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INVENTORY AND ECOLOGY OF TERMITES (BLATTODEA) ATTACKING PLANTS AT KETAMBE RESEARCH STATION, MOUNT LEUSER NATIONAL PARK, SUMATRA

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ABSTRACT

This study investigates the diversity, behaviour, and ecological impact of termite species attacking plants in the Ketambe Research Station, Gunung Leuser National Park, Sumatra. Field observations revealed that termites from the genera Macrotermes, Bulbitermes, Hospitalitermes, and Nasutitermes exhibit varied foraging strategies and target living and dead plant tissues. Species such as Macrotermes malaccensis and Nasutitermes matangensis frequently infested stressed or wounded trees, indicating a preference for weakened hosts. Environmental factors such as high humidity, flooding, and plant stress increased termite activity and colonisation. While termites play a crucial role as decomposers and soil engineers, excessive attacks on live vegetation may threaten forest regeneration and biodiversity. These findings underscore the importance of monitoring termite-plant interactions to support forest ecosystem resilience and sustainable management strategies.

KEYWORDS: Termites, plant-insect interaction, tropical forest, Ketambe, ecological behaviour.

INTRODUCTION

Termites comprise over 3,000 species, classified into 12 families and 330 genera (Krishna et al., 2013; Effowe et al., 2021; Buček et al., 2021). They are widely distributed in tropical, subtropical, and savanna ecosystems (Effowe et al., 2021; Shim et al., 2021). Termites play an important role as decomposers. Their presence in forest ecosystems provides benefits by recycling organic compounds, making them a source

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of plant nutrients. The consumption of organic matter by termites positively impacts the environment by replenishing mineral nutrients in the soil through termite faeces and saliva secretions (Jouquet et al., 2011). In their natural habitats, termites also serve as a food source for various wildlife (Govorushko, 2019; Yanti et al., 2024; Iqbar et al., 2024). The presence of termites significantly affects the richness of organic elements in the soil (Effowe et al., 2021). However, termites are also known to attack living plants, which reduces their productivity (Ahmad et al., 2021). Damage caused by termites can result in the loss of plant stem surfaces and structural damage to the stems (Li et al., 2016). Common signs of termite damage include the presence of termite wings scattered in large numbers and the formation of wandering tunnels on the surface and inside plant stems (Indrayani et al., 2022; Xian & Homathevi, 2023; Gazdick et al., 2024).

Information on termite attacks on plants in tropical regions is still limited in Indonesia, especially in forests (Iqbar et al., 2023). The Ketambe Research Station in the Gunung Leuser National Park is a primary forest conservation area with rich vegetation. This area is home to orangutans, hornbills, bears, and other fauna, and its vegetation provides essential habitat and food for these species. For instance, plants like Ficus spp. and Durio zebethinus are important orangutan food sources (Djufri, 2015). The vegetation in Ketambe is still thriving, with trees that are tens to hundreds of years old, contributing to the area's high plant diversity (Yanti et al., 2024).

The presence of termites on living plants is partly due to the accumulation of dead tissue in the plant stems (Li et al., 2016). Mature plants produce significant amounts of dead tissue, a byproduct of cambium growth (Shtein et al., 2023). This dead tissue attracts termites, and their presence on living plants reduces the value of the tree (Li et al., 2016). Termite attacks on living plants in primary forests are exciting because the abundant litter and decaying wood on the forest floor should generally satisfy termite needs. Attacking living plants carries certain risks for termites, such as having to contend with the secondary compounds produced by plants to defend themselves. However, such attacks also offer benefits, including easier access to water. This study was conducted to identify the termite species and types of attacks on living plants in the Ketambe forest and assess the condition of affected plants. The findings are expected to provide valuable information for forest conservation policies, particularly in primary forest areas.

MATERIALS AND METHODS

Sampling Site: The research was conducted in July 2021 at the Ketambe Research Station, Gunung Leuser National Park, Ketambe, Southeast Aceh, Aceh (Sumatra). The station is located in a primary forest area dominated by tree-like plants. Termite sample collection was carried out by observing termite attacks on plants.

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Sample Identification: Termite sample collection was conducted using the Colony and Exploratory Survey methods (Jones & Eggleton, 2000). Exploratory surveys were performed to identify plants attacked by termites. The presence of wandering tunnels in plants was one indicator of termite activity. The termites found were collected, labelled, and placed into sample bottles containing 70% alcohol. Samples obtained in the field were transported to the laboratory for identification. Termite specimens were identified using morphological characteristics of the soldier and worker castes. The key characteristics of the soldier caste observed include the head, rostrum, mandibles, antennae, and thorax. For the worker caste, the mandibles were the primary distinguishing feature. Termite samples were identified following the methods outlined by Thapa (1981), Tho (1992), and Syaukani (2011), using a morphospecies approach and comparison with the collection in the Biosystematics Laboratory, Universitas Syiah Kuala, Indonesia.

Data Analysis: The data analysis to assess the diversity of termites attacking plants was conducted using the Shannon-Wiener Diversity Index, calculated using the following formula:

$$H = -\sum Pi LN Pi$$

H: Shannon-Wiener Diversity Index,
Pi: Relative proportion (n/N) of individuals of a specific termite species, where n is the number of colonies of one species and N is the total number of all termite colonies found.
LNPi: The natural logarithm (LN) of Pi.
The summation symbol Σ represents the sum of the values, with the final result multiplied by negative one (–1) (Omayio et al., 2019).

RESULT

Termite Diversity: The identification results showed that 10 species of termites attacked plants in Ketambe station, originating Termite Diversity. The identification results revealed ten termite species attacking plants at the Ketambe Research Station. All species belonged to the family Termitidae, with the highest species richness recorded within the subfamily Nasutitermitinae. The genus Macrotermes was the most aggressive plant attacker, responsible for seven recorded incidences (Table 1). A total of 17 termite colonies were recorded during the survey, and the calculated Shannon-Wiener diversity index was 2.05, indicating a moderate level of termite diversity affecting vegetation in the area.

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Table 1. Termite species and their associated host plants

No	Subfamily	Genus	Species	Host Plant(s) Attacked
1	Macrotermitinae	*Macrotermes*	*M. malaccensis* Haviland	*Aglaia odoratissima*, *Pterospermum javanicum*, *Litsea* sp.
2			*M. gilvus* Ahmad	*Shorea parvifolia*
3			*M. ahmadi* Tho	*Aglaia odoratissima*, *Shorea parvifolia*
4	Nasutitermitinae	*Bulbitermes*	*B. neopusillus* Snyder & Emerson	*Artocarpus gomeziana*
5			*B. constrictus* Haviland	*Mallotus* sp.
6			*B. constrictoides* Holmgren	*Quercus* sp.
7		*Hospitalitermes*	*H. hospitalis* Haviland	*Eugenia grandis*, *Shorea parvifolia*
8		*Nasutitermes*	*N. matangensis* Haviland	*Shorea parvifolia*
9			*N. havilandi*	*Shorea parvifolia*, *Bischofia javanica*
10			*N. proatripennis* Ahmad	*Shorea parvifolia*, *Pterospermum javanicum*

Morphological Descriptions

1. Macrotermes gilvus Hagen: The major soldier has a dark brown subrectangular head, with the anterior portion shorter than the posterior (Figure 1a), and a prominent labrum. The minor soldier's head is yellowish-brown and subrectangular with a rounded base and conical labrum (Figure 1b). The major soldier's head capsule exceeds 4.2 mm, while the minor soldier measures approximately 2.0 mm. Worker caste (Left mandible): The apical and first marginal teeth are nearly equal in length; the second and third marginal teeth are obscured, overlapping the molar (Figure 1j). Right mandible: The apical tooth is slightly shorter than the first marginal tooth; the anterior edge of the second tooth is short, and the molar region is slightly convex and pointed proximally (Figure 1k).

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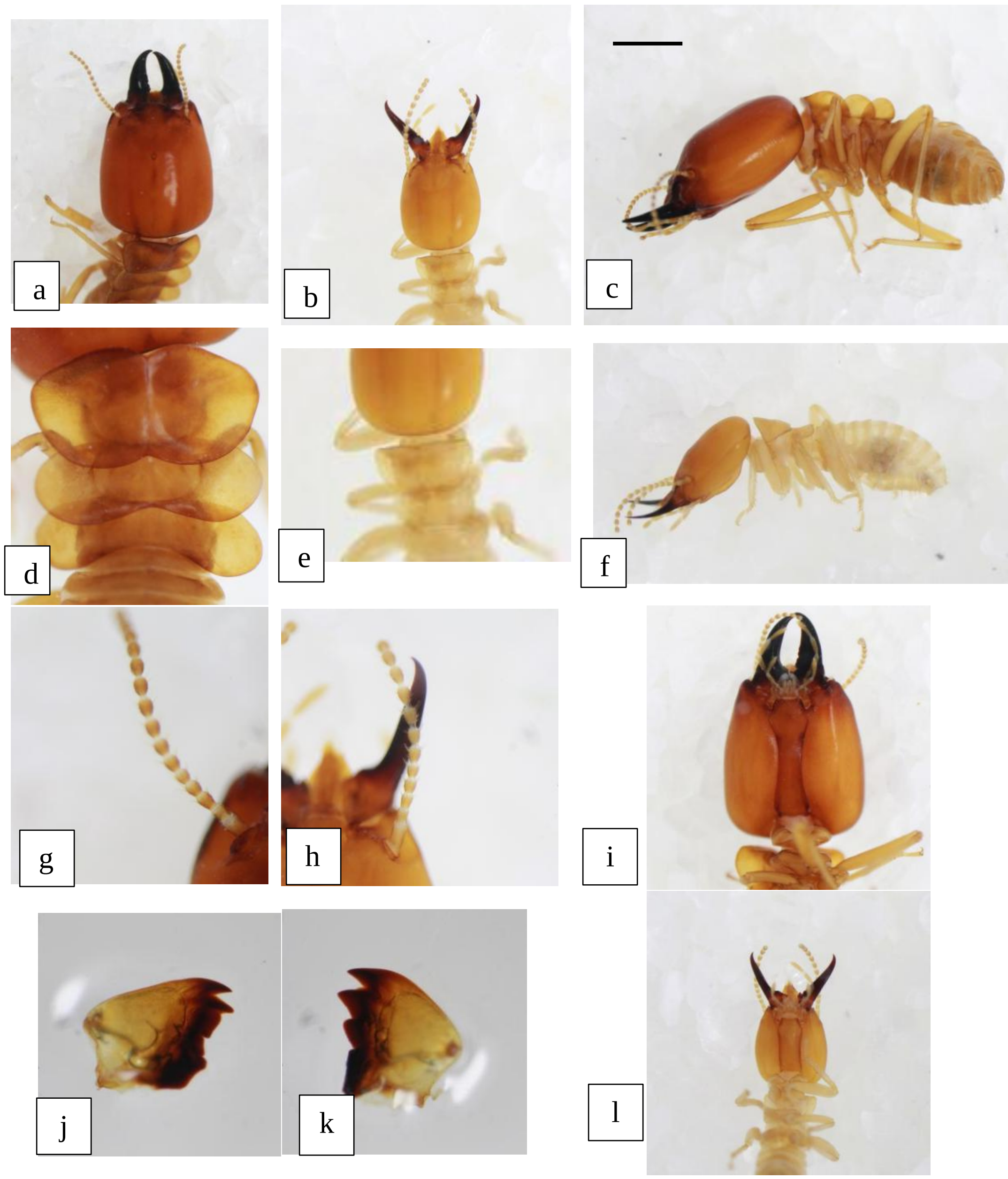

Figure 1 Morphology of soldiers (major and minor) and workers of *M. gilvus*. Major Soldiers (a,c,d,f,g, i), minor soldiers (b,e,h,l) and workers (j,k). Overall lateral view (c,f), head dorsal view (a,b), thorax dorsal view (d,e), antennae (g,h), and left (j) right worker mandible (k). Scale bar: 1 mm.

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2. Nasutitermes matangensis Haviland

Morphologically similar to N. havilandi, this species is distinguished by its 14-segmented antennae (Figure 4.5B) and a reddish-brown head capsule with a curved nasus (Figure 4.5A). The head capsule to be darker at the rostrum. This species was observed attacking the entire stem surface of Theobroma cacao (Figure 4.5C). Worker caste (Left mandible): The apical tooth is nearly equal to the first marginal; the second is absent (depressed), the third slightly protruding, and the molar depressed (Figure 2e). Right mandible: The apical and first marginal teeth are parallel; the first marginal is blunt; the second has a widened posterior edge; the molar is convex with a pointed proximal end (Figure 2f).

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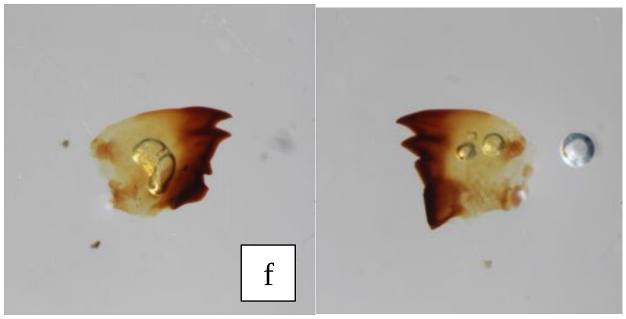
f

Figure 2 Morphology of *N. matangensis* soldiers and workers. Soldiers (a,b,c,d) and workers (e,f). Overall lateral view (a), ventral head (b), dorsal head (c), dorsal thorax (d), left worker mandible (e) right (f). Scale bar: 0.6 mm

Behavior and Attack Patterns of Termite Species in Ketambe

Macrotermes Holmgren: The first observed colony of *Macrotermes malaccensis* was found infesting *Shorea parvifolia* (Figure 3a). The infestation was severe, with visible damage on the root buttress. The compromised health of the *S. parvifolia* tree was exacerbated by the constriction from a neighboring *Ficus* species, hindering its proper growth and facilitating termite intrusion. This physical stress likely created entry points for termites to establish tunnels and nests within the trunk. *S. parvifolia* is known for its substantial stature, reaching heights up to 60 meters, with a trunk diameter exceeding one meter and a crown forming an umbrella shape. The tree also features concave buttresses that do not extend significantly up the trunk. The presence of the *Ficus* species limited the growth of *S. parvifolia,* causing injuries to parts of the buttress and making it more susceptible to termite infestation. According to Kusumawardhani (2024), termites of the *Macrotermes* genus cause significant economic losses, as they are attracted to plantation crops and wooden structures.

The same termite species was also found attacking *Litsea* sp. (Figure 3b), specifically targeting the lower part of a dead tree trunk, where the interior was filled with soil transported by termites to fortify their nest. Additionally, *M. malaccensis* was observed infesting the roots of a living *Aglaia racemosa* tree (Figure 3c).

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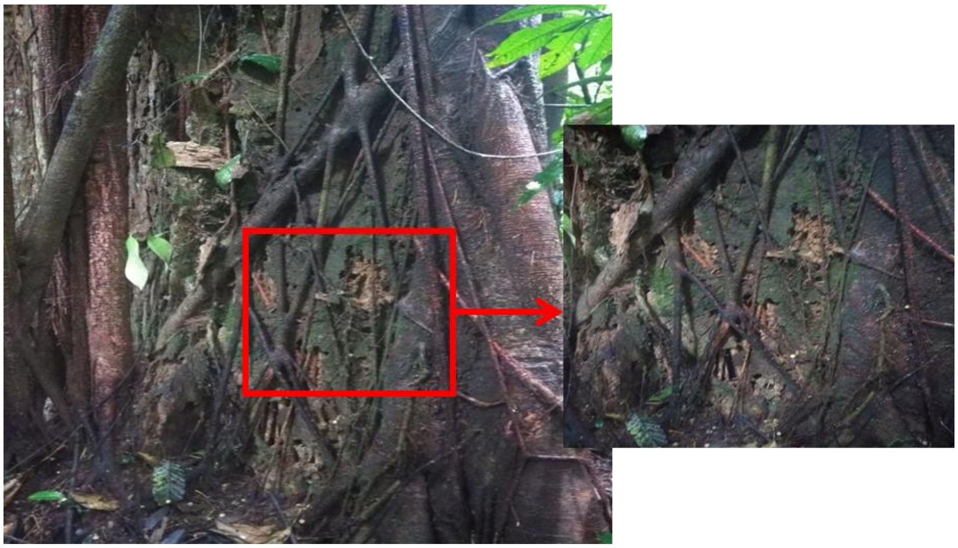

Figure 3. *M. malaccensis* attacks on the base of the *Shorea parvifolia* stem (a), the base of the *Litsea* sp. stem (b), and the roots of the *Aglaia racemosa* tree (c).

Bulbitermes Emerson: Among the *Bulbitermes* species identified, *B. neopusillus* infested a dead *Artocarpus gomeziana* (Figure 4). The entire trunk was permeated with termite tunnels, indicating extensive colonization. *Bulbitermes* species are recognised as wood-feeding termites, contributing to the decomposition of dead plant material.

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Figure 4. *B. neopusillus* infestation at the base of the *Artocarpus gomeziana* trunk.

Hospitalitermes Holmgren: *Hospitalitermes hospitalis* was observed actively foraging on the trunk of a dead *Quercus* sp. (Figure 5). This termite species consumes lichens or crustose mosses on plant stems. The worker and soldier castes of *Hospitalitermes* typically forage in groups on tree trunks, logs, and leaf litter on the forest floor.

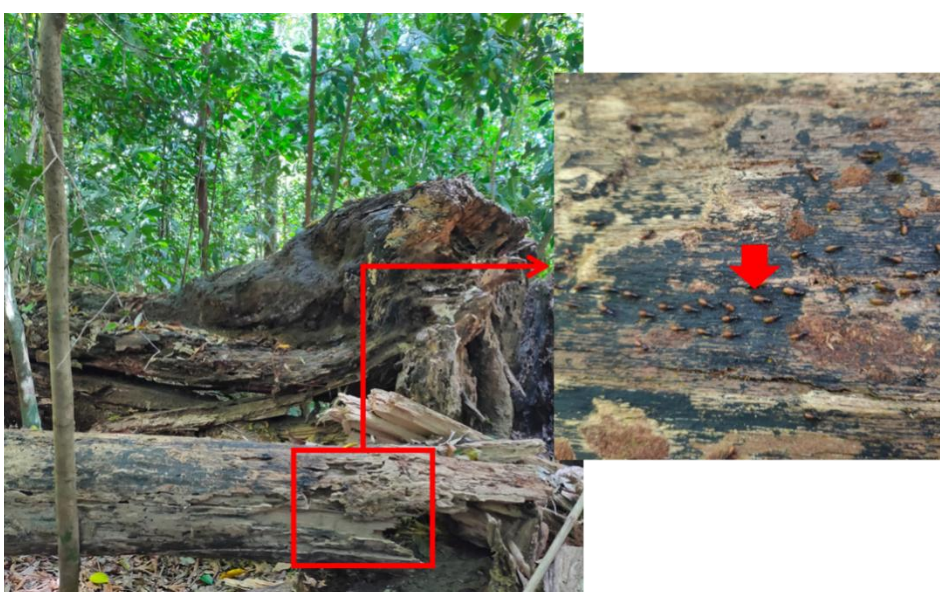

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Figure 5. *H. hospitalis* activity on a dead *Quercus* sp. tree.

Nasutitermes Dudley: Three species of *Nasutitermes* were identified, including *N. matangensis*, which infested *Ficus benjamina*. Numerous galleries were present within the tree trunk (Figure 6). *N. matangensis* is a pest species that targets buildings, books, household items containing cellulose, and plantations.

Figure 6. N. matangensis infestation of Ficus benjamina roots.

Spatial Distribution of Termite Attacks in Ketambe

Termite infestations in Ketambe were categorized based on their occurrence in living plants and dead wood.

Living Plants: *Nasutitermes havilandi* termites were attacking living *Shorea parvifolia* trees (Figure 7), with numerous galleries around the lower trunk. The infestation likely resulted from injuries to the main trunk, possibly due to breakage. These termites are potential pests that can infest both dead wood and living plants.

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Figure 7. N. havilandi attacking a shrub-like S. parvifolia tree trunk

Dead Wood: *Bulbitermes constrictoides* infested a dead *Quercus* sp. (Figure 8), with the entire trunk affected. These termites are known wood-feeders, contributing to the decomposition process.

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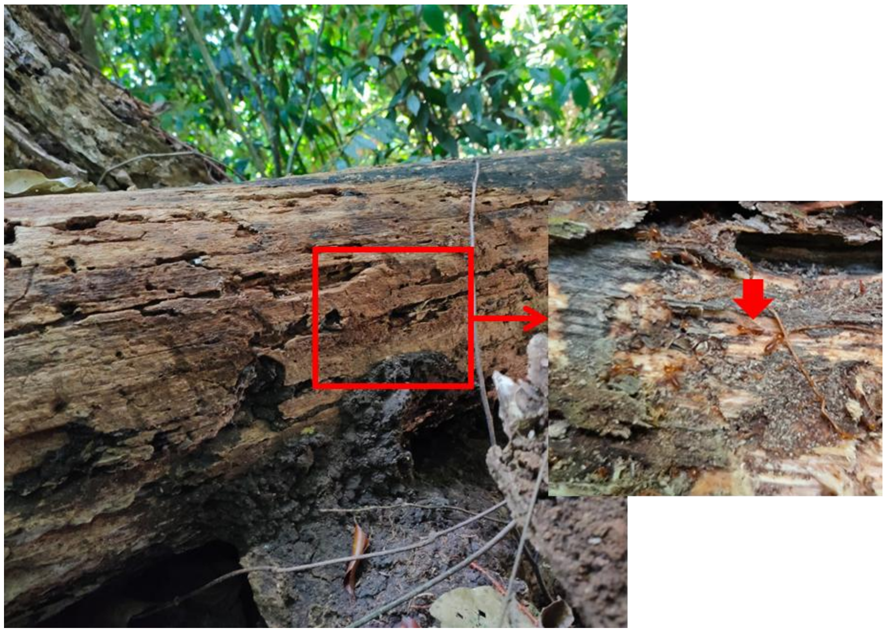

Figure 8. B. constrictoides infestation of an entire Quercus sp. trunk.

Ecological Interactions and Adaptations

The Ketambe area experiences high humidity and cool temperatures in the morning (20–21 °C) and slightly warmer temperatures in the afternoon (23–24 °C). These stable conditions influence termite behaviour; for instance, *H. hospitalis* termites forage without constructing protective tunnels.

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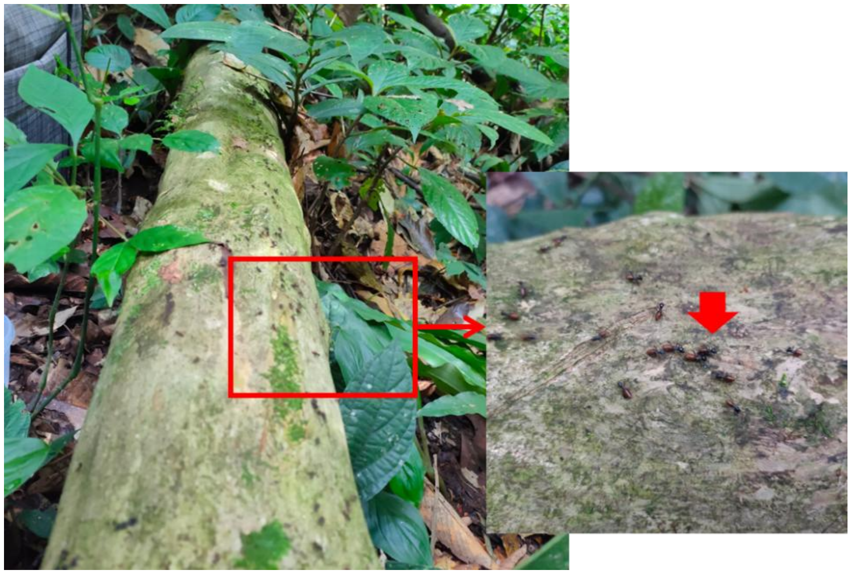

Figure 9. H. hospitalis active on a Eugenia grandis (forest guava) tree.

Adaptations are also evident in N. *proatripennis*, which prefers infesting injured plant stems (Figure 10) over waterlogged litter. Despite being a maintained forest area, Ketambe is subject to intense rainfall and upstream flooding, leading to periodic submersion. This environmental stress may drive termites to inhabit living tree trunks to avoid floodwaters.

Figure 10. *N. proatripennis* attacking the interior of a living *Pterospermum javanicum*.

DISCUSSION

The findings from the Ketambe Research Station reveal that termite infestations are highly associated with both the physiological condition of host plants and the surrounding environmental conditions. Contrary to the general perception that termites directly cause plant mortality, our observations support that termites primarily act as secondary invaders, targeting plants already weakened by biotic or abiotic stressors (Park et al., 2019; Rana et al., 2021).

Termite Preferences and Host Vulnerability

Termites were frequently found attacking trees that exhibited signs of structural weakness or damage, such as broken trunks or constriction by parasitic plants. For instance, *Shorea parvifolia* infested by *Macrotermes malaccensis* was also physically stressed due to encroachment by *Ficus* sp., which impeded its growth and injured its buttress. Such mechanical damage likely facilitated termite entry and colony establishment. Similar patterns were observed with *Nasutitermes havilandi* on *S. parvifolia*, where trunk injuries predisposed the tree to termite attack. This aligns with previous research indicating that plant wounds and stress significantly increase susceptibility to termite infestation (Xian & Homathevi, 2023).

Termites of the genera *Macrotermes*, *Bulbitermes*, and *Nasutitermes* were observed infesting both living and dead wood, though the severity and extent of colonisation varied. In particular, *Macrotermes malaccensis* could build extensive nests inside tree trunks and root systems, even in living trees like *Aglaia racemosa*. This suggests a high degree of adaptability and opportunism in their foraging strategies.

Behavioural and Environmental Interactions Species-specific foraging behaviours were evident. *Hospitalitermes hospitalis*, for instance, was frequently observed foraging in open areas on tree trunks without the protection of mud galleries, likely facilitated by the region's stable and humid microclimate. These termites are known to feed on lichens and crustose mosses (Kawagoe et al., 2022), and their activity during both morning and afternoon hours is supported by the consistently high humidity levels in Ketambe (95–100%).

The tendency of *Nasutitermes proatripennis* to inhabit the stems of living trees rather than leaf litter may reflect an adaptation to avoid waterlogged conditions during frequent flooding. Ketambe experiences significant hydrological stress, despite being a protected forest, due to intense rainfall and upstream runoff. Such environmental pressures can force termite species to relocate to more stable microhabitats such as standing tree trunks, especially during flood events.

Ecological Implications

The presence of termites in forest ecosystems plays a crucial ecological role as decomposers, accelerating the breakdown of organic matter and contributing to nutrient cycling (Effowe et al., 2021). Termite

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tunnelling activities improve soil aeration, enhance water infiltration, and increase carbon flux, enriching the forest floor and supporting plant regeneration.

However, as observed in this study, excessive termite attacks on living plants may negatively affect forest dynamics. Heavy infestations may reduce fruit production and limit seed dispersal, indirectly affecting frugivorous wildlife and overall ecosystem resilience. This emphasises the need to continuously monitor termite activity, especially in regions susceptible to environmental fluctuations and anthropogenic disturbances.

CONCLUSION

This study reveals the termite species' diversity and ecological roles in Ketambe, highlighting their varied foraging behaviours and preferences for living and dead plant materials. Termites such as *Macrotermes malaccensis*, *Bulbitermes neopusillus*, and *Nasutitermes matangensis* were frequently associated with stressed or damaged trees, indicating their opportunistic behaviour in response to host vulnerability and environmental conditions. High humidity and frequent flooding influence termite activity, with some species adapting by colonizing living plant tissues for shelter and food. While termites are key decomposers contributing to nutrient cycling and soil aeration, their shift toward attacking live plants can disrupt forest regeneration and reduce plant productivity. Overall, termite activity in Ketambe reflects a dynamic balance between ecological benefit and potential plant damage, emphasising the need for continued monitoring to support forest health and biodiversity conservation.

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REFERENCES

Ahmad, F., Fouad, H., Liang, S. Y., Hu, Y., & Mo, J. C. (2021). Termites and Chinese agricultural system: applications and advances in integrated termite management and chemical control. *Insect science*, 28(1), 2-20.

Arumugam, N., & Suganthi, A. (2020). Termite Fauna of Sungai Kangkawat, Imbak Canyon Conservation Area (ICCA), Sabah. *Journal of Tropical Biology and Conservation*.

Buček, A., Wang, M., Šobotník, J., Sillam-Dussès, D., Mizumoto, N., Stiblík, P., ... & Bourguignon, T. (2021). Transoceanic voyages of drywood termites (Isoptera: Kalotermitidae) inferred from extant and extinct species. *bioRxiv*, 2021-09.

Djufri, D. (2015, October). Leuser Ecosystem of Aceh Province as a natural laboratory for the study of biodiversity to find the raw materials of drugs. *In Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia* (Vol. 1, No. 7, pp. 1543-1552).

Effowe, T. Q., Kasseney, B. D., Ndiaye, A. B., Bassan, B. S., Amevoin, K., & Glitho, I. A. (2021). Termites' diversity in a protected park of the northern Sudanian savanna of Togo (West Africa). *Nature conservation*, 43, 79.

Gazdick, K., Lee, S. B., Mizumoto, N., Chouvenc, T., & Su, N. Y. (2024). Subterranean termites (*Coptotermes formosanus* [Blattodea: Rhinotermitidae]) colonies can readily intercept commercial inground bait stations placed at label-prescribed distance. *Journal of Economic Entomology*, 259.

Govorushko, S. (2019). Economic and ecological importance of termites: A global review. *Entomological Science*, 22(1), 21-35.

Heriza, S., Buchori, D., Harahap, I. S., & Maryana, N. (2021). Response of termite communities to natural forest conversion. *Biodiversitas Journal of Biological Diversity*, 22(11).

Indrayani, Y., Setyawati, D., Maryani, Y., & Simangunsong, B. (2022, February). A termite attack on rubber plantation on peat soil: Level of damage and identification of pest species. In IOP Conference Series: *Earth and Environmental Science* (Vol. 976, No. 1, p. 012006).

Irina, S. (2024). Seasonal Dynamic of Termite Foraging (Isoptera) In Cat Tien National Park (South Vietnam). *Journal of Tropical Science and Engineering*, (32), 3-11.

Iqbar, I., Djufri, Darusman, Rahmadani, Anjelia, V., Bessania, M. A & Syaukani. (2023, November). Termite attack on succession forest plants at Soraya Research Station, Leuser Ecosystem, Sumatra. In 2024 Frontier in Sustainable *Agromaritime and Environmental Development Conference* (pp. 10-05).

Iqbar, I., Safriana, R., & Fauziah, F. (2024). Feeding behavior and diet preferences of Sumatran orangutans (Pongo abelii Lesson 1827) at Soraya Research Station, Mount Leuser National Park, Indonesia. *Biodiversitas Journal of Biological Diversity*, 25(4).

Jones, D. T., & Eggleton, P. (2000). Sampling termite assemblages in tropical forests: testing a rapid biodiversity assessment protocol. *Journal of applied Ecology*, 37(1), 191-203.

Jouquet, P., Traoré, S., Choosai, C., Hartmann, C., & Bignell, D. (2011). Influence of termites on ecosystem functioning. Ecosystem services provided by termites. *European Journal of Soil Biology*, 47(4), 215-222.

Kawagoe, H., Itioka, T., Hyodo, F., Iku, A., Shimizu-kaya, U., & Meleng, P. (2022). Evidence in stable isotope ratios for lichen-feeding by Lithosiini moths from a tropical rainforest but not from a temperate forest. *Entomological Science*, 25(3), e12519

Krishna, K., David, A., G., Valerie, K., & Michael, S., E. (2013). Treatise on The Isoptera of The World. Bulletin Of The American Museum Of Natural History, Amerika.

Kusumawardhani, D. T., & Almulqu, A. A. (2024). A Review of Termite for Sustainable Green Building. *Al-Hayat: Journal of Biology and Applied Biology*, 7(1), 57-70.

Li, H. F., Yeh, H. T., Chiu, C. I., Kuo, C. Y., & Tsai, M. J. (2016). Vertical distribution of termites on trees in two forest landscapes in Taiwan. *Environmental Entomology*, 45(3), 577-581.

Neoh, K. B., & Lee, C. Y. (2009). Flight activity of two sympatric termite species, *Macrotermes gilvus* and Macrotermes carbonarius (Termitidae: Macrotermitinae). *Environmental entomology*, 38(6), 1697-1706.

Novita, N., Amiruddin, H., Ibrahim, H., Jamil, T. M., Syaukani, S., Oguri, E., & Eguchi, K. (2020). Investigation of termite attack on cultural heritage buildings: A case study in Aceh Province, Indonesia. *Insects*, *11*(6), 385.

Omayio, D., Mzungu, E., & Kakamega, K. (2019). Modification of shannon-wiener diversity index towards quantitative estimation of environmental wellness and biodiversity levels under a non-comparative Scenario. *Journal of Environment and Earth Science*, 9(9), 46-57.

Park, J. S., Husseneder, C., & Schlub, R. L. (2019). Morphological and molecular species identification of termites attacking Ironwood trees, *Casuarina equisetifolia* (Fagales: Casuarinaceae), in Guam. *Journal of Economic Entomology*, 112(4), 1902-1911.

Prayoga, R., Indriyanto, I., & Riniarti, M. (2019). Pola distribusi jenis meranti (Shorea spp.) di Resort Pemerihan Taman Nasional Bukit Barisan Selatan. *Jurnal Hutan Tropis*, 7(2), 225-232.

Rana, A., Chandel, R. S., Verma, K. S., & Joshi, M. J. (2021). Termites in important crops and their management. *Indian Journal of Entomology* 83.

Shim, J., Park, H., Ju, H. J., & Song, J. H. (2021). First record of the termite family Kalotermitidae (Blattodea: Termitoidae) in Korea. *Journal of Asia-Pacific Entomology*, 24(4), 1266-1269.

Subekti, N., & Milanio, R. R. (2023). Termite diversity and abundance based on altitude in Mount Ungaran, Central Java, Indonesia. *Biodiversitas Journal of Biological Diversity*, *24*(6).

Shtein, I., Gričar, J., Lev-Yadun, S., Oskolski, A., Pace, M. R., Rosell, J. A., & Crivellaro, A. (2023). Priorities for bark anatomical research: study venues and open questions. *Plants*, 12(10), 1985.

Syaukani. (2011). A Guide to the Nasustermites (Nasutitermitinae, Termitidae) of Kerinci Seblat National Park, Sumatra, Tokyo, NEF-Tokyo, Kagoshima University-Japan, Syiah Kuala University-Indonesia.

Thapa RS. (1981). Termites of Sabah. Sabah Forest Record 12, 1981.

Tho, Y., P. (1992). Termites of Peninsular Malaysia. Malayan Forest Record No.36. Forest Research Institute Malaysia, Malaysia.

Xian, G. W., & Homathevi, R. (2023). Termite Composition and Activities in Altered Landscape: A Case Study from Universiti Malaysia Sabah, Kota Kinabalu, Sabah. *In 5th International Symposium on Insects* (ISoI 2023) (p. 12).

Yanti, L. A., Moulana, R., Limbong, B. B., Syafruddin, S., Iqbar, I., Siregar, A. W., ... & Rasyid, U. A. (2024, February). Identification of food type and feeding behavior of sumatran orangutans (Pongo abelii) at the Ketambe Research Station in Gunung Leuser National Park. *In IOP Conference Series: Earth and Environmental Science* (Vol. 1297, No. 1, p. 012096). IOP Publishing.