Survey and morphological identification of termites (Insecta: Isoptera) in Teaching Forest of Hasanuddin University, Indonesia

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Abstract This study aimed to observe and identify of Coptotermes species based on morphological characteristics. Termites survey was conducted on Teaching Forest of Hasanuddin University, South Sulawesi area Indonesia with the elevation range 406-628 meter asl; specimens collected used the standardized transect sampling protocols at four different landscapes (natural forest, Swietenia mahagony plantation, Acacia mangium plantation, and Pinus merkusii forest. Observation, and measurement of nine morphological characters of soldier was conducted, i.e: head length without mandibles, head width at the base of mandibles, maximum width of head, left mandible length, number of antennal segments, pronotum length, maximum width of pronotum, postmentum length, and maximum width of postmentum; also three indices were calculated, i.e., hHW/mHW, MHW/HL, LML/HL. The results showed that there are nine species found based on the morphological characteristics and morphometrical data, namely: Odontotermes sp.1, Odontotermes sp. 2, Odontotermes sp.3, Coptotermes curvignathus, Nasutitermes sp., Schedorhinotermes sp. Microcerotermes serrula, Bulbitermes sp., dan Havilanditermes sp.

1. Introduction
Termite (order: Isoptera) play the critical role in the ecosystem, such as decomposers of organic matters into nutrients [1-3], modifying the physical and chemical properties of the soil, maintaining a balance of carbon and nitrogen cycles, and increasing the microbial activity [4]. Among the 3,106 species that have been described [5], there are 10% found in Indonesia, and about five percent are harmful as a pest for the most crops and plantations [6].

Termites are spread naturally in tropical and subtropical regions [7], but their distribution now tends to expand to temperate regions with the boundaries of 50° North and 50° South in Latitude. In tropical regions termites are found from the coast to a height of 3,000 m above sea level [8]. The highest diversity and abundance of termites occurs in the rainforests of Africa, South America and Southeast Asia [9]. Termite surveys carried out in two primary forest habitats at the height of 1,000 meters in Maliau Basin (Malaysia) showed the same species richness and abundance of wood-feeding termites found in both forest types, namely low mountain forests and forests high mountains with dwarf plants; whereas in termites that forage in soil (soil-dwelling termites; soil-feeding thermites) are more common in low mountain forests [10]. Also, the gradient of intensification of land use in lowland rainforests in Jambi Province was also found to have an impact on the decline of termite species wealth [11]. The results of the study by [12] on termite Coptotermes in the South Sulawesi region showed that the highest relative abundance was found in areas in the southern region that have a flatter and warmer regions than those
in low latitudes are highland areas north of South Sulawesi) with relatively lower temperatures. This condition was also stated by [13] that high termite abundance was found in warmer regions and lower altitude places. Another thing that also determines the abundance of termites is the period of collecting specimens that affect the period of termite appearance on the surface of the soil [12].

Geographically and ecologically, South Sulawesi position is strongly suitable for the proliferation of termites. As a consequence of its position in the Wallacea area that located in the Sunda shelf (Wallacea line) and Sahul shelf (Weber line), this region has the potential to endemic fauna species, including isopteran. The lack of information about the species of termites and the financial losses due to termite attack had become a problem for controlling it. To control the target species of *Coptotermes* environmentally friendly with less or no synthetic chemicals, the information aspects of termite biology was needed. Therefore, survey and identification of species based on morphological characteristics of *Coptotermes* soldier spread in South Sulawesi Indonesia was conducted.

2. Materials and Methods

2.1. Study Sites

Four different landscapes at Teaching Forest of Hasanuddin University, South Sulawesi Province (Figure 1.) were studied, each sites representing distinct habitats. The four sites are a natural forest, mahagony (*Swietenia mahagony*) plantation, acacia (*Acacia mangium*) plantation, and pine (*Pinus merkusii*) forest. All sites have the same soil type (Dysropepets). The natural forest was located at 120°2’23.58” E, 5°31’37.74” S with 502 meter asl in elevation; the mahagony plantation was located at 120°4’14.85” E, 5°29’57.79” S with 406 meter asl in elevation; the acacia plantation was located 120°2’12.89” E, 5°30’33.16” S with 628 meter asl in elevation; and pine forest was located at 120°1’34.52” E, 5°34’11.68” S with 569 meter asl in elevation. Temperature and relative humidity range between 26,-28°C and 89-95%. Two transects was run in each site.

2.2. Termite Survey

The object observed in this study was termites from Teaching Forest, with the collected samples or specimens using the standardized transect sampling protocols. The location discovery of termite specimens was also taken the geographical coordinates using a GPS receiver for mapping the distribution of specimen sites. The specimens must represent all castes of the colony, namely reproduction (alates), workers, soldiers, nymphs and imago.

2.3. The standardized Transect Sampling Method

The standardized transect method described by [14] was used for sampling termites. A belt transect was 100 m long and 2 m wide, and divided into 20 contiguous sections (each 5 × 2 m) and numbered sequentially. In each section, two collectors searched termites for 30 min (a total of 1 h of collecting per section) and the following microhabitats, which are common sites for termites: 12 samples of surface soil (each about 12×12 cm, to 10 cm depth); accumulations of litter and hummus at the base of trees and between buttress roots; the inside of dead logs, tree stumps, branches and twigs; the soil within and beneath very rotten logs; all subterranean nests, mounds, carton sheeting and runways on vegetation, and arboreal nests up to a height of 2 m above ground level. The collector can use their experience and judgment during searching termites and recording sample in each section. Specimens from each termite population encountered were sampled. All castes were collected if present, but the priority was given to findings soldiers and workers. Termites were placed and preserved in vials filled with 70% ethanol and numbered with the appropriate location of termite discovery.
Figure 1. Geographic position of transect sampling at Teaching Forest of Hasanuddin University

2.4 Determination of termite species
Termite species were identified based on the key determinants of soldier [15, 16]. Each of the collected specimens was separately put in a bottle containing 70% ethanol. Soldiers were observed and measured for their morphological characters under a microscope stereomicroscope STEMI 2000 with phototube camera ERC 5S (Olympus, USA). The measurement technique was based on previous descriptions by [15].

3. Results and Discussions
Observations on the external anatomy of termite specimens in the laboratory showed the existence of nine species, which are joined in two families (Termitidae and Rhinotermitidae), sub-families (Macrotermitinae, Termitidae, Rhinotermitidae, Coptotermitinae, Nasutitermitinae), and six genera (Odontotermes, Microcerotermes, Schedorhinotermes, Nasutitermes, Coptotermes, Bulbitermes, and Havilanditermes). To see the morphological characteristics and morphometric measurements of each species of termite that is found are described as follows:

3.1. Genus Odontotermes
The genus Odontotermes belongs to the family Termitidae with subfamily Macrotermitinae. In this study, there were 3 (three) types of Odontotermes, namely Odontotermes sp.1, Odontotermes sp.2, and Odontotermes sp.3.

Odontotermes sp.1
This species was a small-sized termite, which is covered in all sites. Diagnosis, measurements, and distribution of the soldier of Odontotermes sp.1 (figure 2) were described as follows:
Diagnosis: Odontotermes sp.1 has the characteristics of a light brown head, oval-shaped, there are marginal teeth on the mandible left, the index value of LKDM/LMK range from 0.62-0.66, the index
value of LMK/PKTM range from 0.74-0.77 and an index value of PMK/PKTM range from 0.56-0.72. The number of antennas is 17 segments.

Figure 2. Soldier of *Odontotermes* sp.1: (a) body, (b) head, dorsal view; (c) left mandible, (d) postmentum, (e) pronotum

*Measurements (mm):* HL: 1.55-1.80, mHW: 1.22-1.36, bHW: 0.76-0.78; PosL: 1.07-1.43, mPosW: 0.52-0.75; PL: 0.81-1.13; PW: 0.50-0.66; LML: 0.96-1.17.

*Habitats:* This species is found in natural forests, and mahogany stands in living trees, dead wood, litter, and takes up the inside of the wood.

*Odontotermes* sp. 2

This species was a big-sized termite, which is covered in all sites. Diagnosis, measurements, and distribution of the soldier of *Odontotermes* sp.2 (figure 3) were described as follows:

**Diagnosis:** *Odontotermes* sp.2 has the characteristics of a black, brown head, oval-shaped, there are marginal teeth on the mandible left, the index value of LKDM/LMK range from 0.59-0.77, the index value of LMK/PKTM range from 0.75-0.84 and an index value of PMK/PKTM range from 0.44-0.67. The number of antennas is 17 segments.

Figure 3. Soldier of *Odontotermes* sp.2: (a) body, (b) head, dorsal view; (c) left mandible, (d) postmentum, (e) pronotum

*Measurements (mm):* HL: 2.11-2.50, mHW: 1.66-1.99, bHW: 1.11-1.32; PostL: 1.35-1.46, PosW: 0.50-0.76; PL: 1.19-1.49, PW: 0.43-0.88; LML: 1.01-1.56.

*Habitats:* This species is found widely spread in acacia stands, mahogany stands, and natural forests. These termites attack living trees, many nesting on dead-wood and decayed wood.

*Odontotermes* sp.3

This species was a medium-sized termite, which is covered in all sites. Diagnosis, measurements, and distribution of the soldier of *Odontotermes* sp.1 (Figure 4) were described as follows:

**Diagnosis:** *Odontotermes* sp.3 has the characteristics of a dark brown head, oval-shaped, there are marginal teeth on the mandible left, the index value of LKDM/LMK range from 0.59-0.72, the index value of LMK/PKTM range from 0.72-0.80 and an index value of PMK/PKTM range from 0.44-0.67. The number of antennas is 17 segments.
Figure 4. Soldier of *Odontotermes* sp.3: (a) body, (b) head, dorsal view; (c) left mandible, (d) postmentum, (e) pronotum

Measurements (mm): HL: 1.72-2.19, mHW: 1.28-1.73, bHW: 0.83-1.17; PosL: 1.09-1.40, PostW: 0.50-0.68; PL: 0.79-1.32, PW: 0.44-0.62; LML: 1.02-1.35.

Habitats: This species is found widely spread in acacia trees, mahogany stands and natural forests, many of these termites nest on living trees, dead wood and already decayed.

3.2. Genus *Nasutitermes*

Species of Nasutitermes sp. belonging to the family Termitidae with subfamily Nasutitermitinae. Diagnosis, measurements, and distribution of the soldier of *Nasutitermes* sp. (Figure 5) was described as follows:

**Diagnosis:** This species has the characteristics of nasut in head anterior and pointed, dark in color, have a very small mandible, the index value of LKDM/LMK range from 0.50-0.75, the index value of LMK/PKTM range from 0.60-0.77. The number of antennas is 13 segments.

Figure 5. Soldier of *Nasutitermes* sp.3: (a) body, (b) head, dorsal view; (c) left mandible, (d) postmentum, (e) pronotum

Measurements (mm): HL: 1.30-1.69, mHW: 0.86-0.12; PosL: 0.22-0.40, PosW: 0.13-0.32; PL: 0.40-0.58, PW: 0.12-0.25.

**Habitats:** *Nasutitermes* sp. is only found in mahogany stands that nest on mahogany trees, *Arytera* sp., and dead wood.

Genus *Coptotermes*

The species found is *Coptotermes curvignathus*, belonging to the Rhinotermitidae with subfamily Coptotermitinae. This species is invasive pest found to damage the building wood. Diagnosis, measurements, and distribution of the soldier of *Coptotermes curvignathus* (Figure 6) were described as follows:

**Diagnosis:** The characteristic possessed by these termites is a large fontanel on the head, an oval head, and a yellowish color. The index value of LKDM/LMK range from 0.57-0.69, the index value of LMK/PKTM range from 0.78-0.90 and index value of PMK/PKTM range from 0.59-0.87. The number of antennas range from 14-16 segments.
Figure 6. Soldier of *Nasutitermes* sp.3: (a) body, (b) head, dorsal view; (c) left mandible, (d) postmentum, (e) pronotum

*Measurements (mm)*: HL: 1.47-1.72, mHW: 1.18-1.42, bHW: 0.71-0.83; PosL: 0.88-1.04, PosW: 0.35-0.44; PL: 0.50-0.63, 0.44-0.62 mm. Panjang mandible Kiri 1.26-0.96 mm.

*Habitats*: These termites are found in pine trees, have nests in the ground that are connected to the trees they attack. This type of termite has a characteristic that the warrior caste will emit milky white liquid as a reaction to maintain the colony from enemy interference.

**Genus Schedorhinotermes**

The species found is *Schedorhinotermes* sp., belonging to the Rhinotermitidae with subfamily Rhinotermitidae. Diagnosis, measurements, and distribution of the soldier of *Schedorhinotermes* were described as follows:

*Diagnosis*: type of *Schedorhinotermes* sp. has the characteristics of a light yellow head; there is a fontanel on the head. This type of soldier is dimorphic, which means that it has 2 (two) types of soldiers, namely a larger major soldier and a small minor soldier, as can be seen in Figure 14. Major soldier: LKDM / LMK index value between 0.57-0.73, LMK / PKTM index 0.91-0.97 and PMK / PKTM index 0.59-0.77. And has an antenna number of 11-17 segments, both curved mandibles, and have marginal teeth that are very prominent on the mandible. Minor soldier: and antennas between 13-16 segments, narrowed and mandible heads are leaner, have long labrums almost parallel to mandibles, have LKDM / LMK index values between 0.67-0.73, LMK / PKTM index 0.84- 0.95 and PMK / PKTM index 0.42-0.67. The major and minor soldier's morphology from *Schedorhinotermes* sp can be seen in Figures 14 and 15.

Figure 7. Mayor soldier of *Schedorhinotermes*: (a) body, (b) head, dorsal view; (c) left mandible, (d) postmentum, (e) pronotum
Figure 8. Minor Soldier of *Schedorhinotermes*: (a) body, (b) head, dorsal view; (c) left mandible, (d) postmentum, (e) pronotum

*Measurements (mm):* Mayor soldier - HL: 1.21-1.42, mHW: 1.15-1.32, bHW: 0.69-0.75; PosL: 0.62-0.74, PosW: 0.34-0.35; PL: 0.68-0.75, PW: 0.4-0.47; LML: 0.72-0.95. Minor soldier – HL: 0.75-0.85, mHW: 0.63-0.70, bHW: 0.42-0.44; PosL: 0.42-0.48, PostW: 0.23-0.26; PL: 0.44-0.46, PW: 0.32-0.34; LML: 0.48-0.60.

*Habitats:* *Schedorhinotermes* sp. were found in 3 stands, that is, in natural forests with only one colony, whereas in mahogany stands there were 3 (three) colonies on different trees and more were found in pine stands, namely 6 (six) colonies. However, after observation and identification, the *Schedorhinotermes* termites in the three stands have the same characteristics, shapes, and sizes, so that they are grouped into one type of *Schedorhinotermes* sp. These termites attack materials above the ground because they always have tunnels made of soil, which functions to connect the nest with the object it attacks.

**Genus Microcerotermes**

*Microcerotermes serrula* is belonging to family Termitidae with subfamily Macrotermiteinae. Diagnosis, measurements, and distribution of the soldier of *Microcerotermes serrula* (Figure 2) was described as follows:

*Diagnosis:* This termite is easily recognized because it has a rectangular capsule head, light brown, both mandibles thick and jagged. The LKDM / LMK index value is 0.67-0.73, the LMK / PKTM index is 0.84-0.95 and the PMK / PKTM index is 0.42-0.67; has 13 segment antenna numbers.

Figure 9. Soldier of *Microcerotermes serrula*: (a) body, (b) head, dorsal view; (c) left mandible, (d) postmentum, (e) pronotum

*Measurements (mm):* HL: 1.51-2.09, mHW: 1.83-1.03, bHW: 0.53-0.83; PostL: 0.81-1.05, PosW: 0.26-0.38; PL: 0.35-0.67, PW: 0.24-0.63; LML: 0.67-1.02.

*Habitats:* *Microcerotermes serrula* are found in all types of forests, both in living trees and in dead wood. These termites make nests at the base of trees and tree branches. The type of *Microcerotermes serrula* is more widely distributed in natural forests; this is because there are more organic materials.
available in the forest. This type of termite can live in the lowlands, secondary forests, plantations, around settlements, many found in rubber gardens and make nests on trees as suggested by Tho (1992).

**Genus Bulbitermes**

This species is belonging to family Termitidae with subfamily Nasutitermitidae. Diagnosis, measurements, and distribution of the soldier of *Bulbitermes* sp. (Figure 10) was described as follows:

**Diagnosis**: *Bulbitermes* sp. has a dark brown color, has nasut on the front of the head, a pear-shaped head notched in the middle and has very small and pointed mandibles. The index value of LKDM/LMK ranges from 0.52-0.71 and index value of LMK/PKTM range from 0.56-0.73.

**Measurements** (mm): HL: 1.10-1.54, mHW: 0.63-0.93, bHW: 0.36-0.69; PostL: 0.26-0.37, PosW: 0.18-0.27; PL: 0.21-0.53, PW: 0.16-0.20 mm.

**Habitats**: This type of termite is found in natural forests and mahogany stands, in weathered wood, in soil and trees that are still alive.

**Genus Havilanditermes**

*Havilanditermes* sp. is belonging to family Termitidae with subfamily Nasutitermitinae. Diagnosis, measurements, and distribution of the soldier of *Havilanditermes* sp. (Figure 2) was described as follows:

**Diagnosis**: These termites have the characteristics of light brown, round head, have a long nasut on the head, one of the apical shaped mandibles. The LKDM / LMK index value is between 0.52-0.64, and the LMK / PKTM index is 0.57-0.75.

**Measurements** (mm): HL: 1.58-2.14, mHW: 1.22-1.31, bHW: 0.69-0.82; PostL: 0.24-0.38, PW: 0.22-0.32; PL: 0.54-0.60 and PW: 0.16-0.21.

**Habitats**: Termites *Havilanditermes* sp. only found in natural forests on lento-lento trees.
4. Discussions
The determination of species based on morphological characteristics was very difficult in termites, including on genus Coptotermes, due to the high variability of the size. In some publications, the morphometric data of the same species also found a very diverse variety of sizes, from one region to another within a country as well as between countries [8, 15-17]. The similar case was also experienced by [8] in distinguishing the species of Coptotermes from several regions in Indonesia.

Observation and measurement of environmental conditions in the field shortly before taking the specimens showed a temperature range of 26.5-28 °C, humidity of 89-95%, and moist soil conditions. The condition of the location of this study is very suitable for the development of termites. This is by what was stated by [8] that the optimal temperature range for the development of termites is 15-38 °C and optimal humidity is 95–98%. But there are other factors that influence the development of life and termite activity, namely habitat, diversity of vegetation, and litter which is a food source for the survival of termites.

In this study, nine species were found, included by two families (Termitidae and Rhinotermitidae), five sub-families (Macrotermitinae, Termitinae, Rhinotermitidae, Coptotermitinae, Nasutitermitinae), and six genera (Odontotermes, Microcerotermes, Schedorhinotermes, Nasutitermes, Coptotermes, Bulbitermes and Havilanditermes). The Termitidae family belongs to a high-level termite group characterized by the absence of protozoa but only bacteria. The Rhinotermitidae family is a member of the low-level termite group characterized by protozoa in the back intestine, which helps digest cellulose. According to [19] termites, Coptotermes curvignathus and Schedorhinotermes sp. including group I. This group eats wood and grass and has a relatively simple intestine. This group is represented by all families of lower termites (Mastotermitidae, Kalotermitidae, Rhinotermitidae, and Serritermitidae). Types of Odontotermes sp.1; Odontotermes sp.2, Odontotermes sp.3, Microcerotermes serrula, Bulbitermes sp. and Havilanditermes sp. including group feeding II. This group eats wood, grass, leaf litter, and mikroepifit, and has a more complex intestine. Species of Coptotermes sp.4 also had a similar description to C. curviganatus, except that the shape of the posterior margin of postmentum different (Fig. 5e) with postmentum are described by [15]. For species of Coptotermes sp. 5, there no identical information to its morphological characteristics; but possibly close to termites from the near location.

Natural forest is a forest that grows naturally without human assistance, so it has a variety of vegetation both from differences in age and tree species. Natural forests have a tight canopy closure which creates a microclimate that supports life and termite activity so that the termite population gets higher. In this study, it was known that the highest abundance of termites in natural forests. In the [20] study also found that the abundance and wealth of higher termite species were found in secondary and primary forests compared to agroforestry land. The second highest abundance is in mahogany stands. The distance between the mahogany trees is irregular but has a large and wide canopy so that the canopy between trees covers each other and in this mahogany stand, has quite a diverse understory and has enough thick litter which is a food source for termites. [21] suggest that canopy closure is the main factor that causes an increase in termite abundance in a plantation area.

The results of species identification based on morphological from Teaching Forest of Hasanuddin University regions was quite difficult to separate at the level of definite species, because of very similar in its morphological characteristics and overlapping in morphometrical measurements. Morphological data can supported and to verified after get molecular data [22]. In case to find an accurate species was necessary to verify with molecular data.

5. Conclusions
There were nine species of termites that identifying at four different landscapes in Teaching Forest, Sulawesi Selatan region, namely: Odontotermes sp.1, Odontotermes sp. 2, Odontotermes sp.3, Coptotermes curvignathus, Nasutitermes sp., Schedorhinotermes sp. Microcerotermes serrula, Bulbitermes sp., dan Havilanditermes sp.

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