnover compared to other parts of Indonesia, is experiencing a period of rapid population growth (Putri et al. 2019). The city's allure as a hub for government and commerce has contributed to this population surge. According to the Direktorat Jenderal Kependudukan dan Pencatatan Sipil Kementerian Dalam Negeri (2021), the population of Jakarta Province increased from 10.5 million people in 2020 to 11.25 million people in 2021.

Termites are insects that are regarded as pests due to their voracious appetite for food and their tendency to invade and infest buildings. They can be found in a multitude of habitats, including forests, agricultural land, plantations, and even residential areas (Subekti et al. 2018a,b; Arif et al. 2021; Nurhadi et al. 2023). This is substantiated by termites' capacity to adapt to urban settings, rendering residential ecosystems vulnerable to termite attacks (Arinana et al. 2022).

The mounting damage caused by termites in government buildings prompted the Provincial Government of Jakarta to issue Governor Regulation No. 35 Year 2013 on Guidelines for Termite Hazard Management in Government-Owned Buildings in the Special Capital Region of Jakarta. This regulation's issuance underscores that termite infestation poses a major challenge requiring attention, potentially hindering the continued development of regions like Jakarta. The impact of termites in urban areas is not solely ecological but also economic. Termites are recognized as significant pests, causing substantial damage to wooden structures and urban vegetation. The financial implications of termite damage are staggering, with estimates suggesting that termite-related losses amount to approximately $40 billion annually worldwide, predominantly due to subterranean termites (Rahman et al. 2020; Nisar et al. 2023). Moreover, the ecological role of termites in urban environments is complex. While they are known for their destructive capabilities, termites also contribute to essential ecological processes such as soil modification and nutrient cycling (Himmi et al. 2019). However, the simplification of natural habitats due to urbanization increases the vulnerability of these ecosystems to termite infestations (Manoppo et al. 2024).

Arinana et al. (2016) conducted comprehensive research on the diversity of subterranean termite species in South Jakarta City and Jakarta Province. The study utilized bait wood as a basis, revealing the presence of numerous subterranean termites causing damage to residential buildings. In residential areas, the most common types of termites belonging to the genus *Coptotermes*, such as *C. curvignathus* (Holmgren, 1913) and *C. gestroi* (Wasmann, 1896). These species are notorious for their destructive behavior, as they primarily feed on wood and other cellulose-based materials found in homes, leading to significant structural damage (Arinana et al. 2016). The presence of these termites is often exacerbated by environmental conditions that favor their proliferation, such as high humidity and the availability of cellulose-rich materials in and around buildings (Subekti et al. 2018a,b). The findings indicated that *C. curvignathus* was one of the subterranean termite species attacking the planted bait wood. According to Kuswanto et al. (2015), *Coptotermes* sp. is identified as the most aggressive subterranean termite species. They also noted that contrary to temperate countries, tropical Asian countries commonly experience the coexistence of several termite species attacking the same building. Furthermore, it was observed that, in such tropical conditions, additional termite species might re-invade the building structure even after successful previous treatments.

The regulation of subterranean termites in buildings in Indonesia is currently overseen by the Indonesian National Standard (SNI), which comprises SNI 2404:2015 (Pre-Construction Soil Treatment) and SNI 2405:2015 (Post-Construction Soil Treatment). The selection of appropriate methods is dependent on the specific type of termites that are present in a given location. It is therefore necessary to conduct further research in order to ascertain the characteristics of subterranean termite infestation on building components and to identify the subterranean termites that infest settlements in the province of Jakarta, Indonesia. The objective of this study is to analyse the subterranean termite species using morphometric data and to assess the characteristics of subterranean termite infestation on building components in the province of Jakarta.

## MATERIALS AND METHODS

### Materials

The materials utilized in the research included collection bottles, soil drills, brushes, plastic spoons, crowbars, tweezers, clear plastic containers, digital cameras, Global Positioning System (GPS), computers, microscopes (Leica S Apo), questionnaires, and stationery. The materials employed in the study comprised 70% alcohol and termite specimens (soldier caste).

### Time and locations

This research was conducted from September 2021 to December 2022. Information on termite infestation and subterranean termite specimens was obtained from 57 locations in Jakarta Province over four months, conducted by Perseroan Terbatas (PT) Larusa Adi Sumindo, Jakarta, Indonesia. Furthermore, termite species were identified at the Integrated Bioproduct Laboratory of the National Research and Innovation Agency (BRIN) in Cibinong, Bogor, Indonesia.

### Procedures

*Termite specimen collection*

The technique employed for collecting termite specimens is incidental sampling, signifying that termite specimens are collected and preserved from locations where termite infestations are detected. The surveys and monitoring conducted in this study focused on assessing termite-induced building damage and monitoring termite bait application. These surveys were carried out across 57 settlement sites in Jakarta Province with PT Larusa Adi Sumindo from September to December 2021. A cross-sectional approach was employed to collect data at a single point in time across the predetermined sample population. Termite specimens are acquired from parts of the building that have suffered termite attacks (Constantino 2021). Soldier caste termite specimens discovered in each location and damaged building are placed into separate collection bottles treated with 70% alcohol (Arinana et al. 2020). Each collection bottle is labeled with the building owner's name and the address where the termite infestation was found.

*Termite identification*

Each termite specimen (soldier caste) from every sample site was identified using Krishna et al. (2013) and Constantino (2021) termite species recognition key. Additionally, morphological and morphometric observations were conducted on termite specimens from each sample location. Morphological observations covered all parts of the termite body, encompassing shape, color, and other characteristics present on the body parts. Morphometric data were acquired by measuring each termite specimen three times from the same collection bottle. The soldier caste's head was measured following the criteria outlined by Takematsu and Vongkaluang (2012), including Head Length Without Mandible (HLWM), Head Width at the Base of the Mandible (HWBM), Maximum Head Width (MHW), left mandible length (ML), pronotum length (PP), maximum pronotum width (LMP), postmentum length (LPos), postmentum width (WPos), and the number of antenna segments. Measurements of the external anatomical parts of the soldier termite head are illustrated in Figure 1. Observations and photographs of specimens were conducted using a digital microscope (Leica S Apo).

*Characteristics termite infestation*

The characterization of termite infestation involved inspecting buildings at 57 locations in Jakarta Province that had experienced termite infestation over four months. Each building damaged by termite infestation was visually documented. Observations were conducted on the condition and evidence of infestation in critical building parts, such as roofs, foundations, wall frames, ceilings, walls, floors, yard drainage, and utilities.

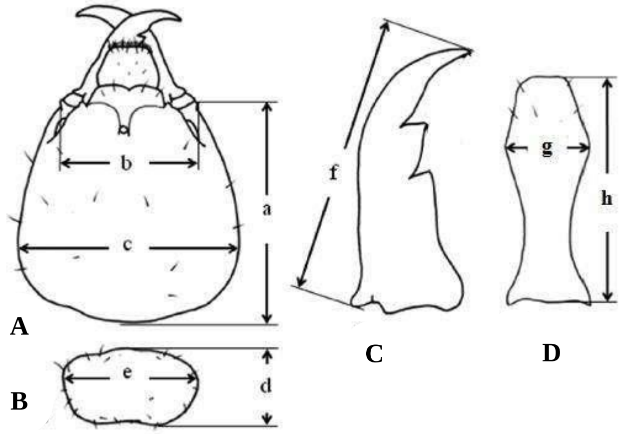



**Figure 1.** Termite measurements: A. Head; B. Pronotum; C. Left mandible; D. Postmentum; a. HLWM; b. HWBM; c. ML; d. PP; e. LMP; f. PMK; g. WPos; h. LPos (Takematsu and Vongkaluang 2012)

### Data analysis

Data on subterranean termite infestation characteristics in settlements was processed using Microsoft Excel 2013. Morphometric data were descriptively analyzed to ascertain each termite specimen's average trend and range. The analysis aimed to establish the relationship between the morphology and morphometry of the collected termite specimens by measuring key morphological features such as whole body length, head length without mandibles, width of head and the width of the base of the mandibles. These measurements were carried out and analyzed using Leica Application Suite Version 3.4.0 software.

## RESULTS AND DISCUSSION

### Identification of subterranean termites

The results showed that in Jakarta Province, there are at least four species of subterranean termites, namely *C. curvignathus* and *C. gestroi*, which are members of the Rhinotermitidae family, and two other species, *Macrotermes gilvus* (Hagen, 1858) and *Microtermes insperatus* (Kemner, 1934), which are members of the Termitidae family. The identification process of subterranean termite species refers to the morphological characteristics of the head capsule (Figure 2), mandibles (Figure 3), and the whole body (Figure 4) of the soldier caste.

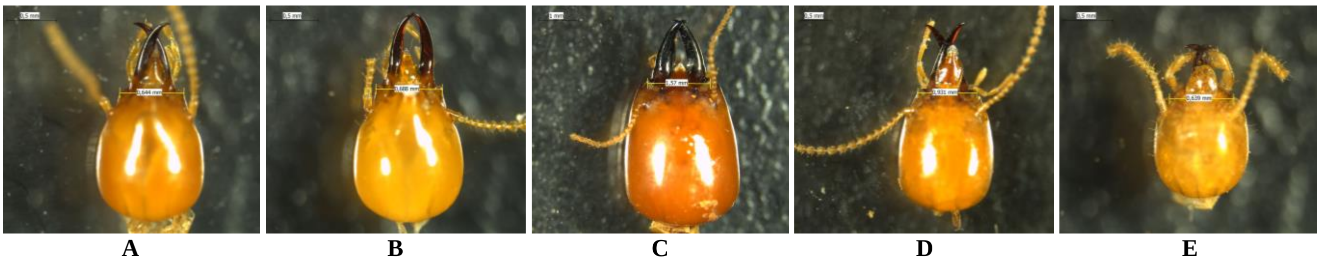



**Figure 2.** Morphological characters of subterranean termite head capsules found invading settlements in Jakarta Province, Indonesia: A. *Coptotermes curvignathus*; B. *Coptotermes gestroi*; C. *Macrotermes gilvus* major; D *Macrotermes gilvus* minor; E. *Microtermes insperatus*


**Figure 3.** Morphological characters of the mandibles of the soldier caste of subterranean termites found invading settlements in Jakarta Province, Indonesia: A. *Coptotermes curvignathus*; B. *Coptotermes gestroi*; C. *Macrotermes gilvus* major; D *Macrotermes gilvus* minor; E. *Microtermes insperatus*


**Figure 4.** Morphological characters of the whole body of subterranean termites found invading settlements in Jakarta Province, Indonesia: A. *Coptotermes curvignathus*; B. *Coptotermes gestroi*; C. *Macrotermes gilvus* major; D *Macrotermes gilvus* minor; E. *Microtermes insperatus*

*Coptotermes curvignathus*

*Coptotermes curvignathus* is a big termite species from the *Coptotermes* genus, specifically the Coptotermitinae subfamily. This species is renowned for its very destructive wood-feeding activity, as it has the highest wood-destroying capacity of all species in its genus (Arinana et al. 2016). This species' descriptions and classification are based on multiple reputable publications, including Krishna et al. (2013), Khan and Ahmad (2018), and Constantino (2021). *Coptotermes curvignathus* is distinguished by its yellow, oval-shaped head. The labrum, placed on the front of the head, is light brown, and the antennae are brownish yellow. Other body components, including as the pronotum, limbs, and dorsal abdominal plate, are yellowish. The abdomen is distinctly distended, with a covering of dense bristles that further differentiate the species. Long hairs can also be found on the head, with two particularly noticeable ones at the tip of the labrum.

Another distinguishing characteristic of this species is the fontanelle, which is a tiny aperture on the forehead. This structure has a frontal gland, which produces a milky white fluid. This substance has a protective purpose, since termites utilize it when predators threaten or assault their colonies. This fluid serves as a deterrence to attackers and demonstrates the defensive systems that termites of this species possess. *Coptotermes curvignathus*' mandibles are reddish-brown in hue, with a lighter tone around the base. These mandibles are long and sword-like in appearance, with a distinct curvature that starts halfway down their length. The right mandible has a flat inner border, which distinguishes this species. Despite being elongated, the mandibles are somewhat shorter than the head. Their size and form make them useful for defense and wood destruction.

*Coptotermes curvignathus* antennae consist of 14 to 15 segments. The second segment is somewhat longer than the third and fourth, which distinguishes this termite's morphology. These sensory organs help the termite navigate its environment and find food sources.

Figure 5 depicts the morphological traits of the soldier caste of *C. curvignathus*. The soldier caste is in charge of guarding the colony, and its particular features—such as powerful mandibles and defense fluid—are crucial in protecting termites from predators and environmental dangers. Three repetitions of 47 soldier caste termite specimens from 14 individual soldier termite locations were measured, namely: PKTM 1.18-1.51 mm, LMK 1.05-1.25 mm, LKDM 0.64-0.76 mm, PPos 0.81-1.03 mm, LPos 0.33-0.41 mm, PP 0.40-0.51 mm, LMP 0.74-0.90 mm, and PMK 0.52-0.95 mm. The measurement results of the specimens from the sample study site stated that the total body length was 4.49-6.20 mm. The number of antennal segments was 14-15. The measurement results of individual *C. curvignathus* soldiers can be seen in Table 1.

*Coptotermes gestroi*

Among the most destructive termites, the genus *Coptotermes* is responsible for significant damage to buildings, structures, and even living trees. Within this genus, *C. gestroi* stands out as one of the most common species involved in such attacks. *Coptotermes gestroi* is notorious for infesting residential and commercial properties, as well as agricultural and forestry assets, making it a major concern in both urban and rural areas. This species shares many morphological and behavioral similarities with *C. curvignathus*, making it challenging to distinguish between the two, especially due to the lack of detailed taxonomic determination keys and the inherent size variations within these species.

Both *C. curvignathus* and *C. gestroi* are well-documented for their long history of destructive behavior, especially in attacking wood within buildings and various crops (Arif et al. 2021; Nurhadi et al. 2023). These termites are considered some of the most problematic pests in Southeast Asia and other tropical regions, where their presence can lead to significant economic losses. Their destructive capacity is highlighted in numerous studies, such as those by Krishna et al. (2013) and Constantino (2021), which describe the species' broad impact and their invasive nature.

**Table 1.** *Coptotermes curvignathus* soldier size (n: 47)

| **Part of *Coptotermes curvignathus*** | **(mm)** | **Average (mm)±SD** |
|---|---|---|
| Whole body length | 4.49-6.20 | 5.33±0.36 |
| Head length without mandibles | 1.18-1.51 | 1.36±0.06 |
| Width of head | 1.05-1.25 | 1.14±0.04 |
| The width of the base of the mandibles | 0.64-0.76 | 0.70±0.02 |

A B C D E

**Figure 5.** Morphology of the soldier caste of *Coptotermes curvignathus*: A. Antennae; B. Fontanelle dorsal view; C. Labrum; D. Pronotum; E. Postmentum

One of the key identifying characteristics of *C. gestroi* is the wide opening of the fontanelle located on the head. This fontanelle is prominently visible, with a light-yellow coloration, and it plays an important role in the termite's defense mechanism. Similar to *C. curvignathus*, *C. gestroi* secretes a milky white fluid from this gland to defend itself against predators and other threats (Haneda et al. 2017). From a dorsal view, the head of *C. gestroi* closely resembles that of *C. curvignathus* (Wikantyoso et al. 2021). The head is reddish-yellow and oval in shape, covered with long, sparse hairs, and the head capsule itself has scattered, fine hairs, which are also present on the pronotum.

The postmentum, located on the lower part of the head, is another distinctive feature, as it possesses a few long hairs. The mandibles of *C. gestroi* are reddish-brown, slightly curved, and relatively straight compared to those of other termite species. These mandibles extend to more than half the length of the head, making them an essential tool for the termite's defense and wood-processing activities. A unique pair of hairs grows at the edge of the fontanelle, further aiding in the species identification.

The legs and abdomen of *C. gestroi* are off-white in color, which contrasts with the reddish-yellow head. The antennae consist of 14 to 15 segments, with the second segment slightly longer than the third. The labrum, located just below the mandibles, is pointed with a hyaline tip and adorned with a pair of fine hairs (Krishna et al. 2013; Constantino 2021). This detailed morphology allows researchers and pest control professionals to differentiate *C. gestroi* from other termite species, though its similarity to *C. curvignathus* often makes close examination necessary.

Figure 6 provides a visual representation of the soldier caste of *C. gestroi*, highlighting the defining features discussed above. The soldier caste plays a crucial role in colony defense, using their formidable mandibles and defensive secretions to protect the colony from predators and environmental threats.

The results of three repetitive measurements of 126 soldier caste termite specimens from 39 sample sites in this study showed that the total body length was 3.32-5.77 mm, PKTM 0.99-1.47 mm, LMK 0.92-1.27 mm, LKDM 0.46-0.81 mm, PPos 0.64-1.03 mm, LPos 0.31-0.43 mm, PP 0.34-0.56 mm, LMP 0.61-1.00 mm, and PMK 0.54-1.02 mm. The number of antennal segments is 14-15. Based on the Coptotermes species determination key (Takematsu and Vongkaluang 2012; Krishna et al. 2013; Constantino 2021), the observed morphometric characteristics of these subterranean termites are close to the criteria of *C. gestroi* species. The measurement results of individual *C. gestroi* soldiers can be seen in Table 2.

*Macrotermes gilvus*

*Macrotermes* termites are widely distributed throughout Southeast Asia, particularly in Indonesia, Malaysia, and Thailand (Khan and Ahmad 2018). These termites predominantly inhabit natural forest ecosystems where the environmental conditions—such as temperature, humidity, and rainfall—remain relatively stable and conducive to survival (Prastyaningsih et al. 2020). The stability of these factors is crucial for *Macrotermes* species, as their colonies thrive in such conditions. However, in recent years, changes in the distribution of *M. gilvus* termites have been observed, primarily attributed to the impacts of global climate change and the transformation of natural forest habitats. These environmental disruptions, including deforestation and altered microclimates, are reshaping the natural range of these termites, pushing them into new areas, or reducing their populations in previously stable habitats (Heriza et al. 2024).

One of the distinctive features of *M. gilvus* termites is their soldier caste dimorphism. This means the soldier termites are divided into two sub-castes based on size: major soldiers and minor soldiers. This division of labor and physical differentiation allows for better protection of the termite colony, as each soldier plays a specific role. The identification of *M. gilvus* soldiers has been thoroughly documented using termite identification keys, as described by Krishna et al. (2013), Khan and Ahmad (2018); and Constantino (2021). These identification systems rely on detailed morphological traits, helping distinguish between the two soldier castes.

**Table 2.** Size of soldier *Coptotermes gestroi* (n: 126)

| Part of *Coptotermes gestroi* | (mm) | Average (mm)±SD |
|---|---|---|
| Whole body length | 3.32-5.77 | 4.46±0.43 |
| Head length without mandibles | 0.99-1.47 | 1.31±0.10 |
| Width of head | 0.92-1.27 | 1.12±0.07 |
| The width of the base of the mandibles | 0.46-0.81 | 0.69±0.05 |

A B C D E

**Figure 6.** Morphology of the soldier caste of *Coptotermes gestroi*: A. Antennae; B. Fontanelle dorsal view; C. Labrum; D. Pronotum; E. Postmentum

**Major soldier**. The major soldiers of *M. gilvus* are notably larger than the minor soldiers, making their body characteristics easier to observe and measure (Krishna et al. 2013). The most distinguishing feature of the major soldiers is their robust, dark brown or reddish head capsule. The head is well-contoured and positioned at the front, contributing to their ability to defend the colony effectively. The head capsule also has fine hairs scattered across its surface, adding to its unique texture.

The mandibles of major soldiers are a striking feature, being symmetrical when closed. These strong, powerful mandibles are used to fend off intruders or threats to the colony, providing a vital defense mechanism. The antennae of major soldiers consist of 17 segments, with the third segment being one and a half times longer than the second and slightly longer than the fourth. This precise antennal structure assists in sensory functions, helping the termite navigate its environment and communicate with colony members.

Another defining characteristic is the pronotum, which is saddle-shaped, a typical trait of *M. gilvus* soldier termites. This pronotum structure, along with the scattered hairs on the body, contributes to the termite's sturdy appearance. These features, when combined, provide a clear morphological distinction for the major soldier caste. Figure 7 illustrates the morphology of the major soldier caste of *M. gilvus*, highlighting these defining characteristics.

The results of three repetitive measurements of 8 major soldier caste termite specimens from 7 sample locations in this study showed that the total body length was 6.94-10.12 mm, PKTM 2.56-3.63 mm, LMK 2.10-3.01 mm, LKDM 1.18-1.83 mm, PPos 1.63-2.70 mm, LPos 0.69-0.89 mm, PP 0.89-1.34 mm, LMP 1.46-2.55 mm, and PMK 0.86-1.84 mm. The measurement results of individual major soldiers of *M. gilvus* can be seen in Table 3.

**Minor soldier**. In contrast to the major soldiers, the minor soldiers of *M. gilvus* are smaller in size but still play a crucial role in defending the colony (Table 4). The most distinctive feature of the minor soldiers is their short labrum, located at the tip of the head. The head capsule is reddish-brown or light brown, and it has fewer hairs than the major soldiers, giving it a smoother appearance.

The minor soldier caste also possesses antennae that consist of 17 segments, similar to the major soldiers. However, in the minor soldiers, the third antennal segment is longer than the second and is approximately the same length as the fourth segment. These sensory organs are essential for detecting threats and navigating their environment. The labrum and antennae are brown in color, matching the lighter tones of the head.

The pronotum of the minor soldiers is lighter in color than the head, offering a subtle but observable contrast. One of the most easily recognizable features of the minor soldiers is the fontanelle—a small, round gland located at the center of the head. The fontanelle is well-defined and trimmed, serving as an important identification marker. This gland secretes defensive fluids that can be used to repel predators, a function shared by many termite species.

Figure 8 shows the morphology of the minor soldier caste of *M. gilvus*, displaying the notable differences between the two castes, particularly in terms of size, coloration, and head shape.

*Microtermes insperatus*

*Microtermes insperatus* is a termite species that has been described based on the taxonomic keys provided by Krishna et al. (2013) and Constantino (2021). Unlike other termite species, such as *Macrotermes*, *M. insperatus* does not exhibit caste dimorphism in its soldiers, meaning that it does not have both major and minor soldier forms. This lack of dimorphism simplifies its identification, as there is a single form of soldier caste within the species.

**Table 3.** Size of major soldier *Macrotermes gilvus* (n: 8)

| **Part of major soldier *Macrotermes gilvus*** | **(mm)** | **Average (mm)±SD** |
|---|---|---|
| Whole body length | 6.94-10.12 | 8.60±1.21 |
| Head length without mandibles | 2.56-3.63 | 3.13±0.45 |
| Width of head | 2.10-3.01 | 2.61±0.40 |
| The width of the base of the mandibles | 1.18-1.83 | 1.55±0.23 |

**Table 4.** Size of minor soldier *Macrotermes gilvus* (n: 7)

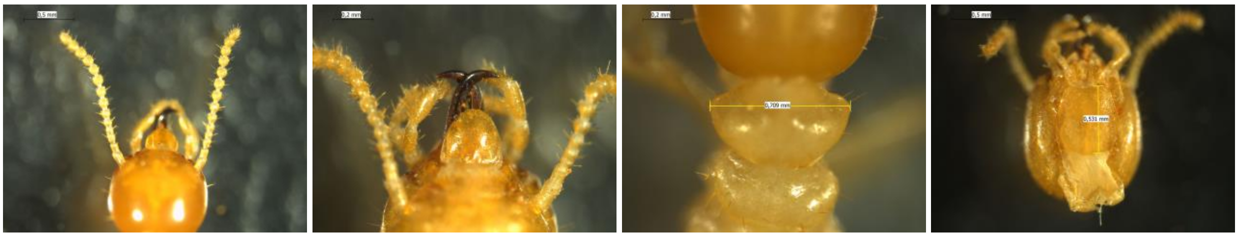
| **Part of minor soldier *Macrotermes gilvus*** | **(mm)** | **Average (mm)±SD** |
|---|---|---|
| Whole body length | 5.75-6.61 | 6.16±0.29 |
| Head length without mandibles | 1.84-2.30 | 2.00±0.18 |
| Width of head | 1.47-1.92 | 1.64±0.17 |
| The width of the base of the mandibles | 0.93-1.13 | 1.01±0.09 |

A B C D

**Figure 7**. Morphology of the major soldier caste of *Macrotermes gilvus*: A. Antennae; B. Labrum; C. Pronotum; D. Postmentum

A B C D

**Figure 8.** Morphology of the minor soldier caste of *Macrotermes gilvus*: A. Antennae; B. Labrum; C. Pronotum; D. Postmentum



A B C D

**Figure 9.** Morphology of the soldier caste of *Microtermes insperatus*: A. Antennae; B. Labrum; C. Pronotum; D. Postmentum

The most distinctive feature of *M. insperatus* soldiers is their mandibles. The left mandible may either lack teeth altogether or have incomplete dentition, a characteristic that sets them apart from many other termite species. The mandibles are hook-like, with a deep depression that further distinguishes them. In addition, the left mandible is equipped with a small denticle, which is positioned slightly in front of the center of the mandible, a bit further forward compared to its counterpart on the right mandible. This asymmetry in the mandibles is a notable trait for identifying *M. insperatus*.

The head of *M. insperatus* is round and typically yellowish in color. It has very few hairs, giving the head a relatively smooth appearance compared to other termite species that may exhibit more pronounced hair coverage. The head shape, combined with the characteristic mandibles, provides a clear visual distinction for this species.

The antennae of *M. insperatus* consist of 14 or 15 segments. The second antennal segment is slightly longer than the third, providing another distinguishing morphological feature. The labrum, or the upper lip of the termite, is tongue-shaped, further contributing to the unique structural attributes of this species. These sensory and feeding structures are essential to the termite's ability to interact with its environment, locate food, and defend the colony.

Figure 9 illustrates the morphology of the soldier caste of *M. insperatus*, showing the distinctive features discussed above, including the hook-shaped mandibles, the round yellowish head, and the segmented antennae. These visual cues are critical for the accurate identification and classification of *M. insperatus* among other termite species.

**Infestation characteristics of subterranean termite species**

The results showed that the components of houses in Jakarta Province that subterranean termites attack are frames, foundations, floors, wall frames, walls, and ceilings. In addition, subterranean termites were also found to attack archives (books) and trees in the garden. Details are presented in Table 5.

Based on the data from Table 5, it can be seen that frames and archives are the building components most prone to termite infestation, with percentages of 49.1% and 42.1%. Meanwhile, the foundation and wall frame are the building components with the lowest damage frequency, with percentages of 3.5% and 5.3%, respectively. Subterranean termite attacks on each component of a house building have the following characteristics:

**Table 5.** Percentage of damage to building components due to termite infestation in Jakarta Province, Indonesia

| Building component | Total | Percentage (%) |
|---|---|---|
| Frame | 31 | 49.1 |
| Foundation | 2 | 3.5 |
| Floor | 15 | 26.3 |
| Wall frame | 3 | 5.3 |
| Wall | 15 | 26.3 |
| Ceiling | 22 | 33.3 |
| Archive | 24 | 42.1 |
| Trees in the garden area | 14 | 17.5 |

*Damage to door and window frames*

The damage can be seen by the presence of termite paths on the outer walls of the building towards the wooden frames. This is because direct contact between the frame and the ground makes it easier for termites to attack it. Termites will build nests near the soil's surface to obtain moisture from the soil. Soil with low acidity can trigger the breeding process of termites. Therefore, the soil as termites' initial medium of life should be continuously monitored (Kurniawan et al. 2015). In addition to soil, moisture is also obtained from low ambient temperature.

Another factor causing damage to the frames is using low-durability wood species that termites quickly attack. The damage that occurs is also in the form of rot and cracks. This damage can be caused by the lack of maintenance of frames, doors, and windows (Arinana et al. 2015). To detect termite infestation on the frame, several symptoms can be noticed, namely the presence of sawdust scattered on the floor, cracks in the paint or joints between the frame and the wall, then visible termite paths on the ground to the frame, termites cause many holes, and the door feels tight, or the window is difficult to open.

*Damage to the foundation*

Damage to the foundation is a critical issue in termite infestations, particularly when lower-quality materials are used in construction or when soil layers are unstable (Gazal et al. 2019). Termites often target wooden components supporting the foundation, and their presence can be detected by pencil-thin mud tunnels starting from the soil and climbing along the foundation wall (Buczkowski and Bertelsmeier 2017). These tunnels serve as protective pathways, allowing termites to maintain the necessary moisture levels as they move from the soil to the foundation. Since foundation components are mostly located below ground level, termites can readily access them without exposure to sunlight. This positioning creates an ideal environment for termites to attack and degrade these structural elements. Regular inspection and proper material selection are essential to prevent foundation damage from termite infestations (Kusumawardhani and Almulqu 2024).

*Damage to the floor*

In the study area, floors are primarily constructed from ceramic materials, though some use decorative wood or floor stickers. Termites exploit any existing cracks in ceramic floors, as these openings allow them to access and attack the building's flooring structure. The presence of soil particles, appearing as granules within these cracks, is a typical indicator of termite activity. Additionally, floors adorned with wood or parquet materials are particularly susceptible to termites, which penetrate the floor's gaps and consume the wood elements. Termite-damaged floors may feel uneven or produce hollow sounds when walked on, and untreated infestations can lead to extensive floor degradation over time. To prevent termite access through the flooring, it's vital to repair cracks promptly and consider termite-resistant materials for floor decoration. Termite infestation through the floor occurs due to the lack of pre-treatment to prevent the presence of termites (Debelo and Degaga 2014).

*Damage to wall frame*

Wall frames are another target for termites, as they provide the necessary wood components and moisture that termites seek. The most noticeable damage is cracking and peeling of the stucco surface on columns and frames. This kind of damage compromises the structural integrity of walls and often appears as hollow or "empty-sounding" columns when tapped, indicating that termites have hollowed out the wooden interior. Additional signs of termite activity include circular holes in wall frames and soft, degraded wood. Termite infestation can even occur in concrete wall framing, where termites build tunnels in the wall to feed (Uzakah and Festus 2022). These infestations, if left untreated, can weaken the walls and lead to visible surface deterioration. To mitigate this risk, regular inspections and the use of more durable, termite-resistant materials are recommended for wall frames.

*Damage to the wall*

Walls infested by termites often show symptoms such as paint peeling, discoloration, cracking, and the detachment of stucco. Some walls may even develop growths of moss or mold due to moisture accumulation, which accelerates the rotting process (Uzakah and Festus 2022). These damages are compounded by the initial construction quality; poor materials and foundation shifts over time can create small cracks and voids, making it easier for termites to enter. Signs of termite infestation on walls include attached mud tunnels, hollow sounds, and soft tearing noises produced by termites feeding on cellulose in the wood. These distinct sounds and structural changes highlight the importance of using high-quality materials and preventive treatments to safeguard walls from termite damage.

*Damage to the ceiling*

Ceiling damage occurs when termites find their way into wooden beams or structures above. The main signs of termite activity on ceilings are discoloration, cracks, and eventual rot, which are often linked to rainwater seepage from a leaking roof. Termites are particularly drawn to the dark and humid conditions often found in ceilings, where moisture from seepage creates an ideal environment for nesting and feeding. Characteristics of termite infestations in ceilings include porous or curved surfaces, small debris piles from tunneling, and discarded larval wings, which are often found in accumulated clusters on the ceiling (Subekti et al. 2018a). This damage compromises the ceiling's stability and appearance. To prevent such infestations, maintaining roof integrity and sealing any gaps where moisture can enter are essential steps.

*Damage to archive*

Termites are highly attracted to paper-based materials, making archives and documents particularly vulnerable (Buczkowski and Bertelsmeier 2017). Infestations in archives often occur in storage cabinets where humidity levels are high and lighting is minimal, which suits termite preferences. The impact of termite infestations extends beyond immediate structural damage, they can also affect the integrity of archival materials. For instance, previous study on termite infestations in buildings revealed that a significant percentage of inspected houses showed signs of infestation, which could lead to severe structural damage over time (Ugbomeh and Diboyesuku 2019). Only fragments of heavily damaged documents may remain identifiable. Cabinets that house these archives are also affected, as termites feed on low-quality wood commonly used in furniture. This dual attack on both the archives and the cabinet structure can lead to quick deterioration. Preserving archival materials requires controlled humidity, proper lighting, and, ideally, storing documents in materials resistant to termite damage.

*Damage to garden area*

Termite activity in garden areas is frequently indicated by visible soil mounds or tunnels formed near tree bases and plants. Termites often establish nests in the garden soil, where the moisture and protection from direct sunlight allow colonies to flourish (Iswanto et al. 2021; Oktiarni et al. 2022; Muarrif et al. 2023). Trees with hollow sounds or thin bark when tapped are signs of internal termite damage, as colonies feed on the wood, leaving only a thin shell. To protect food sources and shelter the colony, termites construct burrows and tunnels along tree trunks or garden structures. These pathways allow termites to avoid exposure to sunlight while moving between soil and trees. Regularly checking garden plants, especially wooden garden structures, for signs of termite presence is essential for early detection and prevention of further infestations.

**Weather characteristics (temperature and humidity)**

The temperature and humidity in Jakarta Province were favorable for developing termite infestation during the study. Termites of different genus or species of the same genus can have different temperature tolerances (Yuhara et al. 2014). Nurhadi et al. (2023) stated that termites have optimal development in the 23-37.6°C temperature range. Another case by Pratiknyo et al. (2020) stated that the optimal temperature for most termites is 15-38°C, and the optimal humidity for termites is 75%-90%. Subterranean termites isolate themselves by building nests and burrows to create optimal air humidity (Richardson and Sun 2023).

Three species were found in South Jakarta and North Jakarta, namely *C. curvignathus*, *C. gestroi* and *M. gilvus. Coptotermes curvignathus* termites infested 3 sample sites in South Jakarta and 5 in North Jakarta. *C. gestroi* species infested 7 sample sites in South Jakarta and 11 in North Jakarta. Then, *M. gilvus* 1 sample site in South Jakarta and 2 sample sites in North Jakarta. Like South Jakarta and North Jakarta, West Jakarta found these species in 4, 16, and 1 sample sites, respectively. West Jakarta also has the highest distribution of termites. Fluctuations in air temperature and humidity in each city in Jakarta Province can be seen in Table 6.

**Geographical distribution of subterranean termites in Jakarta Province**

The results showed that not all sample locations obtained the same termite species. In East Jakarta, four species of subterranean termites were found, namely *C. curvignathus*, *C. gestroi*, *M. gilvus*, and *M. insperatus*. This condition aligns with the results of Arinana et al. (2016), who found the same three species, namely *C. curvignathus*, *M. gilvus*, and *M. insperatus*, in Jakarta. The species *M. insperatus* was only found in East Jakarta, namely in Duren Sawit and Pondok Gede sub-districts. Pondok Gede sub-district borders the Bekasi area where two species were found, the same as previous research, namely *C. curvignathus* and *C. gestroi* (Arinana et al. 2015), but different from the results of research by Arinana et al. (2015) which found one other species, namely *Schedorhinotermes javanicus*. *Coptotermes gestroi* and *M. gilvus* distribution was equally significant in 3 sample sites. In Central Jakarta, two species were found, *C. curvignathus* and *C. gestroi*. The distribution of *C. gestroi* in Central Jakarta was higher than that of *C. curvignathus*, found in 2 and 1 sample sites, respectively.

Three species were found in South Jakarta and North Jakarta, namely *C. curvignathus*, *C. gestroi* and *M. gilvus*. *Coptotermes curvignathus* termites infested 3 sample sites in South Jakarta and 5 in North Jakarta. *Coptotermes gestroi* species infested 7 sample sites in South Jakarta and 11 in North Jakarta. Then, *M. gilvus* 1 sample site in South Jakarta and 2 sample sites in North Jakarta. Like South Jakarta and North Jakarta, West Jakarta found these species in 4, 16, and 1 sample sites, respectively. West Jakarta also has the highest distribution of *C. gestroi* termites.

One species with a minimal geographical distribution, namely *M. insperatus*, is only found in East Jakarta in 2 locations. This is very different from the research by Arinana et al. (2016), which found the highest termite distribution in *M. insperatus* species. *M. gilvus* species were found in 7 locations spread across four municipalities in Jakarta Province. Meanwhile, the species whose geographical distribution is extensive, attacking all municipalities, are *C. curvignathus* and *C. gestroi*, where *C. curvignathus* species are found in 14 locations and the dominating subterranean termite species, *C. gestroi*, is the most common species found in 39 locations. The geographical distribution of subterranean termite species found infesting residential buildings in Jakarta Province is presented in Table 7. Through mapping using ArcGIS version 10.7, a map of the geographical distribution of residential neighborhoods in Jakarta Province infested by each subterranean termite species can be seen in Figure 10.

**Table 6.** Fluctuation of air temperature and humidity in Jakarta Province, Indonesia from September to December 2021 (BMKG 2021)

| City | September | | October | | November | | December | |
|---|---|---|---|---|---|---|---|---|
| | T (°C) | RH (%) | T (°C) | RH (%) | T (°C) | RH (%) | T (°C) | RH (%) |
| West Jakarta | 24-32 | 70-95 | 24-33 | 55-90 | 24-32 | 70-90 | 24-32 | 70-95 |
| Central Jakarta | 25-32 | 75-95 | 25-30 | 70-90 | 25-32 | 70-90 | 25-32 | 70-90 |
| South Jakarta | 24-32 | 65-95 | 24-33 | 60-95 | 24-32 | 65-95 | 24-32 | 70-95 |
| East Jakarta | 24-32 | 65-95 | 24-33 | 60-95 | 24-32 | 65-95 | 24-32 | 70-95 |
| North Jakarta | 25-32 | 75-95 | 25-30 | 70-90 | 25-32 | 70-90 | 25-32 | 70-90 |

Description: T: Temperature; RH: Relative Humidity

**Table 7.** Geographical distribution of subterranean termite species found in Jakarta Province, Indonesia

| City | Number of sample sites where termite species were found | | | |
|---|---|---|---|---|
| | *Coptotermes curvignathus* | *Coptotermes gestroi* | *Macrotermes gilvus* | *Microtermes insperatus* |
| West Jakarta | 4 | 16 | 1 | 0 |
| Central Jakarta | 1 | 2 | 0 | 0 |
| North Jakarta | 5 | 11 | 2 | 0 |
| South Jakarta | 3 | 7 | 1 | 0 |
| East Jakarta | 1 | 3 | 3 | 2 |
| Total | 14 | 39 | 7 | 2 |

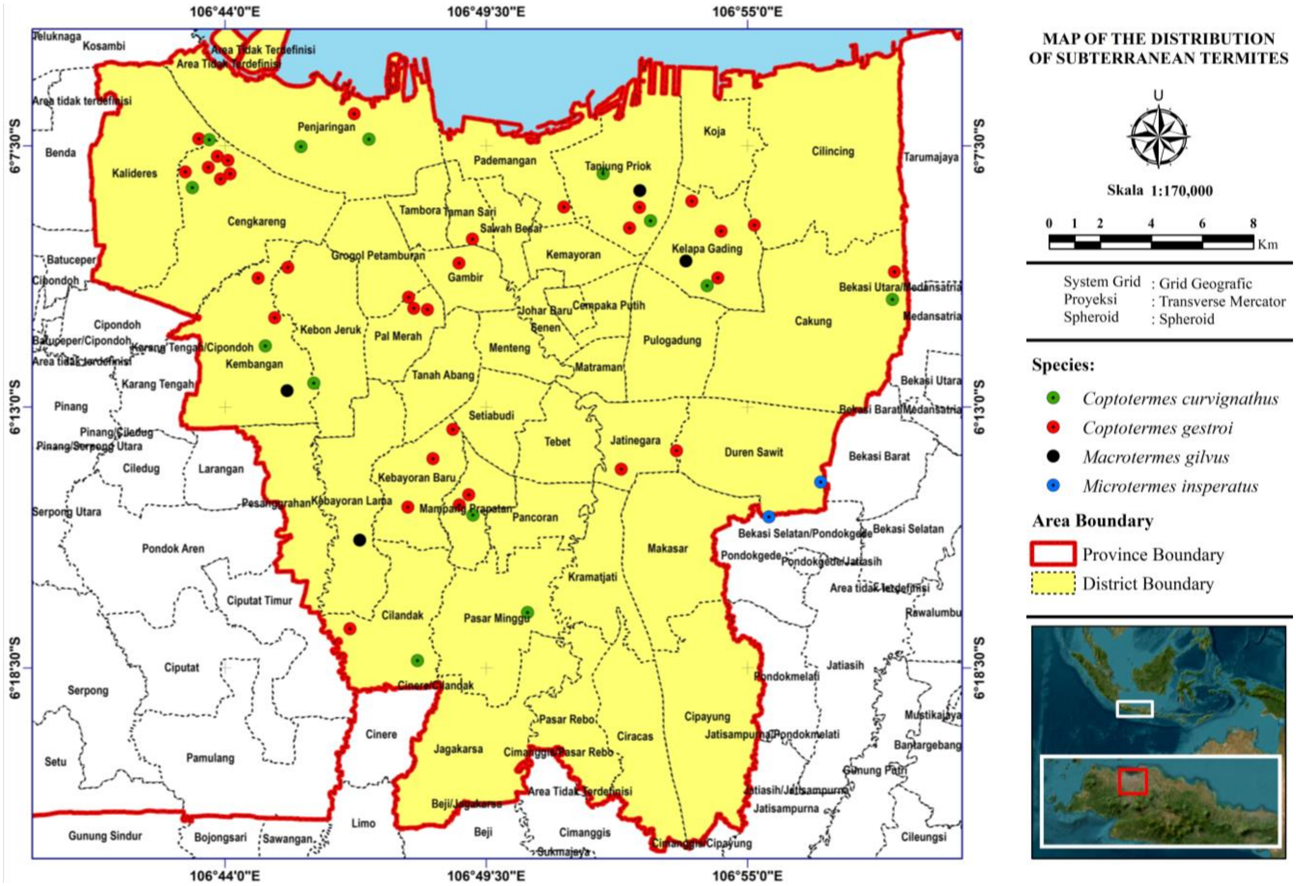



**Figure 10.** Distribution of subterranean termite-infested residential neighborhoods in Jakarta Province, Indonesia

A comprehensive survey of building damage and termite bait application monitoring conducted by PT Larusa Adi Sumindo from September to December 2021 revealed the presence of at least four subterranean termite species in Jakarta Province. These species include *C. curvignathus*, *C. gestroi*, *M. gilvus*, and *M. insperatus*.

Among these, species from the genus *Coptotermes* were the most prevalent across all surveyed areas in Jakarta Province. Not only were *Coptotermes* species the most frequently encountered termites, but they were also responsible for the majority of the damage to structures, making them the primary pest of concern for residents and property owners (Indrayani et al. 2017; Wikantyoso et al. 2021).

The damage caused by subterranean termites in Jakarta Province is widespread and affects multiple building components. Based on the survey results, the distribution of termite-related damage to house structures included foundations (3.5%), floors (26.3%), wall frames (5.3%), walls (26.3%), ceilings (33.3%), archives (42.1%), and trees in garden areas (17.5%). Notably, the frames of buildings experienced the highest level of infestation, with 49.1% of damage occurring in this structural element. This makes the frames the most vulnerable component, as they provide essential support to the building and are often composed of wood, which is highly attractive to termites.

The significant damage to ceilings (33.3%) and floors (26.3%) also highlights the pervasive nature of termite infestations. Often constructed of wooden beams and other cellulose-based materials, ceilings are prone to rapid degradation once termites gain access. Similarly, floors, particularly in older or poorly maintained buildings, offer prime feeding grounds for termites, leading to structural weaknesses that could result in expensive repairs or, in severe cases, structural collapse.

Interestingly, archives also suffered a high level of termite infestation, with 42.1% of damage observed in stored documents and records. This underscores the threat termites pose to physical structures and valuable assets like historical records, books, and other paper-based materials. The loss of archives represents a financial cost and a potential cultural and informational loss, emphasizing the need for vigilance in protecting both physical and intellectual property.

Damage to trees in garden areas (17.5%) further demonstrates that termite infestations are not limited to buildings. Trees, particularly in urban green spaces, provide both aesthetic and environmental value to city landscapes, but they are vulnerable to termite activity, which can weaken the trees' structural integrity and pose risks of falling limbs or even entire trees, thereby creating hazards in public and private spaces.

The prevalence of termite attacks across such a wide range of structural elements and materials suggests that these termites can adapt to various environments, finding food and shelter in any cellulose-rich substance (Subekti et al. 2018b; Manoppo et al. 2024). The ability of *Coptotermes* species to create extensive underground colonies allows them to infiltrate homes and buildings without immediate detection, making termite infestations difficult to manage once they have become established.

These findings provide crucial insights for developing targeted and effective termite management strategies. Understanding the most commonly attacked components of buildings, such as frames, ceilings, and archives, enables homeowners, property managers, and urban planners to implement proactive measures to prevent infestations. Regular inspections, the use of termite-resistant building materials, and the strategic application of termite baits or barriers can mitigate the damage caused by these pests.

Additionally, this data underscores the need for a broader approach to urban pest management that goes beyond individual buildings and includes the protection of green spaces, as termites can easily spread from outdoor areas to adjacent structures. Sustainable urban development in Jakarta Province and other regions must incorporate termite mitigation into planning and maintenance to ensure the long-term resilience of urban infrastructure.

The insights gained from this survey emphasize the critical importance of fostering awareness about subterranean termite threats and promoting integrated pest management solutions. By understanding the distribution and behavior of termite species, stakeholders can implement more effective mitigation tactics, ensuring not only the safety and longevity of urban structures but also the preservation of green spaces and archival materials such as targeted baiting systems, regular structural inspections, and the use of termite-resistant building materials. These tactics are particularly beneficial in urban settings, where a combination of chemical, physical, and biological controls can be integrated to address infestation challenges. Evaluation of these methods suggests that targeted baiting systems, as observed during this study, are highly effective in reducing termite activity and minimizing structural damage over time. This proactive approach is essential for sustainable urban development, ensuring that cities like Jakarta Province remain resilient against the pervasive threat of subterranean termites.

This research provides valuable insights into the distribution and prevalence of subterranean termites in Jakarta Province, identifying *C. curvignathus*, *C. gestroi*, *M. gilvus*, and *M. insperatus* as the key species responsible for infestations. It highlights the most vulnerable building components, such as structural frames, offering essential information for construction practices and pest control efforts. By pinpointing high-risk areas and commonly attacked materials, the study lays a foundation for effective termite management strategies, including regular inspections, bait systems, chemical barriers, and the use of termite-resistant materials. Additionally, the research contributes to sustainable urban development by emphasizing the integration of termite control measures into broader urban planning, protecting both infrastructure and green spaces, and ensuring long-term resilience in urban environments.

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