# TAXONOMY, DISTRIBUTION AND DIVERSITY OF TERMITE (ISOPTERA) FAUNA OF WESTERN GHATS

**VIDYASHREE, A. S.**

**PA1TAC002**

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY**

**UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES, SHIVAMOGGA-577 224**

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# TAXONOMY, DISTRIBUTION AND DIVERSITY OF TERMITE (ISOPTERA) FAUNA OF WESTERN GHATS

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*By*

**VIDYASHREE, A. S.**

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY**

**UNIVERSITY OF AGRICULTURAL AND**

**HORTICULTURAL SCIENCES, SHIVAMOGGA- 577 224**

**SHIVAMOGGA** **MARCH, 2017**

*Affectionately Dedicated to*

*My Beloved parents*

*Mr. Shankar*

*Smt. Susheela*

*&*

*Chairman*

*Dr. C.M. Kalleshwara swamy*

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY**
**UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES, SHIVAMOGGA-577204**

## CERTIFICATE

This is to certify that the thesis entitled "**TAXONOMY, DISTRIBUTION AND DIVERSITY OF TERMITE (ISOPTERA) FAUNA OF WESTERN GHATS**" submitted by **Ms. VIDYASHREE, A. S.**, bearing ID No. PA1TAC002, in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY** in **Agricultural Entomology** to the University of Agricultural and Horticultural Sciences, Shivamogga is a record of research work carried out by her during the period of her study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any other degree, diploma, associate ship, fellowship or other similar titles.

Shivamogga
March, 2017

**(C. M. KALLESHWARA SWAMY)**
Major advisor

**APPROVED BY:**

**CHAIRMAN:** ____________________
**(C. M. KALLESHWARA SWAMY)**

**MEMBERS:** 1. ____________________
**(M. MANJUNATHA)**

2. ____________________
**(R. ASOKAN)**

3. ____________________
**(SHARANABASAPPA)**

4. ____________________
**(H.M. CHIDANANDAPPA)**

5. ____________________ 13/3/17
**(M. DINESHKUMAR)**

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*Shivamogga*

*March, 2017* **(Vidyashree, A. S.)**

**TAXONOMY, DISTRIBUTION AND DIVERSITY OF TERMITE (ISOPTERA) FAUNA OF WESTERN GHATS**

**VIDYASHREE, A.S.**

**ABSTRACT**

Western Ghats is one of the important biodiversity hot spots in the world, rich in flora and fauna including insects. The diversity of termites from this region has been poorly described. Studies were made to identify the species diversity existing in Western Ghats with their distribution pattern. A total of 42 termite species belonging to 13 genera and six subfamilies under two families *viz.,* Rhinotermitidae and Termitidae were recorded. Termitidae was the most dominant family which represented 97.99 per cent with 37 species in eleven genera. Among the subfamilies, Macrotermitinae contributed the highest (81.11%) followed by Amitermitinae (7.36%), Nasutitermitinae (6.68%), Termitinae (2.84%), Coptotermitinae (1.34%) and Heterotermitinae (0.67%) in the overall collections. Highest number of species (18) collected belongs to two genera, namely *Microtermes* and *Odontotermes* of the subfamily Macrotermitinae. An illustrated identification key was developed for the termite species collected in the study area. The morphological identification is consistent with the molecular findings. Statistically distinct 16S rRNA profiles were observed in Amitermitinae, Macrotermitinae, Nasutitermitinae and Rhinoterminae. Species diversity and richness varied across three habitats. The forest habitat had more number of species (12) than plantation habitat (10) and pasture habitat (7). Distribution maps were developed for all collected species, however, the following species recorded in only one locality which includes *Coptotermes kishori, C. heimi, Heterotermes balwanti, Eurytermes buddha, E. assmuthi assmuthi, O. bhagwatii, O. globicola, O. horni, O. peshawarensis, Nasutitermes gardneri, Trinervitermes nigrirostris, Angulitermes fletcheri* and *Dicuspiditermes incola.* All the collected specimens were deposited in Department of Entomology, UAHS, Shivamogga.

March, 2017

Department of Agricultural Entomology
College of Agriculture, Shivamogga

Dr. Kalleshwara swamy, C.M.
(Major advisor)

# ಪಶ್ಚಿಮ ಘಟ್ಟಗಳಲ್ಲಿ ಗೆದ್ದಲು ಹುಳುಗಳ (ಐಸೋಪ್ಟೆರ) ಜೀವಿ ವರ್ಗೀಕರಣಶಾಸ್ತ್ರ, ಹರಡುವಿಕೆ ಮತ್ತು ವೈವಿಧ್ಯತೆಯ ಅಧ್ಯಯನ

**ವಿದ್ಯಾಶ್ರೀ ಎ.ಎಸ್**

## ಸಾರಾಂಶ

ಪಶ್ಚಿಮ ಘಟ್ಟವು ಸಸ್ಯ, ಪ್ರಾಣಿ ಮತ್ತು ಕೀಟಗಳ ವೈವಿಧ್ಯತೆಯನ್ನು ಹೊಂದಿರುವ ಪ್ರಮುಖ ತಾಣವಾಗಿದ್ದು, ಈ ಘಟ್ಟಗಳಲ್ಲಿ ಗೆದ್ದಲು ಹುಳುಗಳ ವೈವಿಧ್ಯತೆಯ ಬಗ್ಗೆ ಇದುವರೆಗೆ ಕಡಿಮೆ ಅಧ್ಯಯನ ಮಾಡಲಾಗಿದೆ. ಆದ್ದರಿಂದ, ಗೆದ್ದಲು ಹುಳುಗಳ ವೈವಿಧ್ಯತೆ ಮತ್ತು ಅವುಗಳು ಹರಡಿರುವ ರೀತಿಯ ಬಗ್ಗೆ ಸಂಶೋಧನೆ ನಡೆಸಲಾಯಿತು. ಒಟ್ಟಾರೆ 42 ಗೆದ್ದಲು ಹುಳುಗಳ ಜಾತಿಗಳು ಮತ್ತು 13 ಪ್ರಭೇದಗಳು, ಆರು ಉಪಕುಟುಂಬಗಳು (ಮ್ಯಾಕ್ರೋಟರ್ಮಿಟಿನೆ, ಅಮಿಟರ್ಮಿನೆ, ನಸುಟಿಟರ್ಮಿಟಿನೆ, ಟರ್ಮಿಟಿನೆ, ಕೊಪ್ಟೋಟರ್ಮಿಟಿನೆ, ಹೆಟಿರೋಟರ್ಮಿಟಿನೆ), ಎರಡು ಕುಟುಂಬಗಳೊಳಗೆ ರೈನೋಟರ್ಮಿಟಿಡೆ ಮತ್ತು ಟರ್ಮಿಟಿಡೆಗಳನ್ನು ದಾಖಲಿಸಲಾಯಿತು.

ಒಟ್ಟು ಸಂಗ್ರಹಿಸಿದ ಗೆದ್ದಲು ಹುಳುಗಳ ಉಪಕುಟುಂಬಗಳ ಕೊಡುಗೆಯಲ್ಲಿ ಟರ್ಮಿಟಿಡೆ ಅತ್ಯಂತ ದೊಡ್ಡ ಕುಟುಂಬವಾಗಿದ್ದು, ಇದು 97.99 ಪ್ರತಿಶತದೊಂದಿಗೆ 37 ಜಾತಿಯ ಗೆದ್ದಲು ಹುಳುಗಳು, ನಾಲ್ಕು ಉಪವರ್ಗಗಳನ್ನು ಒಳಗೊಂಡಿದ್ದು, ಅವುಗಳೆಂದರೆ ಮ್ಯಾಕ್ರೋಟರ್ಮಿಟಿನೆ ಹೆಚ್ಚಿನ ಪ್ರತಿಶತ (81.11), ನಂತರ ಅಮಿಟರ್ಮಿಟಿನೆ (7.36), ನಸುಟಿಟರ್ಮಿಟಿನೆ (6.68), ಮತ್ತು ಟರ್ಮಿಟಿನೆಯನ್ನು (2.84) ಪ್ರತಿನಿಧಿಸುತ್ತವೆ. ಮ್ಯಾಕ್ರೋಟರ್ಮಿಟಿನೆಯಲ್ಲಿ ಅತ್ಯಧಿಕ ಜಾತಿಯ (18) ಗೆದ್ದಲು ಹುಳುಗಳು ಕಂಡುಬಂದಿದ್ದು, ಅವುಗಳು ಒಡೊಂಟೊಟರ್ಮಿಸ್ ಮತ್ತು ಮೈಕ್ರೋಟರ್ಮಿಸ್ ಎಂಬ ಎರಡು ಪ್ರಭೇದಗಳನ್ನು ಹೊಂದಿದೆ. ಸೈನಿಕ ಹುಳುಗಳನ್ನು ಬಳಸಿ ಸಚಿತ್ರಕೀಲಿಯನ್ನು ಅಭಿವೃದ್ಧಿಪಡಿಸಲಾಗಿದ್ದು, ಈ ಕೀಲಿಯು ಪಶ್ಚಿಮ ಘಟ್ಟಗಳ ಗೆದ್ದಲು ಹುಳುಗಳನ್ನು ಸುಲಭ ಮತ್ತು ನಿಖರವಾಗಿ ಗುರುತಿಸಲು ಸಹಾಯವಾಗುತ್ತದೆ. ಅಣ್ವಿಕ ಸಂಶೋಧನೆಯ ಪ್ರಕಾರ, ಸಾಂಖ್ಯಿಕವಾಗಿ 16S rRNA ಬಳಸಿ ಗೆದ್ದಲುಹುಳುಗಳ ಜಾತಿಗಳನ್ನು ಕಂಡುಹಿಡಿಯಲಾಯಿತು, ಕ್ರಮವಾಗಿ ಹುಲ್ಲುಗಾವಲು, ತೋಟ, ಮತ್ತು ಅರಣ್ಯ ಪ್ರದೇಶದಲ್ಲಿ 7, 10 ಮತ್ತು 12 ಜಾತಿಯ ಗೆದ್ದಲುಹುಳುಗಳು ಕಂಡುಬಂದವು. ಜಾತಿಗಳ ವೈವಿಧ್ಯತೆ ಮತ್ತು ಅವುಗಳ ಶ್ರೀಮಂತಿಕೆಯು ಈ ಮೂರು ಪ್ರದೇಶಗಳಲ್ಲಿ ಬೇರೆ ಬೇರೆಯಾಗಿ ಕಂಡುಬಂದಿದೆ.

ಸಂಗ್ರಹಣೆ ಮಾಡಿದ ಗೆದ್ದಲು ಹುಳುಗಳ ವಿತರಣೆ ನಕ್ಷೆಯನ್ನು ತಯಾರಿಸಲಾಯಿತು. ಅದಲ್ಲದೆ, ಈ ಕೆಳಗೆ ತಿಳಿಸಿರುವ ಗೆದ್ದಲುಹುಳು ಜಾತಿಗಳು ಒಂದೇ ಪ್ರದೇಶದಲ್ಲಿ ಕಂಡುಬಂದವು. ಅವುಗಳೆಂದರೆ ಕೊಪ್ಟೋಟರ್ಮಿಸ್ ಕಿಶೋರಿ, ಕೊಪ್ಟೋಟರ್ಮಿಸ್ ಹೆಮಿ, ಹೆಟಿರೋಟರ್ಮಿಸ್ ಬಲ್ವಂತಿ, ಯುರಿಟರ್ಮಿಸ್ ಬುದ್ದ, ಯುರಿಟರ್ಮಿಸ್ ಅಸ್ಮುತಿ ಅಸ್ಮುತಿ, ಒಡೊಂಟೊಟರ್ಮಿಸ್ ಭಗ್ವತಿ, ಒಡೊಂಟೊಟರ್ಮಿಸ್ ಗ್ಲೋಬಿಕೊಲ, ಒಡೊಂಟೊಟರ್ಮಿಸ್ ಹಾರ್ನಿ, ಒಡೊಂಟೊಟರ್ಮಿಸ್ ಪೆಶವರ್ನೆಸೆಸ್, ನಸುಟಿಟರ್ಮಿಸ್ ಗಾರ್ಡ್ನೆರಿ, ಟ್ರೈನರ್ವಿಟರ್ಮಿಸ್ ನಿಗ್ರಿರೊಟ್ರಿಸ್, ಅಂಗುಲಿಟರ್ಮಿಸ್ ಫ್ಲೆಚೆರಿ, ಡೈಕಸ್ಪಿಡಿಟರ್ಮಿಸ್ ಇನ್ಕೋಲ. ಎಲ್ಲಾ ಸಂಗ್ರಹಿಸಿದ ಗೆದ್ದಲು ಹುಳುಗಳನ್ನು ಕೀಟಶಾಸ್ತ್ರ ವಿಭಾಗ, ಕೃಷಿ ಮಹಾವಿದ್ಯಾಲಯ, ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕೆ ವಿಶ್ವವಿದ್ಯಾಲಯ, ಶಿವಮೊಗ್ಗದಲ್ಲಿ ಸಂಗ್ರಹಿಸಿ ಇಡಲಾಗಿದೆ.

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# *Introduction*

# I. INTRODUCTION

There are 34 global biodiversity hotspots in the world based on the criteria of exceptional concentration of endemic plants and higher degree of anthropogenic pressure. India accommodates part of four global biodiversity hotspots namely the Himalaya, the Western Ghats, Indo-Burma and Sundaland, which are also facing challenges due to anthropogenic disturbance and climate change (Chitale *et al.,* 2015). Among these four hotspots, the Western Ghats are a mountain range that runs along India's west coast, covering the states of Karnataka, Maharashtra, Goa, Tamil Nadu, Kerala and Gujarat. The Western Ghats comprises a total area of 1,59,000 km$^2$, stretching from 22$^o$ N to 8$^o$ N, 73$^o$ to 77$^o$ E with considerable gradients of elevation, temperature and rainfall, resulting in numerous distinctive species associations regarded as one of the eight hotspots of biological biodiversity in the world and remarked as world heritage site by United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2012. Although the total size is less than six per cent of the land area of India, Western Ghats contains more than 30 per cent of all plant and animal species found in the country and has a high proportion of endemic species. The region also has a largely intact assemblage of large mammals and is home to several wildlife sanctuaries, tiger reserves and national parks. Current knowledge of insect species richness and composition is inadequate in this recognized biodiversity hotspot.

The biodiversity hotspots situated in densely populated tropical countries are experiencing threats due to urbanization, agricultural expansion and rapid economic development (Chitale *et al.,* 2015). Cincotta *et al*. (2000) reported higher human population density in the hotspots located in the tropics, where in among all hotspots, Western Ghats accommodated the highest human population density (>300 persons/sq.km). As a result, anthropogenic threats are manifold in the Western Ghats as large tracts of forest are being lost or converted to open/cultivated lands, coffee and areca plantations, or hydroelectric reservoirs (Menon and Bawa, 1997). Being a biodiversity hotspot, the region is expected to be rich in insect fauna including termites. Termites are the most dominant macro arthropod detritivores in the tropics. They are particularly diverse and abundant in these areas (Pearce, 1999; Eggleton, 2000) strongly influenced by local environmental factors such as vegetation type (Jones, 2000), habitat disturbance (DeBlauwe *et al*., 2008) and habitat fragmentation (DeSouza and Brown 1994; Davies *et al*., 2003).

A diverse species of termites belong to order Isoptera and are responsible for versatile soil related activities. Their major activities include redistribution of soil particles, alteration in mineral and organic composition, hydrology, drainage (Jones *et al*., 1994; Konate *et al*., 1999) and infiltration rates (Mando *et al*., 1996). The varied groups of termites comprising wood feeders, grass harvesters and soil feeders exerts different ecological effects on soil ecosystems (Donovan *et al*., 2002; Josens, 1983). Hence they are considered as key soil ecosystem engineers specially in tropical and sub-tropical systems.

However, despite their importance in tropical and subtropical systems, detailed knowledge on termites and their function in ecosystems is scarce, with even basic natural information lacking for many species (Dangerfield *et al*., 1998; Gromadzki, 2003). This can largely be attributed to taxonomic and sampling difficulties. Although termites are often considered to be 'taxonomically tractable' (Brown, 1991), there are still major gaps in their taxonomy and particularly more so for southern hemisphere regions (Eggleton *et al*., 1996) wherein many genera are in need of revision (Eggleton, 1999; Uys, 2002).

Termites are classified in seven families, 14 subfamilies with 280 genera and >2650 species (Krishna, 1970; Pearceand Waite, 1994; Kambhampati and Eggleton, 2000). Almost 300 species of termites are known from the Indian region (Roonwal and Chhotani, 1989). Thakur (1987 and 1990) reported 22 species belonging to six genera from Karnataka. Kalleshwaraswamy *et al*. (2013) listed 56 species in 24 genera so far reported South India.

Termite taxonomy work was at its peak, with many taxonomists were intensively working in India during 1950-1990. In this period, number of termitologists from ZSI, Kolkata and FRI, Dehradun have described more than hundred species of termites. Few publications (Thakur, 1987 and 1990; Bose, 1984; Roonwal and Chhotani, 1989) of renowned termitologists/taxonomists indicate that many described genera are endemic to Western Ghats. These publications also suggest patchy efforts and that it requires systematic work on termite species of Western Ghats.

Much of termite taxonomy is based on the soldier caste or worker caste (soldierless termite groups) as these castes are most readily encountered in the field, during their foraging activity when they move away from the nest. The adult reproductive forms of termites are the alates, which can usually be collected at light, but are rarely found together with the workers and soldiers in the field, as they remain in or close to the nest. As a result, it is often difficult to match the alate form with other castes of the same termite species, particularly where termite diversity is high.

The soldier and worker castes are derived from developmental pathways regulated chemically by hormone balances within the colony and hence, their development, morphology can be influenced by the age and state of the colony or their environment, such as the habitat in which they occur (Miller, 1969). So, it is more common to find a high degree of variation in morphology among different colonies of the same species and between populations of different habitats or vegetation-types (Kirton, 2005). Natural variation also occurs within a species in different parts of its geographic range. These sources of variation possess problems for taxonomists, as it means that species can often only be properly delineated when sufficiently large samples across a large geographical range are obtained and studied. Added to this is the common problem of the lack of clear distinguishing features between different species and the high degree of overlap in size ranges and shape. To overcome such problems, taxonomists often have to rely on multiple characters to distinguish species.

Today, the modern taxonomist has access to tools that were not available to predecessors in this field. Numerical and statistical methods that have been developed and used in taxonomic research have helped to provide more objective means of defining species limits and studying variation within and between populations (Hebrant, 1981; Mayr and Ashlock, 1991).

The advent of molecular techniques has provided taxonomists with an invaluable tool for studying populations and species at the genetic level. This has been demonstrated for a few termite genera, particularly *Reticulitermes* (Clement *et al.*, 2001; Austin *et al.*, 2002; Szalanski *et al.*, 2003). Through these techniques, taxonomists are now able to match castes reliably and determine species boundaries (Hebert *et al.*, 2003). Not only does DNA taxonomy and barcoding help to solve these problems, but it also strengthens phylogenetic analysis of organisms where, morphological characters can be used in identification. However, when morphology is studied hand-in-hand with genetic structure, it provides a powerful tool in recognition, characterisation and classification of species (Clement *et al*., 2001).

The evolutionary origin of termites remains unresolved for more than half a century (Nalepa and Bandi, 2000). Several studies took into account to study the phylogeny of termites using different molecular markers (Singla *et al*., 2015). Recently, molecular phylogenetic studies have been reported for many species (Kambhampati *et al*., 1996; Lo *et al*., 2000; Miura *et al*., 1998; Kambhampati and Eggleton, 2000; Thompson *et al*., 2000a). Phylogeny of termites based on analysis of morphological characters have been proposed and discussed by many researchers (Ahmad, 1950; Krishna, 1970; Miller, 1986; Noirot, 1995; Donovan *et al*., 2000).

In a nutshell, termite diversity is poorly studied in Western Ghats and also molecular identification of termites was not attempted so far in India. The distribution of termites study have not attempted in Western Ghats which gives an idea on conservation decision making. Keeping this in mind the present study was undertaken with the following objectives.

1. Collection of termites in Western Ghats and species identification using soldier caste
2. Molecular identification of selected termites
3. Estimation of termite diversity in different types of ecosystems
4. Developing distribution maps for termites of Western Ghats

# Review of Literature

# II. REVIEW OF LITERATURE

The literature pertaining to the present study "Taxonomy, distribution and diversity of termite (Isoptera) fauna of Western Ghats"has been reviewed and presented below.

## 2.1 Collection of termites in Western Ghats and species identification using soldier caste

### 2.1.1 Species diversity with respect to different parts of the world

There are about 2650 species of termites with 280 genera and seven families have been described so far, and still more number of species have to be described (Kambhampati and Eggleton, 2000) across the world.

Deliberate surveys have yielded five termite species from the collected samples at Georgia including, *Coptotermes formosanus* Shraki (Family: Rhinotermitidae) and *Calcaritermes nearticus* (Snyder), *Coptotermes brevis* (Walker), *Incisitermes minor* (Hagen) and *Kalotermes approximatus* Snyder (Family: Kalotermitidae) bringing the total number of termite species in Georgia to nine. Among them, *C. formosanus, C. brevis* and *I. minor* are non-endemic pest species (Scheffrahn, 2001).

The termite species diversity in Shivamogga district studied by Sathish (2015) reported that, 229 termite samples were collected and reported 25 species. They were belonging to 11 genera, six subfamilies under two families *viz.*, Rhinotermitidae and Termitidae. The subfamilies found were Amitermitinae, Coptotermitinae, Heterotermitinae, Macrotermitinae, Nasutitermitinae and Termitinae.

Kambhampati and Eggleton (2000) reported Termitidae is the largest among the seven termite families with approximately 85 per cent of all known genera and 70 per cent in the world. This family has four subfamilies which are Amitermitinae, Macrotermitinae, Nasutitermitinae and Termitinae. Termitidae is considered as the most evolved group of termites, is mainly due to lack of symbiotic cellulolytic protists in their gut region (Ohkuma, 2003).

The subfamily Amitermitinae is the most primitive and has evolved from the family Rhinotermitidae (Krishna, 1970). The subfamily Macrotermitinae contains fungus growing termite species that feed on wide range of dead and living plant materials which is fully by their fungal symbionts (the basidiomycete, Termitomyces) on fungus combs in the nest (Darlington, 1994). The subfamily Nasutitermitinae is highly specialised form of higher termites (Homathevi, 1999; Eggleton *et al*., 1999). The subfamily Termitinae includes both the soil feeding and wood-feeding species (Collin, 1988).

Traun and Perry (1998) reported 150 species in Western Australia which belongs to 27 genera and 4 families namely, Mastotermitidae, Kalotermitidae, Rhinotermitidae and Termitidae. Among them, Termitidae was the most dominent with 126 species and 19 genera followed by Rhinotermidae with 17 species and three genera, Kalotermitidae with 6 species and three genera and Mastotermitidae with one species.

Scheffrahn *et al*. (2006) surveyed 33 islands of the Bahamas and Turks and Caicos (BATC) archipelago for termites. They observed 3533 colony samples in 593 different sites and reported 27 species in three families and 12 genera based on the characters of soldier (or soldierless worker) and the winged imago.

Seventy species of termites were collected in forests of Amazon, Brazil which includes seven new species, *Orthognathotermes humilis*, *Spinitermes longiceps*, *Armitermes gnomus*, *Araujotermes nanus*, *Embiratermes ignotus*, *Subulitermes constricticeps*, *Syntermes robustus* and also described an imago of *Cavitermes parvicavus* for the first time (Constantino, 1992). In Anhembi, Brazil 17 termite species were reported by Junqueira *et al*. (2015) which belong to three families (Kalotermitidae, Rhinotermitidae and Termitidae) and three subfamilies (Apicotermitinae, Nasutitermitinae and Termitinae).

Mugerwa *et al*. (2011) reported 16 termite species from eight genera, three subfamilies and one family in semi-arid Nakasongola, Uganda. Species from the subfamily Macrotermitinaeconstituted 69 per cent of the total number of species sampled. Members under *Macrotermes* were dominant species and constituted 38 per cent of the total number of species sampled. In Thailand, 11 termite species belongs to five genera of Rhinotermidae were recorded including three new species (*Reticulitermes assamensis, Prorhinotermes microdentiformisoides* and *P. telreepeni*) (Takemastsu and Vongkaluang, 2012).

A total of 27 species belonging to 11 genera, three families (Kalotermitidae, Rhinotermitidae and Termitidae) and five subfamilies were reported by Hemachandra *et al.* (2014). They found that Termitidae was most dominant family with 24 species, followed by Kalotermitidae with two species and Rhinotermitidae with only one species at Knuckles region, Sri Lanka.

### 2.1.2 Species diversity with respect to India

Almost 300 species of termites are known from Indian region (Roonwal and Chhotani, 1989). Publications of Thakur 1987 and 1990, Bose 1984, Roonwal and Chhotani, 1989, indicate many described genera are endemic to Western Ghats. Collections of termites from south India at Zoological Survey of India, Kolkata and Forest Research Institute, Dehradun, includes 95 species grouped in 29 genera and three families (Bose, 1984). Thakur in 1987 and 1990 reported 22 species belonging to six genera from Karnataka. Kalleshwaraswamy *et al*., (2013) recorded 56 species covering 24 genera from south India, where none of them were found to be endemic to Karnataka.

The richest concentration of termite species is distributed in Western Ghats and north eastern region of India. Alfred *et al.* (1998) reported the taxonomic species strength was 253 under 54 genera belonging to seven families, of which 172 species are endemic to India (ZSI).

Fifty eight species of termites were recorded in Kerala which belongs to three families (Kalotermitidae, Rhinotermitidae and Termitidae), six subfamilies (Coptotermitinae, Heterotermitinae, Apicotermitinae, Macrotermitinae, Nasutitermitinae, Termitinae) and 28 genera. Termitidae was the most diverse family with 22 genera and 46 species. Four genus with eight species were reported from the family Kalotermitidae (Mathew, 2015).

Poovoli and Rajmohana (2013) reported a new species, *Heterotermes indicola,* for the first time from Kerala as well as the whole of south India and later it has been reported from Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Maharashtra, Punjab, Rajasthan, and Uttar Pradesh. A few termites sampled from a badly damaged pile of old paper in a godown at Bellipedi ($12^0$35′12.57″N, $75^0$18′12.95″E) Kasargod district, have been taxonomically identified as *H. indicola* (Maiti, 2006).

Eight subterranean species of termites of the genus *Odontotermes* were reported from Chhattisgarh, India (Saha *et al*., 2016). Basu *et al.* (1996) reported 12 species of termites belonging to eight genera, three subfamilies (Termitinae, Macrotermitinae and Nasutitermitinae) and one family *i.e.,* Termitidae in Sagar forest range, Shivamogga, Karnataka.Transect and quadrat methods were employed to survey the termites in Puducherry and reported ten species of termites belonging to eight genera and three families (Anantharaju *et al.*, 2014).

Varma and Swaran (2007) reported 14 termite species belonging to seven genera, five subfamilies and two families, namely Rhinotermitidae and Termitidae with one species and 13 species, respectively. Subfamily Macrotermitinae (nine) was most dominant followed by Termitinae, Amitermitinae, Nasutitermitinae and Coptotermitinae in Malayattur forest area of Kerala.

Most of the wood feeding termites were restricted to uncleared forest whereas, grass feeders restricted to re-growth forest region in Savanna, Australia (Dawes, 2010). Fifteen termite species belonging to two families Termitidae and Rhinotermitidae and seven genera (*Coptotermes*, *Heterotermes*, *Amitermes*, *Microcerotermes*, *Odontotermes*, *Microtermes*, *Trinervitermes*) were recorded in sugarcane crop field (Pardeshi *et al*., 2010).

Ten termite species were recorded in Delhi by Mahapatro and Kumar (2013) which belongs to four genera, three subfamilies and two families, namely Rhinotermitidae and Termitidae. Termitidae was the most dominant family with eight species of genera *Odontotermes* and *Microtermes* which belongs to subfamily, Macrotermitinae. Rhinotermitidae was represented by a species of the subfamilies, Coptotermitinae and Heterotermitinae.

Thirteen species of termites including five genera, four subfamilies and two families (Rhinotermitidae and Termitidae) were recorded in Western Ghats, India (Shanbhag and Sundararaj, 2013). Ten termite species (*Hypotermes obscuriceps, Macrotermes convulsionarius, Odontotermes anamallensis, O. brunneus, O. globicola, Microcerotermes fletcheri, Microtermes obesi, Trinervitermes biformis*, *Coptotermes heimi* and *Neotermes assmuthi*) were reported in North-eastern Puducherry by Anantharaju *et al.* (2014) and they represent seven genera and three families *viz.*, Termitidae, Rhinotermitidae and Kalotermitidae.

The *Coptotermes beckeri* forms the first record of the species from Kerala. Three species of *Coptotermes* known from Kerala are *C. heimi*, *C. ceylonicus* and *C. kishori* (Mathew, 2015). Sixty species were listed in the recent checklist on termites of Kerala by Amina and Rajmohana (2014) and the further study updated the total number to 61 (Poovoli *et al*., 2016).

**2.1.3 Taxonomic key of termites based on morphological characteristics of soldiers**

Various morphological characters of soldiers were used in identification and classification of termites. In Thailand, Sornnuwat *et al*. (2004) identified and classified termites into 37 genera in four families and ten subfamilies based on soldier characteristics. Generally accepted systematics of Isoptera relies heavily on soldier external morphology and to a lesser extent, on mandibles morphology of alates and workers. Other morphological characters may be the number of cerci segments and wing microsculpturing (Bergamaschi *et al*., 2007).

Illustrated and morphological measurement of soldier caste as a taxonomic key for identification of termites into genera and species level in Rhinotermidae was used by Takemastsu and Vongkaluang (2012) and they reported 11 termite species belonging to five genera and four species (*Reticulitermes assamensis, Parrhinotermes microdenti formisoides* and *P. telreepeni*) and were found to be new species in Thailand.

An illustrated identification key to termites of Shivamogga, India was developed by Sathish (2015) for quick identification of termite species found in Shivamogga.

Mukherjee and Maiti (2008) reported two new species *(Angulitermes nepalensis* and *Ahmaditermes sikkimensis*) of termites from the Himalaya, India withproper illustrations. The genus *Angulitermes* sjostedt easily recognized by its frontal projection of the soldier caste, is so far only known from the new world.

Taxonomic keys were developed, based on the soldier caste and the winged imago for the fauna of Isoptera of Puerto Rico and U.S. Virgin islands by Scheffrahn *et al*. in 2006 and they observed that, Kalotermitidae as the most dominant family with 12 species of five genera, followed by Termitidae with six species of five genera and Rhinotermitidae with a species each in three genera.

Kalleshwaraswamy *et al.* (2013) developed the illustrated identification keys to termites of South India, based on the morphological features with pictorial representation of soldier castes for 35 genera comprising five families.

**2.2 Molecular identification of selected termites**

Traditional phylogenetic studies of termites based on morphological characters have suffered from one or more fundamental problems, making them problematic (Inward *et al.*, 2007b). Some of these problems include a bias towards certain groups, only analyzing certain biogeographic regions, lack of a rigorous cladistic analysis, or the use of a limited number of characters (Eggleton, 2001).

The morphological and molecular studies supported scheme in which cockroaches and mantids are sister groups and termites are a sister group to the cockroaches-mantids clades (Thorne and Carpenter 1992; Kambhampati, 1996).

Molecular phylogenetics of termites will be a fundamental in the development of future termite classification and identification with reference to climate change adaptation techniques, quarantine and pest control systems (Ahmed and French, 2005; Su and

Scheffrahn, 2000). However, research into molecular phylogenetics with better understanding in termite morphology, ecology and physiology is needed (Lo *et al*., 2006).

Molecular phylogenetics and barcoding have many advantages but, if not done rigorously, can suffer the same shortcomings as phylogenetic studies based on morphological studies, such as poor taxon sampling or an insufficient number of gene loci. To date, the most comprehensive termite phylogenetic studies have been conducted by very few researchers (Donovan *et al.*, 2000; Bitsch and Noirot, 2002; Noirot, 1995 and 2001). Mitochondrial DNA is the most widely used molecule for identification of insects as well as for animals in general (Hillis *et al*., 1996) at molecular level. The popularity of mtDNA markers derives in large part from its relative ease of isolation and amplification, even from marginally preserved specimens, and for the presence of universal primers (Simon *et al*., 1994). Although molecular methods are able to provide information not readily available from morphology, they remain only one of many tools needed by taxonomists to address questions about species and populations (Kirton, 2005). Because of its moderate size and range of evolutionary rates across sequences, 16S rRNA has great importance in phylogenetic studies across the wide range of insects (Simon *et al*., 1994).

Most termite identification systems, in the past, relied almost solely on the taxonomists with the use of morphological and physiological features as the major classification and identification system (Su and Scheffrahn, 2000). In Australia, Europe and USA, molecular phylogenetics is considered as an alternative approach to termite identification, classification and distribution as the existing taxonomical classification is limited in its scope. The lack of qualified taxonomists needs a fresh look and a wholly biorational approach to termite taxonomy and distribution studies (French, 1994; Ahmed and French 2005).

It is generally accepted that Mastotermitidae was the most basal family and the Termopsidae, Hodotermitidae, and Kalotermitidae are basal to the Termitidae and the Rhinotermitidae, which now contains what used to be the Serritermitidae (Miura *et al*. 1998, Lo *et al*. 2004). While the Termitidae are established as the most derived, monophyletic group in relation to the other families, the relationship of subfamilies within the Termitidae is still unresolved. The only subfamily forming a clear monophyletic clade is the Syntermitinae, the mandibulate nasutes. This monophyly was first inferred by Inward *et al*. (2007a).

The first molecular study on Isoptera inter family relationships was performed by Kambhampati *et al.* (1996) on a portion of the mitochondrial large ribosomal subunit gene (16S rRNA), in ten genera of five families. Miura *et al*. (1998) analyzed the COII sequences in 3 Rhinotermitidae and 12 Termitidae genera.Termite molecular phylogeny will assist to enhance our understanding of phylogenetic, geographical distributions and uses of mitochondrial and nuclear genes which can explore the existence of new species (Badawi *et al*., 2008). Subsequently, the relationships within the family, Rhinotermitidae with their correlation to Termitidae and Serritermitidae were investigated by Lo *et al*. (2004) and Ohkuma *et al*. (2004), through the analysis of different mitochondrial markers. They found a substantial conflict with many previous hypotheses relative to the family, Rhinotermitidae and its taxa, including the idea that it is monophyletic (Emerson, 1971). They suggested Rhinotermitidae as paraphyletic to Termitidae (in agreement with Miura *et al*., 1998 hypotheses), with Serritermitidae being its sister group; this study also supported the wide accepted monophyly of the Termitidae.

Eggleton and Davies (2003) reported that the *Nasutitermes* group which belongs to Nasutitermitinae in Madagascar and Southeast Asia show strikingly similar parallel diversification in feeding strategies and associated mandible structure. These incongruencies with traditional methods illustrate the necessity for new methods that compliment morphology and morphometrics and may lead to the inference of more strongly defended phylogenies.

'Advent of molecular techniques' presented by Kirton (2005) is an invaluable tool for taxonomists to study populations and species at the genetic level. This has been demonstrated for termite genera, *Reticulitermes* (Clement *et al*., 2001; Austin *et al*., 2002; Szalanski *et al*., 2003). Phylogenetic analysis of evolutionary relationships may lead to increased accuracy of insecticide-based management, on this basis the related species are likely to share similar physiologyas observed in *Coptotermes formosanus*, the most significant pest, appears to be paraphyletic with respect to several other species in the genus, and may represent two cryptic species (Gentz *et al*., 2008).

Genetic relationship among termites collected from various locations was characterized based on 12S rRNA gene using specific primers. Sequence analysis and divergence among the species was assessed. Gene bank accession numbers were obtained for the different species. Phylogenetic tree based on Maximum-Likelihood method was drawn on the basis of multiple sequence alignment, which revealed clustering of individuals according to the genera. Among the species, *Microtermes obesi* and *Neotermes koshonensis* were distinct from others (Murthy *et al*., 2015).

Legendre*et al*. (2008) studied a phylogenetic hypothesis of termite relationships with DNA sequence data and they sequenced seven gene fragments (12S rDNA, 16S rDNA, 18S rDNA, 28S rDNA, cytochrome oxidase I, cytochrome oxidase II and cytochrome b) for 40 termite exemplars, representing all termite families and 14 outgroups. Termites were found to be monophyletic with *Mastotermes darwiniensis* (Mastotermitidae) as sister group to the remainder of the termites. In this remainder, the family Kalotermitidae was sister group to other families. The families Kalotermitidae, Hodotermitidae and Termitidae were retrieved as monophyletic whereas, the Termopsidae and Rhinotermitidae appeared as paraphyletic. All these results were very stable and supported with high bootstrap and bremer values.

Many recent studies demonstrated the need for a sound knowledge of termite molecular phylogenetics when applying termite adaptability to different climatic conditions and possible termite control (Lo *et al*., 2006). A DNA-based system for the identification of *Reticulitermes flavipes* (Koller) was established with different parameters such as, adequate molecular variation, comprehensive specimen sampling, explicit morphological species identification, and cladistic analysis and concluded that species were monophyletic (Foster *et al*., 2004).

Austin *et al*. (2004) examined the COII gene of 38 Rhinotermitidae species representing 10 genera and they suggested that the Rhinotermitidae should be polyphyletic and that Serritermitidae could be a subfamily of Rhinotermitidae. Moreover, several studies took into account single genus or limited group of genera. Miura *et al*. (2000) presented a phylogenetic analysis of 17 Pacific Tropical species of the highly species-rich genus *Nasutitermes* using COII and 16S rRNA sequences. They concluded that the genus is clearly polyphyletic, with Neotropical and Australian species forming a single clade together with some of the Asian taxa; a subset of Asian taxa appears highly separated from congeneric species in the phylogenetic tree.

Thompson *et al.* (2000a) considered the relationships among 25 species from 7 genera of Australian lineages of drywood termites (Kalotermitidae) based on COII and Cytb sequences. They proved the monophyly of the genera. Lo *et al.* (2006) studied the Australian *Coptotermes* species using COII sequences and found that *C.acinaciformis* may be a species complex rather than a single entity. Ozeki *et al.* (2007) considered the phylogeography of *Amitermes laurensis* on COII sequences, observing a correlation with mound shapes and environmental conditions.

The taxonomy and phylogeography of *Reticulitermes* taxa in Europe, were the object of several studies (Marini and Mantovani, 2002; Uva *et al*., 2004; Luchetti *et al*, 2004; Austin *et al*., 2006) based on different molecular markers. Nine main entities, either of specific or subspecific rank, are recognized in these works and their phylogenetic relationships are highlighted.

A molecular genetics study involving DNA sequencing of a portion of the mitochondrial DNA 16S rRNA gene was undertaken to determine the extent of genetic variation in drywood termites, *Incisitermes minor* and *I. snyderi*. The genetic variation among *I. minor* haplotypes ranged from 0.7 to 3.7 per cent and variation for *I. snyderi* ranged from 0.7 to 2.4 Per cent. Maximum parsimony and maximum likelihood analysis revealed 3 distinct clades for *I. snyderi*, whereas, *I. minor* had two distinct clades (Austin *et al*., 2012).

Molecular taxonomy based on mitochondrial DNA has proved to be an efficient alternative to species identification and their phylogenetic relationships. Infact, mitochondrial markers have been used with a number of insects for systematic and identification purposes (Kumari *et al*., 2009, Virgilio *et al*., 2010). The use of mitochondrial genome sequence is further supported by the occurrence of cladistically informative gene order rearrangement events. Mitochondrial sequence data have, therefore, been extensively used in the past 10 years to evaluate the population structure, gene flow, phylogeny, phylogeography and taxonomy of termites (Jenkins *et al*., 2001). Indeed, several studies based on mitochondrial genome sequences such as the cytochrome oxidase genes and the AT rich region have thrown a great deal of light on termite taxonomy.

The use of mitochondrial DNA in population genetic studies have been popular due to the extensive intraspecific polymorphism it exhibits, and it has become increasingly clear that genetic variability among and within the populations of pests, affects the success of biological control agents (Lander and Botstein, 1989).

*Reticulitermes aegeus* (Rhinotermitidae) is described by Ghesini and Marini, (2015), based on samples of alates and soldiers collected on the island of Cyprus. The range of the species includes the island of Losinj (Croatia), northeastern Greece (Halkidiki and northeastern Greece), Eastern Peloponnese, Northern Turkey, Crete, Cyprus and Amorgos (Cyclades Islands). The ascertained range of *R. aegeus* does not overlap with the ranges of other species occurring in the eastern Mediterranean lands. From the phylogenetic point of view, *R. aegeus* belongs to the eastern Mediterranean *Reticulitermes* clade, that also includes *R. urbis*, *R. balkanensis* and *R. clypeatus*, as well as taxa not yet described from Turkey and the island of Samos. *R. aegeus* is genetically distinct from other eastern Mediterranean *Reticulitermes* species, while its morphological characters do not allow a reliable diagnosis without further support. DNA analysis provides such corroboration.

Phylogenetic relationship studies on COII, 16S and 12S genes were carried outon the six species of termites belonging to the genus *Reticulitermes* (Rhinotermitidae). The average nucleotide composition in 12S rRNA fragment of various species of *Reticulitermes* reveals 43.98 per cent (A), 22.29 per cent (T), 12.45 per cent (G) and 21.27 per cent (C), as with average AT bias of 66 per cent. The present Isopteran species under study also have the same range of AT content. It had also been showed that Californian *R. flavipes* closely resembled the Chilean *R. flavipes*, on the basis of their combined mitochondrial DNA sequences. It also suggested that both Chilean and Californian *R. flavipes* have the same origin in North America (Su *et al*., 2006).

**2.3 Estimation of termite diversity in different types of ecosystems**

Termite diversity and composition are highly variable across continents and along latitudinal gradients which are predominantly due to the climatic and geological history of land masses and ecological zones (Bignell and Eggleton, 2000). Belt transect method was used to sample the termites in three different ecosystems, (teak plantation, coffee plantation and semi-evergreen forest) in North Wayanad, Kerala, India and they observed ten species in seven genera belongs to four subfamilies under one family. Bhavana *et al.* (2015) measured species diversity, richness, evenness and beta diversity and also observed the presence of highest similarity index (42%) in teak and coffee plantations and they also reported that the termites are good biological indicators of habitat quality.

Kaiser *et al*. (2015) conducted the first inventory of termites and ants in Burkina Faso (West Africa) from 2004 to 2008 where these important ecosystem engineers are the only active, quantitatively remarkable soil macrofauna during a long dry season. They combined two standard assessment protocols for tropical forests and adapted them to semi-arid (agro) ecosystems to representatively characterize termite and ant communities in two agricultural systems and assess their response to land-use intensification. In total, 65 ant species and 41 termite species were collected along parallel transects replicated during consecutive years. Both taxa were highly sensitive to human impact. Their taxonomic and functional richness strongly decreased with increasing intensification from a near-natural savannah towards cotton fields with recent pesticide application (North Sudan region), and recovered along a succession of the traditional rehabilitation technique Zaï from barren, crusted land towards a long-term fallow with diverse flora and fauna (sub-Sahel region). Fungus-growers dominated the termite communities in all habitats, with the highest variations between habitats noted among soil and grass-feeders (Kaiser *et al*., 2015).

Per cent abundance of termite species was maximum in trees (62%) followed by wood structure (24%) and lowest in soil (14%) of total sampled habitats in island of Luzon, Philippines (Acda, 2013).

Shanbhag and Sundararaj (2013) compared the species diversity of termites in forest and unmanaged plantation and they found higher species richness in forest ecosystem with six unique species as compared to one species in plantation ecosystem. They revealed that the variation in these two ecosystems was due to higher floral diversity in forest than plantation.

The diversity and distribution of termites are greatly influenced by factors such as vegetation type (Jones, 2000), habitat disturbance (Jones *et al*., 2003, DeBlauwe *et al*., 2008) and habitat fragmentation (DeSouza and Brown, 1994, Davies *et al*., 2003). Hence, termites have been used as indicator species to study the effect of land use conversion on biodiversity in several areas (Eggleton *et al*., 1996, Dibog *et al*., 1999).

A total of 28 species of termites were recorded at Maharashtra, India belonging to 13 genera under two families, namely, Rhinotermitidae (two species) and Termitidae (26 spp.). The members of the former family are partially wood and soil inhabiting, while those of the latter are purely soil-inhabiting species. Interestingly enough, the purely wood-inhabiting species belonging to the families, Kalotermitidae and Hodotermitidae being so common all over the country, are altogether absent, in spite of unique ecological habitats available in the evergreen rain forest in the Western Ghat area of Maharashtra (Roy, 2005).

Basu *et al.* (1996) reported that the density of termites was maximum in the month of February and lowest in April in undisturbed evergreen forest, October and August in slightly disturbed forest, February and December in acacia plantation. Shannon's index was maximum in undisturbed evergreen forest (0.78) followed by highly disturbed forest (0.73), slightly disturbed forest (0.59) and lowest in Acacia plantation (0.51). A comparative study (three forests, two pastures, one acasia plantation) of termites carried out in Western Ghatsto understand the impact of human disturbance on the different ecosystems by Basu *et al*. (1996) reveals that maximum number of species present in undisturbed evergreen forest and minimum in slightly disturbed forest.

The drastic reduction in termite species richness and the elimination of soil-feeding termites due to burning of the site after forest clearance was observed in forests of Tabalong district, Indonesia by Jones and Prasetyo (2002). They also reported that lower species richness was due to higher pH of the soil or naturallly occurring toxic concentrations of elements in the soil.

Six species of termites, *Psammotermes rajasthanicus*, *Coptotermes heimi, Odontotermes obesus, Microtermes unicolor, Microtermes mycophagus* and *Eramotermes paradoxalis* were recorded in Bahawalpur district, Pakistan by capturing identification survey and they reported that the maximum alpha diversity was found in August as 64 per cent on Simpson scale and 95 per cent on Shannon scale in September, where as in Beta diversity, maximum overlapping of species was observed by Ali *et al.* (2013), further they reported Shannon's and Simpson's indices were maximum in the month of August and lowest in November where as, evenness was maximum in the month of September and lowest in November.

Calderon and Constantino (2007) reported 28 termite species which belongs to Termitidae and Rhinotermitidae in a plantation of *Eucalyptus urophylla* in Buritis. It has lower species richness, a much lower proportion of soil-feeders and a higher proportion of litter-feeders when compared with native fauna.

Varma and Swaran (2007) reported that the maximum number of species were found in the month of November (5 species) and lowest in August (2 species) in *Eucalyptus* plantation. *Odontotermes obesus* was dominant (39%) followed by *O. feae* (20%) and *Microcerotermes fletcheri* (18%).Eleven termite species were recorded under two families and four subfamilies at eucalyptus plantation in Kerala. The subfamily

Macrotermitinae was dominated with eight species while the other three subfamilies were represented by a single species each. During April-November, a single species, *Odontotermes obesus* was most abundant. During December-January, *Microcerotermes fletcheri* was dominant, while *Odontotermes feae* dominated during February and March.

Junqueira *et al*. (2009) reported that the largest species richness (13) was found in the advanced succession area and the smallest species richness (8) was found in the three year old *Eucalyptus urophylla* forest. Abundance showed variations among the environments. Even with low abundance, observed occurrence linked to the presence of wood on the soil. Termite diversity was less in eucalyptus-grown areas than in forest fragments.

Termites were abundant in uncleared forest followed by regrowth forest and least in cleared forest (Dawes, 2010). Jasmi and Ahmad (2011) reported seven termite species belonging to six genera, viz., *Coptotermes curvignathus*, *Schedorhinotermes medioobcursus*, *S.malaccensis*, *Odontotermes sarawakensis*, *Prorhinotermes aequalis*, *Macrotermesmalaccensis* and *Hospitalitermes hospitalis* in the *Araucaria cunninghamii* plantation at Teluk Bahang Forest Park (TBFP), Penang.

Land use pattern also affect the Isoptera diversity. The results of belt transects conducted in different land-use types (protected lands, rangelands, and farmlands) in Ethiopia revealed termite abundance and diversity was determined by land use types (Debelo and Degaga, 2014).

Termites occurred less frequently in converted habitats than in old growth forest (Luke *et al.*, 2014). All termite feeding groups had low occurrence in disturbed habitats, with soil feeders occurring even less frequently than wood feeders within standardized volumes of soil and dead wood in old growth forest, logged forest and oil palm plantation in Sabah, Malaysian Borneo.

Density of termites also varies with season. Singh and Singh (1981) reported that *Odontotermes obesus* and *O. redemanni* were found with mound density of 5.05 and 3.95 mounds/ha respectively in the forest dominated by *Shorea robusta* in Varanasi, India.

The lowest termite population size existed in April while the maximum occurred in August (*O. obesus*) or in September (*O. redemanni*).

Highest species richness (14 species) occurred in sparse vegetation category followed by dense category (11) and the least (eight species) occurring on bare ground (Mugerwa *et al*., 2011). Samb *et al*. (2011) revealed 16 termite species belong to two families (Rhinotermitidae and Termitidae), of five subfamilies and 12 genera in ecosystems of grazing land, farms and houses, Senegal. Among the species, *Amitermes hastatus* was reported for the first time. Termite diversity and species distribution were affected by human activity which favours entry of potential pest species to human and his environment. In houses, *Amitermes evuncifer*, *Psammotermes hybostoma* and *Odontotermes* spp. are reported to cause minor damages. In sahelian agro-ecosystems, termites are minor pests attacking particularly farm fences inducing deforestation.

Togola *et al*. (2012) reported four termite species in the shrubs of Savanna and six species in upland rice field in Benin. The commonest species on rice were *Microcerotermes parvus*, *Microtermes* sp., *Pseudacanthotermes militaris* and *Amitermes evuncifer*. Termite attack was diverse, but mainly affected roots and stems.

Manzoor *et al*. (2013) reported six species of termites *i.e., Coptotermes heimi*, *Microcerotermes* spp., *Odontotermes obesus, Microtermes obesi*, *Microtermes mycophagus* and *Odontotermes guptai* from wheat fields and garden trees in Bhakkar district. Among the species, *M. mycophagus* was found to be dominant species in both garden treesas well as wheat crop. Shanbhag and Sundararaj (2013) used various diversity indices (Species diversity, Simpson's index, Margalef's diversity index, Menhinick's index and Shannon-Weiner index) to calculate termite biodiversity in forest and plantation area.

Hemachandra *et al.* (2014) reported that the termite diversity declined with increased elevation, with upper montane forests recording a single endemic species, *Postelectrotermes militaris* in the Knuckles Forest Region in central Sri Lanka. Transect sampling in lower montane forests yielded 26 species, with a higher number from dry forests (22 species) than from wet forests (15 species). Species specificity was also high in dry forests (11 species) compared with wet forests (four species). However, abundance did not show a distinct trend in dry and wet forests. In dry forests, both species richness (82%) and abundance (88%) of fungus-growing wood feeders were higher.

Species density data were collected using a standardized belt transect (100×2 m) while the abundance measurements were done using a standardized protocol based on 2×2-m quadrats in Cameroon, Malaysia and Peru. Highest estimates for abundance were found in Cameroon (1234±437 individuals/$m^2$) followed by Malaysia (327±72 individuals/$m^2$) and then Peru (130±39 individuals/$m^2$) (Dahlsjo *et al*., 2014). .

Study of the termite presence in five land-uses along a gradient of increased landuse intensity in the Central Highlands of Vietnam: viz., mixed deciduous forest (MF), secondary forest (SF), planted pine forest (PF), rubber plantation (RP), and coffee plantations (CP). The estimated number of termite species decreased along the landuse gradient. In coffee agroecosystems, the termite species richness was lower than that of the forest areas and monoculture rubber plantation. In terms of beta diversity, the termite faunal composition in CP was significantly separated from those of the other landuses, in which the similarity was only 28.67 per cent. Litter depth, canopy cover, and wood basal area were positively associated with the termite communities present in MF and SF, whereas the termite community in PF was positively associated with soil bulk density, leaf litter and understory vegetation. The ecological characteristics in RP and CP appeared to be negatively associated with wood basal area, leaf litter and understory vegetation where well represented by *Ancistrotermes pakistanicus* (Ahmad, 1950). The sites also supported a few soil feeding termites [e.g., *Dicuspiditermes garthwaitei* (Gardner), *Pericapritermes latignathus* (Holmgren) and *Pseudocapritermes sinensis* Ping and Xu in RP; only *D. garthwaitei* in CP (Neoh, 2015).

The species diversity was more in the family Termitidae, in closed-canopy tropical rainforests (Eggleton, 2000). The Termitidae not only constitute the majority of species, but also exhibit the widest range of ecological and behavioral diversity, including many traits that are fundamental to the evolution of the Isoptera, such as soil feeding and fungus-growing (Inward *et al.* 2007b) that allow this group to utilize other sources of cellulose in addition to wood. Due to their ecological and economic importance, termite identification is essential in urban and agricultural pest management, study of soil fauna, analysis of the diet of vertebrates and for other ecological or biological studies (Constantino, 2002).

Three subterranean termite species in the family, Rhinotermidae were observed (*Reticulitermes flavipes*, *R. virginicus* and *R. hageri*) from dead wood material and installed pine stakes in Southern Mississippi forests (Wang *et al*., 2009).

Kumar and Pardeshi (2011) reported 15 termite species belonging to seven genera and two families in the fields of sugarcane, wheat, castor and cotton. Out of which only five species were found as pests. *Odontotermes obesus* was the dominant species (28.16%) followed by *M. obesi* (25.26%), *M. mycophagus* (16.69%), *O. redemanni* (9.03%) and *C. heimi* (5.38%).

Mugerwa *et al.* (2011) reported 16 termite species from eight genera, three subfamilies and one family in Nakasongola, Uganda. Subfamily *Macrotermitinae* constituted 69 per cent of the total number of species sampled. Members from the genus *Macrotermes* were dominant species largely foraging on litter and nest in epigeal mounds and constituted 38 per cent of the total number of species sampled. Vegetation cover categories were noted to influence species richness. Highest species richness (14 species) occurred in sparse vegetation followed by dense (11 species) and the least (eight species) occurring on bare ground.

Rao *et al.* (2012) reported termites of Bhadrachalam region of Dhadakarnyam forest in Khammam district, Andhra Pradesh. Twelve termite species belongs to six genera, four subfamilies and two families *viz.*, Termitidae and Rhinotermitidae were recorded.

Twenty two termite species belongs to nine genera and three families were recorded in Yibin city. The dominant species were *Odontotermesformosanus* (32.15%), *R. chinensis* (24.24%), *R. flaviceps* (15.98%), and *R. aculabialis* (7.31%). *Reticulitermes* *chinensis* was the dominant species in the building region (75.61%). *Odontotermes formosanus* was found to be dominant species in garden region (55.28%), farmland region (40.44%), mountain slope-rangeland region (33.89%), man-made forest region (38.43%) and nature forest region (44.50%) (Hui *et al.*, 2013).

Bandeira *et al*. (2003) sampled the termites in different habitats at Brejo dos Cavalos, an island of humid, evergreen, highland forest surrounded by Caatinga (dry savanna) in Brazil. They reported that the diversity was drastically reduced by habitat disturbance and no termite was found at the site under annual monoculture. The termite fauna at the Brejo has a lower diversity when compared to the Amazon and northern Atlantic Forests, which maybe a consequence of habitat disturbance as well as of altitude and degree of isolation.

The effect of wet and dry season on termites foraging was examined in cropland, forest and grassland by sampling on monthly basis using standardized transect lines over a period of one year in Rufiji district by Matheru *et al.* (2013) and they revealed that the species abundance was significantly different between the three locations, but species richness was not significantly different. Further they also reported that termite abundance was higher in disturbed habitat due to the removal of vegetation which denies termites food and areas for nesting. Furthermore movement of termites from lower horizons during the wet season was higher than in the dry season.

**2.4 Developing distribution maps for termites of Western Ghats**

Termite identification is crucial for understanding termite distribution and their relationship to climate change (Ahmed *et al*., 2011). Ethiopian biogeographical region was most genus rich, while the Neotropical and Indo-Malayan regions were less as per the maps developed by Eggleton *et al*. (1997) using termite generic richness data.

Spatial distribution of termite mounds were recorded in 20 northern landscape zones of the Kruger National Park, South Africa by belt-transects method and activity within the termitaria was determined. The main mound-building genera were *Macrotermes* Holmgren (accounting for 62.4% of all active mounds), *Cubitermes*

Wasmann (29.8%), *Amitermes* Silvestri (4.3%), *Odontotermes* Holmgren (2.1%) and *Trinervitermes* Holmgren (1.4%). *Macrotermes* had an average mound density of 0.73/ha, with *M. natalensis* (Haviland) and *M. ukuzii* Fuller comprising the dominant species at densities of 0.27 and 0.25 mounds/ha respectively, were also mapped (Meyer *et al*., 1999).

Distribution map of 229 termite collections at University of Lagos Campus, Akoka, Lagos, reveals that *Amitermes* spp. was the most widely distributed species, followed by *Ancistrotermes*spp. While *Capritermes* spp. and *Microcertermes* spp.are considered as rare species and their distribution was limited (Kemabonta and Balogun, 2014).

Termites of Chhattisgarh, India were mapped by using DIVA GIS based on different habitat parameters such as vegetation type, ground cover, shrub density and distance from water body (Saha *et al*., 2016).

The distribution map developed from 289 termite samples collected from 45 counties in Indiana reveals that, *R. flavipes* was the dominant and most widely distributed species in Indiana (44 counties) followed by *R. virginicus* (13 counties). The three other *Reticulitermes* species, *R. arenincola*, *R. tibialis* and *R. hageni* were encountered in only five counties. *R. arenincola* was considered as a rare species and its distribution has been limited to sand dunes near Lake Michigan (Wang *et al*., 2009).

The spatial distribution and termite mounds density and their activity were studied in order to assess the biological restoration level in a protected area, knowing that termites are considered as tropical ecosystem engineers. The superposition of spatial distribution maps of the three types of termite mounds showed an impressive abundance of termite mounds in all national floristic center area. In total, there were recorded 165 termite mounds. They were composed of 119 epigeal termite mounds and 46 tree-dwelling termite mounds. The average density of the three types of termite mounds on the national floristic center area was 23.57 mounds/ha with a dispersion coefficient of 0.07 (Pierre *et al*., 2015).

# Material and Methods

# III. MATERIAL AND METHODS

In order to know the taxonomy, distribution and diversity of termite (Isoptera) fauna of Western Ghats, a study was undertaken in the Department of Agricultural Entomology, College of Agriculture, University of Agricultural and Horticultural Sciences (UAHS), Shivamogga during 2013-16. Materials used and methodologies followed during the course of investigation are presented in the following sections of this chapter.

## 3.1 Collection of termites in Western Ghats and species identification using soldier caste

### 3.1.1 Study Area

Sampling was done by surveying across Western Ghats region in different states such as Karnataka, Kerala, Tamil Nadu, Maharashtra, Gujarat and Goa (Fig. 1). The choices of sampling sites covered are the most commonly encountered microhabitats of termites. Sampling involved visual searching of nests, mud galleries and foraging sites in agricultural field, horticultural land, forest, pastures, along the avenues, rural and urban shelters and also different habitats of termites *viz*., wood (both damp-wood and dry-wood), subterranean nests (under soil at a depth of 1-30 cm), dung, litter, mounds, galleries and carton nests/arboreal nests.

In each selected places, geographical information’s like altitude, longitude and latitude were recorded using Global Positioning System (GPS) (Montana 650 Garmin, USA). Other details of sampling sites such as name of the place, host if any and date of collection were also recorded.

### 3.1.2 Sampling for termites

Pick axe or shovel was used to exposedifferent habitats of termites*viz*., termataria or mound, by digging the soil or splitting the infested wood (Plate 1-6).A forcep or moistened camel hair brush was used to transfer directly for a labelled vial containing 70

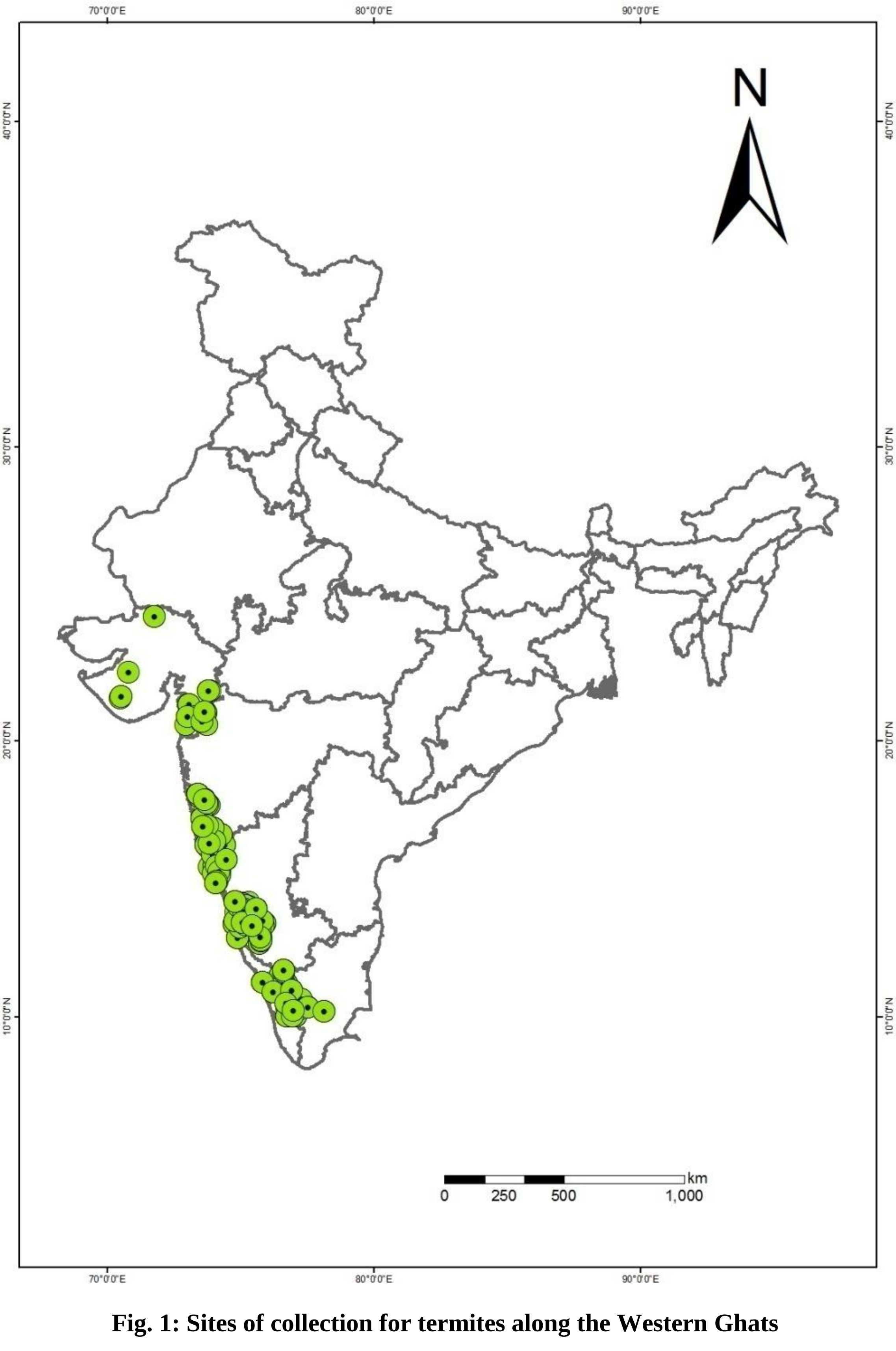


**Fig. 1: Sites of collection for termites along the Western Ghats**

Plate 1: Closed mound

Plate 2: Soil nest of *Trinervitermes*

Plate 3: Arboreal nest of *Nasutitermes*

Plate 4: Dead wood

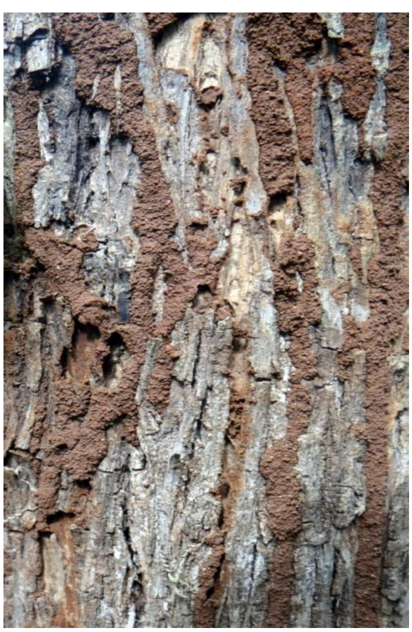

Plate 5: Soil gallery on forest tree

Plate 6: Cowdung

**Plate 1-6: Different habitats of termites**

per cent ethyl alcohol. Representatives of each of the castes were collected in a similar way for exploring further studies (Plate 7 and 8).

### 3.1.3 Labelling and preservation of samples

All the collected specimens were brought to the laboratory and transferred to Borosil vial (5 ml) containing 70 per cent ethyl alcohol and preserved as a permanent collection in insect specimen tube box/cabinet boxes (75 mm X 25 mm) maintained in the Department of Entomology, College of Agriculture, UAHS, Shivamogga, Karnataka and later used for further studies.

Collected samples were labelled with computer generated acid free bond paper/master sheet with label size of 2.5cm x 1.5cm. The label contains date of collected sample, place of collection (State: District: Village), latitude, longitude, altitude, type of habitat and name of the collector.

### 3.1.4 Identification of collected specimens based on the soldier caste

Major objective of the study was to provide an easy to use illustrated key for species level identification of termites of Western Ghats. The soldier caste was used for identification. Species level identification (some time genera also) involves measurement of different body parts of soldier caste. For accurate measurements, the alcohol preserved specimens were kept straight with the help of a specially designed arena/ platform and measured using ocular micrometer.

### 3.1.5 Arena/Platform for study

It consists of petriplate (5 cm diameter) with a semicircular thick foam placed firmly (Plate 9). One or two 'V' shaped notches of different length and width preferably 2 mm X 1 mm and 3 mm X 2 mm were made on the diagonal side of the foam to hold the specimen firmly and stretch the specimen straight with the help of forceps and micro needle for accurate measurement.


**Plate 7(A-C): Collection of termites from different habitats**

**Plate 8: Cleaning debris and transferring termites to a Borosil vial**

**Plate 9: Arena with specimen for microscopic observation**

### 3.1.6 Identification

Samples of soldier caste were picked up randomly from the labelled vial and measured under stereo binocular microscope (model: Lawrence and Mayo NSZ-606, Xiamen of China) with a magnification of 10-50X for taxonomic identification. Measurements were taken with the aid of calibrated ocular micrometer (0-10 divisions) and values are converted into mm using correction factor of ocular micrometer for each magnification. Soldier specimens of all the species collected were identified to species level using the keys or descriptions as mentioned by Roonwal and Chhotani (1989), Chhotani (1997) and Kalleshwaraswamy *et al*. (2013).

#### 3.1.6.1 Measurement and indices for mandibulate soldiers

The following measurements and indices were used for species level identification (Fig. 2 and 3). For soldier caste the following parameters were measured in milimeter (mm):

i) Length of head with mandibles

ii) Length of head without mandibles

iii) Width of head at the base of mandibles

iv) Maximum width of head

v) Length of left mandible

vi) Tooth of left mandible from tip

vii) Length of pronotum

viii) Width of pronotum

ix) Length of postmentum

x) Width of postmentum

xi) Length and width of labrum

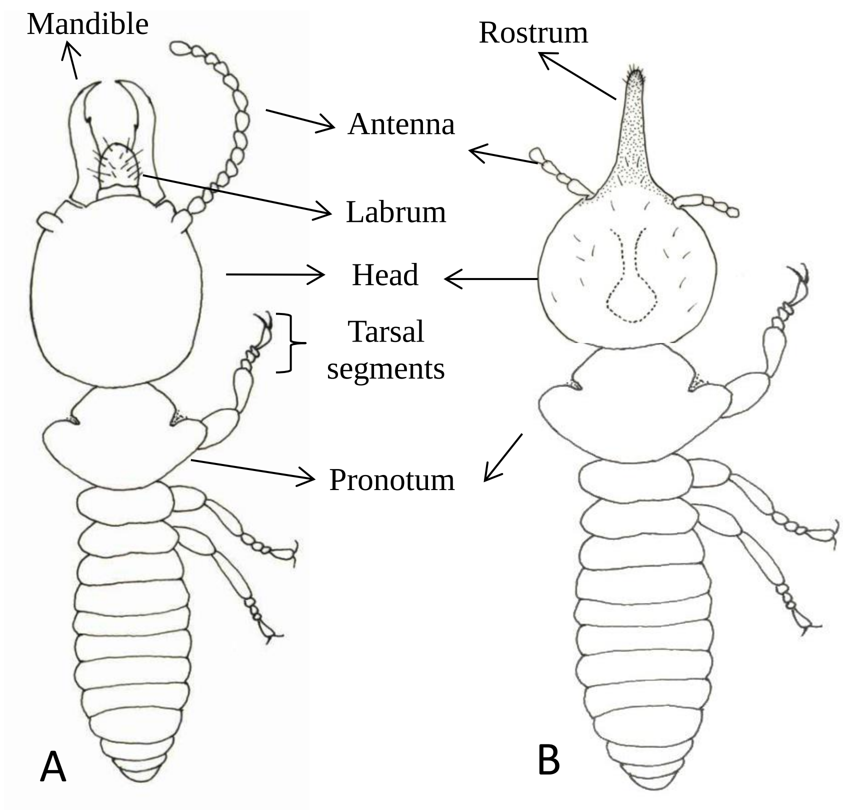


**Fig. 2: General view of termite soldier caste A. Mandibulate B. Nasutoid**

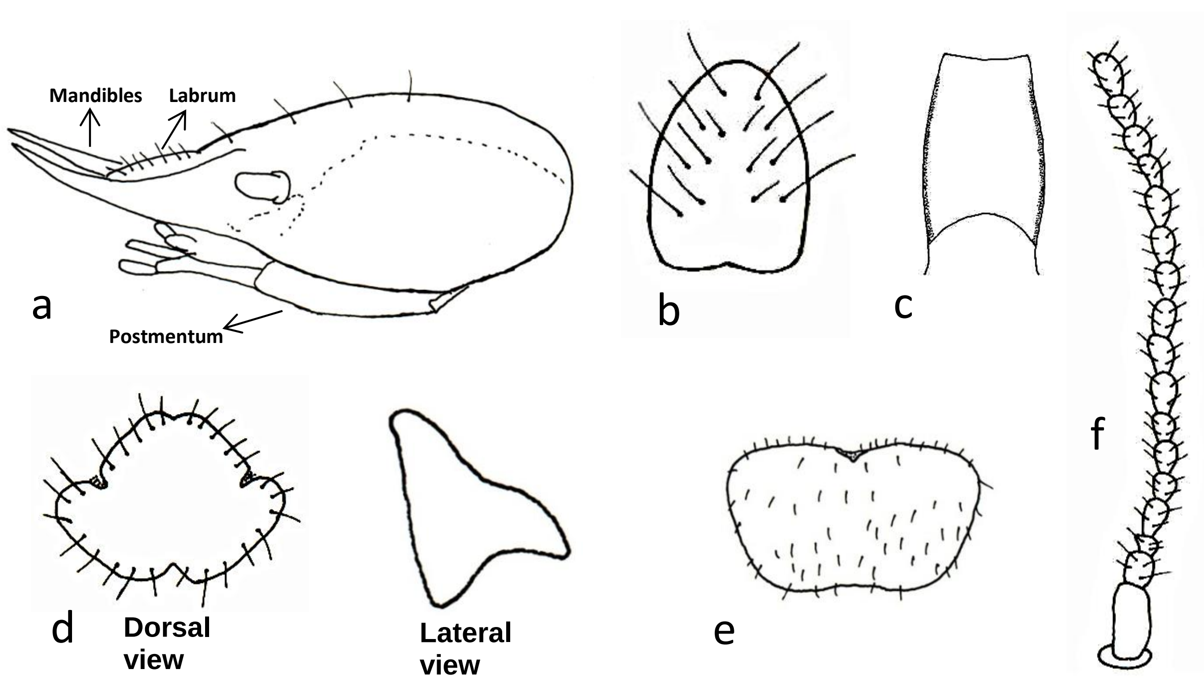


**Fig. 3: Schematic representation of different morphological structures.**

a. Head lateral view  b. Labrum  c. Postmentum  d. Saddle shaped pronotum
e. Flat shaped pronotum  f. Antenna

Indices used in the study are mentioned here under

1. Mandible index=Mandible length/Length of head to lateral base of mandibles
2. Head index= Head width /Length of head to lateral base of mandibles
3. Labrum index= Width of labrum/Length of labrum
4. Tooth index=Tooth distance from tip/Maximum length of mandibles
5. Pronotum index= Maximum width of pronotum/Length of pronotum
6. Postmentum index= Maximum width of postmentum/Length of postmentum
7. Head contraction index=Minimum width of Head/Maximum width of head with eyes

### 3.1.6.2 Morphological characters used in Nasutitermitinae

The subfamily Nasutitermitinae of Termitidae differs from other subfamilies or families with respect to head character. They can be easily distinguished by their snout like projection of the frons and vestigial or degenerated mandibles. The most important traits like, head and the rostrum including the length of the head, the length of head without the rostrum, the length of rostrum, and width of the head at base of rostrum were used to characterize or describe (Fig. 2 and 3).

The soldiers of few species are dimorphic or monomorphic. Wherever, dimorphism is found, they were referred as soldier major and soldier minor. The shape of the head varies markedly which helps in genus level identification. It may be pear shaped, round, depressed behind antennae or depressed at the base of rostrum. Mandibles are vestigial but presence or absence of a short spine like process is useful in the identification. Other characters used are number of antennal segments, pronotum length and width, rostrum-head index, *etc*.

**Indices used in Nasutitermitinae**

1. Rostrum head index: Rostrum length to head length

2. Head bulge index: Head production length to head length without rostrum

For keying out/identification, all the measurements and indices were calculated for five specimens in each of the collected species. All the termite species with an important taxonomic character studied were photographed using Leica M205C (Wetzlar and Mannheim, Germany) with auto montage.

### 3.1.7 Description

Description of each of the species identified was provided. In case of known species, description of additional characters or variations observed, if any, was given and information on the locality and remarks regarding the specimens were mentioned.

## 3.2 Molecular identification of selected termites

The work was carried out at Division of Biotechnology, Indian Institute of Horticultural Research (IIHR), Bengaluru. The technique employed for molecular identification mentioned hereunder. Mitochondrial 16s ribosomal RNA gene was used as a marker for molecular identification.

### 3.2.1 Isolation of genomic DNA (gDNA)

Genomic DNA was isolated with a slight modification in the STE buffer method proposed by Yeap *et al*. (2009) and the modified procedure is outlined here as follows.

1. Individual termite specimen was allowed to dry on filter paper II. The whole insect was homogenized in pestle and mortar using liquid nitrogen to a fine powder.
2. Added 800 µl of STE buffer (50mM sucrose, 25mM Tris HCl pH7.0 and 10mM EDTA).
3. DNA was extracted by incubation with proteinase K at 55ºC for 10 minutes followed by addition of 10% SDS and incubated for 30 min.
4. After a single extraction using phenol and chloroform, total DNA was precipitated with ethanol and then passed through nylon membrane column.
5. Added ethanol to the column and centrifuged for 1 minute at 10,000 rpm to dry the column. Discarded the flow-through and placed the column in the same collection

tube. Centrifuged the column for an additional 1 minute at 10,000 rpm to remove the traces of wash solution.

6. Finally, the genomic DNA was eluted with TE buffer 50µl and incubated for 1 minute at room temperature and centrifuged at 10,000 rpm for 1 minute to elute the DNA.
7. It was stored at –20°C, after checking with 0.8 per cent agarose gel.

### 3.2.2 Quantification of DNA by nanodrop spectrophotometer

The concentration of DNA sample was determined by nanodrop analysis (qualitative and quantitative) and electrophoresing DNA samples with 0.8 per cent agarose gel. The concentration of the fragment of interest was estimated by comparing the intensity of ethidium bromide fluorescence to that of the known DNA concentration standards. Two µl of DNA sample was loaded on 0.8 per cent agarose gel. The gel was run at 90 volts for 30min. Thereafter, the DNA bands were visualized under ultraviolet light and photographed.

### 3.2.3 PCR amplification of 16s RNA gene fragment

A fragment of ~420 base pairs of the 16s RNA gene fragment was amplified from the isolated DNA. The PCR was conducted using forward primer LR-J-13007/16f 5'-TTA CGC TGT TAT CCC TAA-3' (Kambhampati and Smith, 1995) and reverse primer LR-N-13398/16sr 5'-CGC CTG TTT ATC AAA AAC AT-3' (Simon *et al.,* 1994). The mtDNA amplification reactions were conducted using a thermal cycler programmed for 35 cycles (Eppendorf, CA) in 25 µl volume containing 3 µl genomic DNA, 1 µl of 10 mMdNTP, 0.7 µl of 10pM primer, 2.5 µl of 10× reaction buffer, 0.7 µl of 25mM $Mgcl_2$, 0.3 µl of DMSO, 1 µl of 2 unit of Taq DNA polymerase (Genie) with the following conditions:

| **Steps** | **Temperature (˚C)** | **Time** |
|---|---|---|
| Initial denaturation | 94 | 2 min |
| Denaturation | 94 | 45sec |
| Annealing | 51.30 | 45sec |
| Elongation | 72 | 60 sec |
| Final extension | 72 | 10 min |

The PCR negative control contained the identical amount of PCR mixture with 5 µl distilled water instead of DNA template. A PCR positive control was also included, containing the PCR mixture plus DNA that had been successfully put through the PCR reaction in previous studies.  PCR products were visualized after electrophoresis on a 1.5per cent agarose gel stained with ethidium bromide (10µg/ml) and visualized in a gel documentation system (UVP, UK). Expected products were observed as the single band and gel-eluted using Nucleospin Extract II (Machery Nagel, Germany) according to manufacturer's protocol.

**3.2.4 Gel elution of PCR product**

NucleoSpin Extract II kit (Machery Nagel, Germany) was used and followed protocol as per manufacturer's instructions.

1. **Excise DNA fragment/solubilize gel slice-**A clean scalpel was used to excise the DNA fragment from an agarose gel. Excised gel slice containing the fragment was cut carefully to minimize the gel volume. The weight of the gel slice was determined and transferred it to a clean tube. For each 100mg of agarose gel, 200µl Buffer NT (Binding buffer) was added. Sample was incubated for 5 to 10 min at 50°C. The sample was vortexed briefly for every 2-3 min until the gel slice was completely dissolved.

2. **Bind DNA-**NucleoSpin Extract II column was placed into a collection tube (2ml) and sample was loaded. Centrifuged for 1 min at 11,000 rpm. Flow-through was discarded and the NucleoSpin Extract II column was placed back into the collection tube.

3. **Wash silica membrane-** 700µl Buffer NT3 (Wash buffer) was added to the NucleoSpin Extract II column. Centrifuged for 1 min at 11,000 rpm. Flow-through was discarded and the NucleoSpin Extract II column was placed back into the collection tube.

4. **Dry silica membrane-** The column was centrifuged for 2 min at 11,000 rpm to remove Buffer NT3 quantitatively which contains ethanol that might inhibit

subsequent reactions. Care was taken that the spin column did not come in contact with the flow-through while removing it from the centrifuge and the collection tube.

5. **Elute DNA-** Nucleospin Extract II column was placed into a clean 1.5ml microcentrifuge tube. 15-50 µl buffer NE (Elution Buffer) was added and incubated at room temperature for 1 min to increase the yield of eluted DNA. Centrifuged for 1 min at 11,000 rpm.

### 3.2.5 Molecular Cloning

The InsTAclone PCR Cloning Kit takes advantage of the terminal transferase activity of *Taq* DNA polymerase and other non-proof reading thermostable DNA polymerases. Then added a single 3'-A overhang to both ends of the PCR product. The structure of these PCR products favours direct cloning into a linearized cloning vector with single 3'-ddT overhangs. Such overhangs at the vector cloning site not only facilitate cloning, but also prevent the recircularization of the vector. As a result, more than 90 per cent of recombinant clones contain the vector with an insert. Recombinant clones are selected based on blue/white screening and confirmed by colony PCR.

### 3.2.6 Cloning Protocol

#### a) Ligation of eluted PCR product

Joining linear DNA fragments together with covalent bonds is called ligation. More specifically, DNA ligation involves creating a phosphodiester bond between the 3' hydroxyl of one nucleotide and the 5' phosphate of another. The enzyme used to ligate DNA fragments was T4 DNA ligase, which originates from the T4 bacteriophage. The enzyme will ligate DNA fragments having overhanging, cohesive ends that are annealed together.

Following ingredients were placed and mixed in the ice tray, and whole ligation procedure was carried out inside the laminar air flow (LAF) chamber.

| Component | Volume |
|---|---|
| Vector, pTZ57R/T | 0.8µl |
| 5X Ligation Buffer | 4.0µl |
| Eluted PCR product | 6.0µl |
| Water, nuclease-free | 8.7µl |
| T4 DNA Ligase | 0.5µl |
| **Total volume** | **20 µl** |

1. The ingredients were added as per the order.
2. Ligase enzyme was added at last, in order to prevent the self-ligation of the vector ends.
3. The tubes were vortexed briefly and centrifuged for 3-5 seconds.
4. The ligation mixture was incubated overnight at 4°C.
5. During ligation process, the competent *E. coli* (DH5α) cells were prepared using the provided reagents.
6. 6 µl of the ligation mixture was directly used for bacterial transformation.

**b) *Escherichia coli* (DH5α) competent cells preparation and transformation**

1. The day before the transformation, overnight culture was seeded by inoculating 2 ml of LB broth with a single freshly streaked (DH5α) bacterial colony. The culture was incubated overnight at 37°C in a shaker.
2. 150µl of the overnight DH5α bacterial culture was added to 900 µl of pre-warmed C-media in 1.5 ml tube and incubated for 1 hour at 37°C in a shaker incubator at the speed of 220 rpm.
3. The bacterial cells were pelleted out by 3 minutes centrifugation in 4°C at 6,000 rpm and the supernatant was discarded.
4. The pelleted cells were resuspended in 120 µl of TA/TB solution (1 TA : 1 TB mixture) and incubated on ice for 5 minutes.

5. Centrifugation was performed at 6,000 rpm for 3 minutes at 4°C, supernatant was discarded.
6. The pelleted cells were resuspended in 60 µl of TA/TB solution and incubated on ice for 5 minutes.
7. 6µl of ligated mixture was added to new microcentrifuge tubes and chilled on ice for 2 minutes.
8. 30µl of the prepared cells were added to each tube containing ligated sample mixed and incubated on ice for 5 minutes.

### 3.2.7 Colony selection

**Blue/White colony selection**

The transformation mixture was plated immediately on pre-warmed LB-ampicillin agar plates with X-gal and IPTG and spread thoroughly on LB-ampicillin agar plates using a spreader. The plates were wrapped with the parafilm and incubated overnight at 37°C. Transformed white colonies and untransformed blue colonies were formed.Transformed (white) colonies were selected and sub-streaked on pre-warmed LB-ampicillin agar plates with X-gal and IPTG and incubated overnight at 37°C.

### 3.2.8 Analysis of recombinant clones

White colonies were verified for the presence of DNA insert using colony PCR.

**a) Colony PCR**

Colony PCR was the screening of bacterial (*E.coli*) clones for correct ligation or plasmid products. White colonies of bacteria were picked from substreaked plates with a sterile toothpick or pipette tip from a LB-ampicillin agar plates with X-gal and IPTGgrowth plate. This was then inserted into the PCR master mix or pre-inserted into autoclaved water. PCR was then conducted to determine if the colony contains the DNA fragment of interest.

The following protocol for colony screening by PCR was used. Enough PCR master mix was prepared for the number of colonies analyzed. For each 20 µl reaction, the following reagents were mixed:

| **Component** | **Volume** |
|---|---|
| 10X *Taq* Buffer | 2.0 µl |
| dNTP mix, 2 mm each | 2.0 µl |
| 25 mM $MgCl_2$ | 1.2 µl |
| LCO forward primer, 10 µM | 0.6 µl |
| HCO reverse primer, 10 µM | 0.6 µl |
| *Taq*DNA polymerase 5 u/µl | 0.1 µl |
| Water, nuclease-free | 13.5 µl |
| **Total volume** | **20 µl** |

1. 20µl of the mix was aliquated into the PCR tubes on ice.
2. Substreaked individual white colony was picked and resuspended in 20 µl of the PCR master mix.
3. PCR was performed: 94°C, 2 min; 94°C, 30 s, 54°C, 30 s, 72°C 1 min/kb; 30 cycles.
4. Presence of the PCR product of the expected length was analysed on the gel.

### 3.2.9 Plasmid isolation of recombinant clones

Plasmid purification was carried out from incubated transformed colonies multiplying in LB broth vials with the help of Gene JET™ Plasmid Miniprep Kit (Thermo Scientific, Fermentas, Lithuania) according to manufacturer's protocol.

1. Colony PCR selected transformed (white) restreaked colonies were inoculated into 15 ml Falcon tubes with 5 ml LB-ampicillin broth with the help of autoclaved plastic tooth-pick sand wrapped with the parafilm.
2. The tubes were incubated in a shaker incubator overnight at 37°C at the speed of 220 rpm.

3. The bacterial culture was harvested by centrifugation at 8,000 rpm in a 2 ml microcentrifuge for 2 minutes at room temperature. The supernatant was discarded and the remaining medium was removed. This step was repeated twice.
4. The pellet was resuspended in 250 µl of the resuspension solution. Cell suspension was transferred to a microcentrifuge tube. The bacteria were resuspended completely by vortexing or pipetting up and down until no cell clumps remained.
5. 250 µl of the Lysis Solution was added and mixed thoroughly by inverting the tube 4-6 times until the solution became viscous and slightly clear.
6. 350 µl of the Neutralization Solution was added and mixed immediately and thoroughly by inverting the tube 4-6 times. The neutralized bacterial lysate should become cloudy.
7. Centrifuge for 5 min to pellet cell debris and chromosomal DNA. Supernatant was transferred to the GeneJET spin column by decanting or pipetting. Avoid disturbing or transferring the white precipitate. Centrifuge for 1 min. Flow-through was discarded and the column was placed back into the same collection tube.
8. 500 µl of the wash solution (diluted with ethanol prior to first use) was added to the GeneJET spin column. Centrifuged for 30-60 seconds and discarded the flow-through. Column was placed back into the same collection tube.
9. Wash procedure (step 8) was repeated using 500 µl of the wash solution.The flow-through was discarded and centrifuged for an additional 1 min to remove residual wash solution. This step was essential to avoid residual ethanol in plasmid preps.
10. The GeneJET spin column was transfered into a fresh 1.5 ml microcentrifuge tube. 50 µl of the elution buffer was added to the center of Gene JET spin column membrane to elute the plasmid DNA. Care was taken not to contact the membrane with the pipette tip. Column was incubated for 2 min at room temperature and centrifuged for 2 min.
11. The column was discarded and the purified plasmid DNA was stored at -20°C until further use.

### 3.2.10 Sequencing

Isolated plasmid DNA, from an overnight bacterial culture, using a reliable plasmid miniprep method was sequenced using standard M13 sequencing primers. Termite mitochondrial 16s rRNA gene fragments were sequenced using purified recombinant plasmids. Sequencing was performed in triplicates of the above clones and the PCR products in an automated sequencer (ABI prism® 3730 XL DNA Analyzer; Applied Biosystems, USA at Eurofins Labs Pvt. Ltd. Bengaluru).

### 3.2.11 Sequence Analysis and Data Interpretation

Chromatograms were edited to discard ambiguous bases and edited sequences were aligned by using the Basic Local Alignment Search Tool (BLAST, http://www.ncbi.nlm.nih.gov), with the sequences of same or related genera retrieved from the nucleotide database (PUBMED) of National Centre for Biotechnology Information (NCBI). Sequences containing insertions, deletions, nonsense or stop codons were considered as having resulted from PCR/sequencing errors or represented pseudogenes (numt), and were thus excluded from the analyses. *In silico* analyses of the sequences were carried out to confirm the sequence accuracy. 16s rRNA gene sequences corresponding to different geographical location and hosts of termites and other related species used in this study were downloaded from the National Center for Biotechnology Information (NCBI) GenBank for phylogenetic analysis. Sequence alignment was performed employing CLUSTAL-W multiple alignment tool in BioEdit. 7.0.5.3. sequence alignment editor. The sequences were further analyzed using MEGA.6.0 (Tamura *et al*., 2007) to obtain conspecific and congeneric distances, whilst Neighbor-Joining trees were constructed using the Kimura-2-parameter (K2P) distance model (Kimura, 1980; Saitou & Nei, 1987) employing MEGA.6.0 (Tamura *et al*., 2007). All the sequences generated in the present study were deposited in NCBI-GenBank. Test for substitution saturation was conducted using the software DAMBE (Xia, 2013). Phylogenetic analyses were conducted in Mr. Bayes: Bayesian Inference of Phylogeny.

### 3.3 Estimation of termitediversity in different ecosystems

The study was conducted to understand the impact of anthropogenic disturbance and depleting organic matter content on the diversity of termites.

### 3.3.1 Habitat

A representative location/habitat was selected in each of the three habitats along the Western Ghats of Karnataka representing reserve forest, pasture (uncultivated waste land with grasses) and manmade plantation (Teak).

The habitats selected for studies include (i) a pasture in Kalkodu, near Agumbe, Thirthahalli taluk, Shivamogga district (Long. $13^0$ 34’ N, Lat. $75^0$ 07’E, altitude 631 m above mean sea level) (ii) A reserved forest in Balehonnur, Narasimharajapura taluka, Chikkamagluru district (Long. $13^0$ 24’ N, Lat. $74^0$ 50’E, altitude. 791m above mean sea level) and iii) as a representative of a teak plantation in Ayanur, Shivamogga taluk and district (Long. $13^0$ 34’ N, Lat. $75^0$ 07’E, altitude 683m above mean sea level). The method of sampling is described as under.

### 3.3.2 Transect method

Thestandard protocol followed was the belt transect method (Jones and Eggleton, 2000; Davies, 1997; Eggleton *et al.*, 1997) for sampling termites. Sampling was done at bi-monthly interval from July-2015 to May-2016 in reserve forest, pasture and plantation habitats. Transect of 100 mlong and 2 m wide was chosen for the study and this area divided into 20 contiguous sections of each measuring 5 m x 2 m. Within each section, the microhabitats of termites weresearched, which include dead logs, fallen tree, branch, sticks, leaf litter, vegetation *etc.* All the castes (soldiers and workers) were collected and labelled with section number.The termitescollected were kept in vials containing 70 per cent ethyl alcohol and labelled. Specimens were later sorted to castes in the laboratory and preserved specimens were counted based on castes and soldier caste was used for the species identification.

A total of 37, 49 and 94 samples were collected in pasture, plantation and forest ecosystem, respectively. The number of species encountered in each transect was used as an indicator of relative abundance of species. The species diversity was compared in three different habitats and the percentage of its occurrence was calculated.

In these ecosystems, samplings were made six times over one year *ie*., in July, September and November months in 2015 and January, March and May months in 2016, to record the extent of variation in detail as a part of study to indicate diversity and abundance of different termites species.

#### 3.3.2.1 Soil analysis

Soil samples were collected from three different represented habitats and analyzed for particle size distribution, pH, organic carbon and nitrogen content.

##### 3.3.2.1.1 Collection and preparation of soil samples

Surface soil samples (0-15 cm depth) were collected from three different habitats. These samples were dried, powdered and passed through 2 mm sieve and preserved for analysis.

##### 3.3.2.1.2 Particle size distribution analysis

Particle size analysis to assess the proportion of sand, silt and clay was carried out by international pipette method as per procedure described by piper (1966).

##### 3.3.2.1.2 Chemical properties

**Soil reaction (pH)**

Soil pH was determined in 1:2.5 soil water suspension after stirring intermittently for half an hour using digital systronic 361 pH meter with glass electrode (Jackson, 1973).

**Electrical Conductivity (EC)**

Electrical conductivity of the soil samples was determined by 1:2 soil water extract using a conductivity meter and results were expressed in the terms of $dSm^{-1}$ at $25^0C$ (Jackson, 1973).

**Organic Carbon (OC)**

The organic carbon in soil samples was determined by treating a known weight of soil sample (0.50 g) with a known excess quantity of chromic acid (Sulphuric acid & Potassium chromate) to oxidize the organic carbon present in the soil to carbon dioxide. After oxidation, the un-reacted potassium dichromate left in the contents was back titrated against standard ferrous ammonium sulphate using diphenylamine indicator (Walkley and Black, 1934).

**Available nitrogen**

Available nitrogen in soils was determined by alkaline potassium permanganate methods as described by Subbaiah and Asija (1956).

**3.3.2.2 Data analysis**

After completion of survey, taxonomy and distribution studies, the data was used to ascertain the diversity of termites across habitats, locations, soil type, soil organic matter *etc.*The termite diversity, richness, density and per cent contribution of termite species at the bi-monthly interval in three habitats and number of species encountered were calculated. The relative variations across each of these factors were quantified using the following diversity indices and these have been successfully demonstrated to be useful measures of diversity (Magurran, 1988).

**3.3.2.3 Shannon-Wiener index (H)**

Shannon-Wiener index is one of the most widely used indices to measure the diversity. Ittakes both the number of species and relative abundance of each of these species in a community/sample into account to determine the diversity index.

Shannon- Weiner (also called as Weaver) diversity index is calculated as:

$$H' = -\sum P_i ln P_i$$

Where,

$P_i$= the proportion of individuals in the $i^{th}$ species in the sample.

### 3.3.2.4 Simpson's diversity index (D)

Simpson's diversity index is the measure of dominance and abundance of the commonest species rather than measure the species richness. Simpson's index (Simpson, 1949) describes the probability that a second individual drawn from a population could be of the same species as the first. It is calculated by using the following formula.

$$D = \sum_{i=1}^{R} \frac{N_i\ (N_i - 1)}{N_t\ (N_t - 1)}$$

Where,

$N_i$ = number of individuals in the $i^{th}$ species and

Nt = the total individuals in the sample.

So, the larger its value the greater is the dominance.

### 3.3.2.5 Evenness (E)

Evenness is ratio of Shannon's index to the natural logarithm of number of species. It indicates the number of species and is given by following formula.

$$\mathrm{E} = \frac{\mathrm{H}}{\ln \mathrm{S}}$$

Where,

H = Observed Shannon-Weiner index

S = Total number of species in the habitat

#### 3.3.2.6 Margalef's diversity index (Dmg)

It is measure of the species diversity and calculated using the following formula.

$$D_{mg} = \frac{(S - 1)}{\ln N}$$

Where,

S = number of species

N = total number of individuals

#### 3.3.2.7 Menhinick's index (Dmn)

It is also measure of species diversity by using the following formula.

$$D_{mn} = \frac{S}{\sqrt{N}}$$

Where,

S = number of species

N = total number of individuals

#### 3.3.2.8 Density

It is measure of the number of individuals per unit area.

$$\text{Density} = \frac{\text{Total number of individuals}}{\text{sampled area } (m^2)}$$

#### 3.3.2.9 Dominant species

Species which contributes the maximum number in a sampling in a habitat is considered as dominant species and expressed in percentage.

#### 3.3.2.10 Alpha diversity

It is referred to the number of species found within a habitat.

#### 3.3.2.11 Beta diversity

It is referred to change in the species diversity between the ecosystems or habitats. The species are unique to each of ecosystem.

#### 3.3.2.12 Gamma diversity

It is a measure of the overall diversity for different ecosystems within a region.

## 3.4 Developing distribution maps for termites of Western Ghats

A GIS is a computerized database designed for the management and use of spatial data (Hasmadi *et al*, 2010). At the time of sampling of termites, for each location analtitude (above mean sea level), longitude and latitude data was noted using Montana 650 Garmin Global Positioning System (GPS) device. This collected data was used to georeferencing in a Quantum geographical information system (Q-GIS) software to obtain maps to show termite distribution on all the surveyed areas. These distribution maps, helps to identify the pattern, species richness and species poorness.

# Experimental Results

# IV. EXPERIMENTAL RESULTS

Investigations were undertaken to know the termite species diversity of Western Ghats, to develop the taxonomic key based on the soldier caste, to compare the species diversity in the three ecological regions using species diversity indices and the development of distribution maps. The results of the investigation are presented below.

## 4.1 Collection of termites in Western Ghats and species identification using soldier caste

### 4.1.1 Termite fauna found in Western Ghats

Survey on the termite fauna of Western Ghats indicated the presence of 42 species belonging to 13 genera and six subfamilies under two families *viz.*, Rhinotermitidae and Termitidae (Table 1).

Rhinotermitidae was represented by 2.01 per cent of the total collections with two subfamilies *viz.*, Coptotermitinae and Heterotermitinae. The subfamily, Coptotermitinae included three species *i.e. Coptotermes ceylonicus* Holmgren, *Coptotermes kishori* Roonwal and Chhotani, *Coptotermes heimi* (Wasmann) and represented 1.34 per cent of total sample collections and covered 66.67 per cent of the family. Whereas, Heterotermitinae, represented 0.67 per cent of the total collections and 33.33 per cent of the family, included two species namely, *Heterotermes balwanti* Mathur and Chhotani and *H. malabaricus* Snyder. Rhinotermitidae was represented by only five species.

Termitidae was the most dominant family which represented 97.99 per cent of the total collections with 37 species in 11 genera belonging to four subfamilies *viz.*, Amitermitinae, Macrotermitinae, Nasutitermitinae and Termitinae. Among the subfamilies, highest numbers of species (18) were observed in Macrotermitinae, followed by seven species in Nasutitermitinae, and six species each in Termitinae and Amitermitinae. Macrotermitinae was represented by 81.11 per cent of the total sample collections and covers 82.76 per cent of the family Termitidae and included two genera, *i.e., Microtermes* and *Odontotermes*. There were two species (*Microtermes obesi* Holmgren and *M. incertoides* Holmgren) in the genera *Microtermes.* Whereas, the genus

*Odontotermes* represented highest number (16) of species, (*O. anamallensis* Holmgren and Holmgren, *O. assmuthi* Holmgren, *O. bellahunisensis* Holmgren and Holmgren, *O. bhagwatii* Chatterjee and Thakur, *O. boveni* Thakur, *O. brunneus* (Hagen), *O. ceylonicus* (Wasmann), *O. feae* (Wasmann), *O. globicola* (Wasmann), *O. horni* (Wasmann), *O. obesus* (Rambur), *O. peshawarensis* Akhtar, *O. redemanni* (Wasmann), *O. vaishno* Bose, *O. wallonensis* (Wasmann) and *O. yadevi* Thakur. The subfamily, Amitermitinae was contributed 7.36 per cent of the total collections and 7.51 per cent with respect to family Termitidae, respectively and they belonging to three genera and six species namely, *Eurytermes buddha* Bose and Maiti, *Eurytermes assmuthi assmuthi* Wasmann, *Microcerotermes fletcheri* Holmgren and Holmgren, *M. pakistanicus* Akhtar, *M. minor* Holmgren and *Synhamitermes quadriceps* Wasmann. Nasutitermitinae had a share of 6.68 per cent of the total collections of samples and covered 6.82 per cent of the family Termitidae. It was represented by two genera with seven species, namely *Nasutitermes anamalaiensis* Snyder, *N. dunensis* Chatterjee and Thakur, *N. gardneri* Snyder, *N. indicola* (Holmgren and Holmgren), *Trinervitermes biformis* (Wasmann), *T. nigrirostris* Mathur and Sen-Sarma and *T. sensarmai* Bose. Termitinae comprises 2.84 per cent of the total sample collections and covers 2.90 per cent of the family Termitidae. This subfamily represents six species with four genera, namely *Labiocapritermes distortus* (Silvestri), *Angulitermes fletcheri* (Holmgren and Holmgren), *Pseudocapritermes fletcheri* (Holmgren and Holmgren), *Dicuspiditermes gravelyi*, (Silvestri), *D. incola* (Wasmann) and *D. obtusus* (Silvestri) (Table 1).

A total of 42 species were recorded in the present study. Among the species, *O. obesus* was most frequently occurred in the collections (210 samples) and also shared highest percentage to the total collections followed by *O. feae* (90 samples), O. *bellahunisensis* (46 samples) and *O. assmuthi* (38 samples).

Among the family Rhinotermitidae, the species *Coptotermes ceylonicus* occupied highest percentage (1.00) (Table 1). In the family Termitidae, *O. obesus* occupied highest percentage (35.11%) and which comes under subfamily Macrotermitinae. Among the subfamilies, Macrotermitinae contributed for highest percentage (81.11%) followed by

**Table 1. Termite species found in Western Ghats during study period (September 2013-May 2016)**

| Sl. No. | Families | Subfamilies | Species | Samples | % |
|---|---|---|---|---|---|
| 1 | Rhinotermitidae (2.01%) | Coptotermitinae (1.34%) | *Coptotermes ceylonicus* Holmgren | 6 | 1.00 |
| 2 | | | *C. kishori* Roonwal and Chhotani | 1 | 0.17 |
| 3 | | | *C. heimi* (Wasmann) | 1 | 0.17 |
| 4 | | Heterotermitinae (0.67%) | *Heterotermes balwanti* Mathur and Chhotani | 1 | 0.17 |
| 5 | | | *H. malabaricus* Snyder | 3 | 0.50 |
| 6 | Termitidae (97.99%) | Amitermitinae (7.36%) | *Eurytermes buddha* Bose and Maiti | 1 | 0.17 |
| 7 | | | *E. assmuthi assmuthi* Wasmann | 1 | 0.17 |
| 8 | | | *Microcerotermes pakistanicus* Akhtar | 9 | 1.50 |
| 9 | | | *M. fletcheri* Holmgren and Holmgren | 24 | 4.01 |
| 10 | | | *M. minor* Holmgren | 4 | 0.67 |
| 11 | | | *Synhamitermes quadriceps* Wasmann | 5 | 0.84 |
| 12 | | Macrotermitinae (81.11%) | *Microtermes obesi* Holmgren | 26 | 4.34 |
| 13 | | | *M. incertoides* Holmgren | 17 | 2.84 |
| 14 | | | *Odontotermes assmuthi* Holmgren | 38 | 6.35 |
| 15 | | | *O. anamallensis* Holmgren and Holmgren | 3 | 0.50 |
| 16 | | | *O. bellahunisensis* Holmgren and Holmgren | 46 | 7.69 |
| 17 | | | *O. bhagwatii* Chatterjee and Thakur | 1 | 0.17 |
| 18 | | | *O. boveni* Thakur | 3 | 0.50 |
| 19 | | | *O. brunneus* (Hagen) | 6 | 1.00 |
| 20 | | | *O. ceylonicus* (Wasmann) | 5 | 0.84 |
| 21 | | | *O. feae* (Wasmann) | 90 | 15.05 |
| 22 | | | *O. globicola* (Wasmann) | 1 | 0.17 |

| Sl. No. | Families | Subfamilies | Species | Samples | % |
|---|---|---|---|---|---|
| 23 | | | *O. horni* (Wasmann) | 1 | 0.17 |
| 24 | | | *O. obesus* (Rambur) | 210 | 35.11 |
| 25 | | | *O. peshawarensis* Akhtar | 1 | 0.17 |
| 26 | | | *O. redemanni* (Wasmann) | 8 | 1.34 |
| 27 | | | *O. vaishno* Bose | 15 | 2.51 |
| 28 | | | *O. wallonensis* (Wasmann) | 6 | 1.00 |
| 29 | | | *O. yadevi* Thakur | 8 | 1.34 |
| 30 | | Nasutitermitinae (6.68%) | *Nasutitermes anamalaiensis* Snyder | 4 | 0.67 |
| 31 | | | *N. dunensis* Chatterjee and Thakur | 5 | 0.84 |
| 32 | | | *N. gardneri* Snyder | 1 | 0.17 |
| 33 | | | *N. indicola* (Holmgren and Holmgren) | 11 | 1.84 |
| 34 | | | *Trinervitermes biformis* (Wasmann) | 14 | 2.34 |
| 35 | | | *T. nigrirostris* Mathur and Sen-Sarma | 1 | 0.17 |
| 36 | | | *T. sensarmai* Bose | 4 | 0.67 |
| 37 | | Termitinae (2.84%) | *Labiocapritermes distortus* (Silvestri) | 2 | 0.33 |
| 38 | | | *Angulitermes fletcheri* (Holmgren and Holmgren) | 1 | 0.17 |
| 39 | | | *Pseudocapritermes fletcheri* (Holmgren and Holmgren) | 3 | 0.50 |
| 40 | | | *Dicuspiditermes gravelyi* (Silvestri) | 2 | 0.33 |
| 41 | | | *D. incola* (Wasmann) | 1 | 0.17 |
| 42 | | | *D. obtusus* (Silvestri) | 8 | 1.34 |
| **Total** | | | | **598** | **100** |

Amitermitinae (7.36%), Nasutitermitinae (6.68%), Termitinae (2.84 %), Coptotermitinae (1.34 %) and Heterotermitinae (0.67 %).

The species, *Microcerotermes fletcheri* in the subfamily, Amitermitinae represented highest percentage (4.01 %), followed by *M. pakistanicus* (1.50 %) and *Synhamitermes quadriceps* (0.84 %).

In Nasutitermitinae, *Trinervitermes biformis* had highest percentage (2.34%), followed by *Nasutitermes indicola* (1.84%) and least per cent of 0.17 by *Nasutitermes gardneri* and *Trinervitermes nigrirostris.*

Within the subfamily of termitinae, *Dicuspiditermes obtusus* (1.34%) found to be more dominant followed by *Pseudocapritermes fletcheri* (0.50%), *Labriocapritermes distortus* and *Dicuspiditermes gravelyi* which contributed 0.33 per cent each.

#### 4.1.1.1. Termite species contribution in Western Ghats

The highest contribution was by *O. obesus* with 35.11 per cent. This species represented 35.80 and 43.30 per cent of total samples, with respect to family Termitidae and subfamily Macrotermitinae, respectively. This was followed by *O. feae* (which contributed 15.05, 15.36 and 18.55 per cent of total samples with respect to species, family Termitidae, subfamily Macrotermitinae, respectively). The next was *O. bellahunisensis* contributed 7.69, 7.84 and 9.48 per cent of total samples, family Termitidae and subfamily Macrotermitinae, respectively. The least 0.17% was contributed by *Coptotermes kishori*, *C. heimi*, *Heterotermes balwanti*, *Eurytermes budda*, *Eurytermes assmuthi assmuthi*, *O. bhagwatii*, *O. globicola*, *O. horni*, *O. peshawarensis*, *Nasutitermes gardneri*, *Trinervitermes nigrirostris*, *Angulitermes fletcheri* and *Dicuspiditermes gravelyi.*

### 4.1.2. Taxonomical key developed based on the soldier caste

#### 4.1.2.1 Key to the family of Isoptera

1. Pronotum saddle shaped (Plate A1)**-----------------------------------**Termitidae Westwood

1a. Pronotum flat (Plate A2)**---------------------------------------------**Rhinotermitidae Froggatt

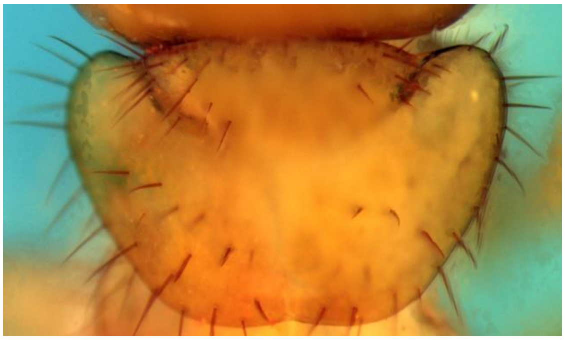

Plate A1: Saddle shaped pronotum

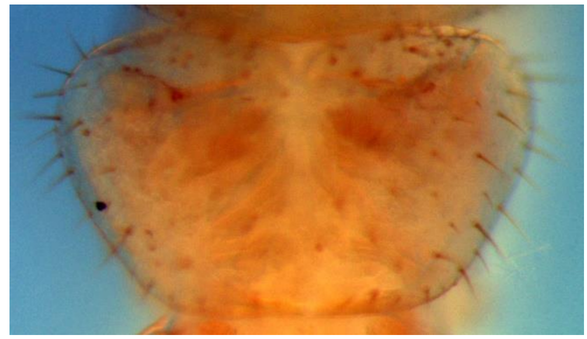

Plate A2: Flat shaped pronotum

Plate B1: Rectangular or sub-squarish type of head

Plate B2: Oval type of head

#### 4.1.2.2 Key to the sub families of Rhinotermitidae

1. Head rectangular or sub squarish, mandible without tooth (Plate B1) ---------------------------------------------------------------------------------------------------------Heterotermitinae Froggat

1a. Head oval, both mandibles 1-2 sharply pointed teeth (Plate B2)--------------------------------------------------------------------------------------------------------Coptotermitinae Wasmann

#### 4.1.2.3. Key to the species of genus *Heterotermes*

1. Head length to base of mandibles 1-1.10, width 0.70-0.75 mm. Mandibles slender, longer in comparison to head length without mandibles (Plate C1)…………………… .........................................................................................*balwanti* Mathur and Chhotani

1a. Head length to base of mandibles 1.30-1.77, width 0.83-1.00 mm, postmentum narrower at waist, index value of 0.38-0.43 (Plate C2)……………………………. .........................................................................................................*malabaricus* Snyder

#### 4.1.2.4 Key to the species of genera *Coptotermes*

1. Waist of postmentum lying below middle of line connecting the level of maximum width and the hind margin (Plate D1)………………………………………….. ……………………………………………...............*kishori* Roonwal and Chhotani

1a. Waist of postmentum lying in middle of line connecting the level of maximum width and the hind margin……………….......................................................................2

2. Postmentum minimum width smaller (0.20-0.29 mm); Head contraction index 0.57-0.69 (Plate D2).............................................................................*ceylonicus* Holmgren

2a. Postmentum minimum width larger (0.25-0.34 mm); Head contraction index 0.63-0.76 (Plate D3)......................................................................................*heimi* Wasmann

#### 4.1.2.5 Key to the sub families of Termitidae based on soldier caste

1. Head produced into snout or rostrum, fontanelle prominent (Plate E) ------------------------------------------------------------------------------------------------------NasutitermitinaeHare

1a. Head not produced as snout, fontanelle is dot like or indistinct---------------------------2

Plate C1: *Heterotermes balwanti*

Plate C2: *Heterotermes malabaricus*

Plate D1: *Coptotermes kishori*

Plate D2: *Coptotermes ceylonicus*

Plate D3: *Coptotermes heimi*

2. Each mandible with a serration on inner margin (Plate F)--------------------------------------------------------------------------------------------------------Amitermitinae Kemner

2a. Mandible without any serrations on inner margin------------------------------------------3

3. Mandible twisted, largely asymmetrical (Plate G)-------------------Termitinae Sjostedt

3a. Mandible not twisted, less/ more symmetrical (Plate H)--------------------------------------------------------------------------------------------------------Macrotermitinae Kemner

**4.1.2.6 Key to the genera of family Termitidae**

1. Head produced into snout or rostrum-------------------------------------------------10

1a. Head not produced into snout-----------------------------------------------------------2

2. Mandibles twisted, weakly or strongly asymmetrical----------------------------------3

2a. Mandibles not twisted, strongly symmetrical------------------------------------------6

3. Mandibles weakly asymmetrical, long and slender-----------*Angulitermes* Sjostedt

3a. Mandibles strongly asymmetrical (Plate I)-------------------------------------------- 4

4. Antero-lateral corners of head tuberculated, right mandible strongly twisted at middle (Plate J1)--------------------------------------------*Discuspiditermes* Krishna

4a. Antero-lateral corners of head not tuberculated.....................................................5

5. Left mandible weakly bent at middle distal end bent like a beak (Plate K) ...........................................................................*Pseudocapritermes* Kemner

5a. Left mandlible strongly bent at middle, labrum greatly swollen and enlarged (Plate L)............................................................*Labriocapritermes* Krishna

6(2a). Mandibles without tooth/crenulations/serration on inner margin (Plate M1) .................................................................................*Microtermes* Wasmann

6a. Mandibles with tooth/crenulations/serration on inner margin................................7

7. Inner margin of mandible with crenulations/serration (Plate N1)............................................................................................*Microcerotermes* Silvestri

7a. Inner margin of mandible with prominent tooth....................................................8

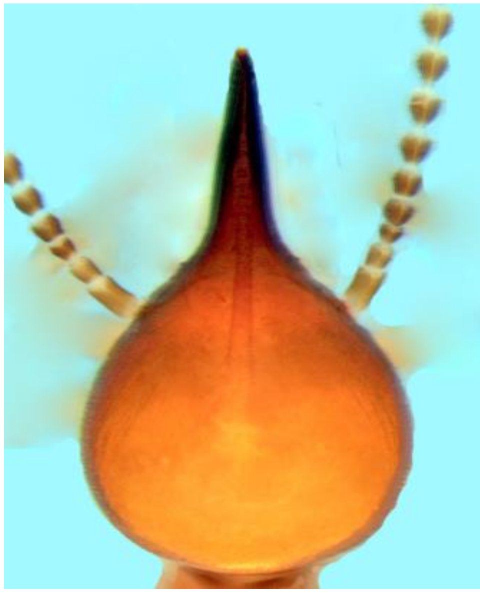

Plate E: Head produced into snout

Plate F: Mandibles with serration

Plate G: Twisted mandibles

Plate H: Asymmetrical mandibles

8. Left mandible with a prominent teeth on the inner margin; right mandible with a rudimentary teeth (Plate O1)...........................................*Odontotermes* Holmgren

8a. Each mandible with a prominent teeth...................................................................9

9. Head squarish; mandibles thick, stout and less to heavy at the base (Plate P1) ..........................................................................................*Eurytermes* Wasmann

9a. Head subsquarish; mandibles fairly strongly curved apically (Plate Q)……… ...................................................................................*Synhamitermes* Holmgren

10(1). Soldier dimorphic, antennal segments elongated (Plate R1)……………… ...................................................................................*Trinervitermes* Holmgren

10a. Soldier monomorphic, antennal segments not elongated (Plate S1)……………… ..........................................................................................*Nasutitermes* Dudley

**4.1.2.7 Key to the species of genus *Odontotermes***

1. Head length excluding mandible >2 mm..................................................................2

1a. Head length excluding mandible <2 mm..................................................................5

2. Tooth of left mandible situated slightly above middle point of mandible (tooth index 0.41-0.55 mm)..................................................................................................3

2a. Tooth of left mandible situated at middle or below middle point of mandible (tooth index 0.50-0.65)........................................................................................................4

3. Head broad and oval, postmentum wider in comparison to length, workers monomorphic (Plate O1)..........................................................................*yadevi* Thakur

3a. Head subrectangular and narrower, postmentum narrower. Workers dimorphic (Plate O2).....................................................*anamallensis* Holmgren and Holmgren

4. Labrum tongue shaped. Head sides straighter widest medially (Plate O3) ..........................................................................................................*horni* Wasmann

4a. Labrum triangular, with a sharp tip. Head sides widest near posterior margin (Plate O4)..............................................................................................................*feae* Wasmann

5. Head subrectangular, sides of head subparallel........................................................6

5a. Head subrectangularly oval to broadly oval, sides of head weakly to strongly convex.......................................................................................................................8

6. Tooth of left mandible minute and basally placed, mandibles shorter (Plate O5) ........................................................................*bhagwatii* Chatterjee and Thakur

6a. Tooth of left mandible larger and forwardly placed..................................................7

7. Tooth of left mandible, larger and placed at middle (Plate O6)……………. ..........................................................................................*ceylonicus* Wasmann

7a. Tooth of left mandible placed infront of middle (Plate O7)…………………. ............................................................................................*assmuthi* Holmgren

8. Antennae uniformly coloured (Plate O8).............................................*boveni* Thakur

8a. Antennae darker distally and paler basally...............................................................9

9. Smaller species: Head length to base of mandibles 0.90-1.14 and and max. Head-width 0.83-1.00 mm...................................................................................................10

9a. Larger species: Head length to base of mandibles 1.0-2.0 and and max. Head-width 0.95-1.50 mm...........................................................................................................12

10. Tooth of left mandible forwardly placed. Labrum sharply pointed at tip (Plate O9)...........................................................................................*globicola* Wasmann

10a. Tooth of left mandible near distal third. Labrum sharply or broadly rounded at tip.............................................................................................................................11

11. Antennae with 16 segments (Plate O10)...............................................*vaishno* Bose

11a Antennae with 15 segments (Plate O11)..................................*peshawarensis* Akhtar

12. Tooth of left mandible situated in front of distal third of mandible (tooth index-0.21-0.33 mm). Mandibles less stout and longer (Plate O12)…………………… ..................................................................*bellahunisensis* Holmgren and Holmgren

12a. Tooth of left mandible situated in front of distal third of mandible (tooth index-0.33-0.46 mm). Mandibles generally longer..........................................................13

13. Larger in size. Head length to base of mandibles 1.5-2.0, max.head width 1.28-1.50 mm..........................................................................................................................14

13a. Smaller in size.Head length to base of mandibles 1.10-1.67, max. Head width 0.90-1.40 mm...................................................................................................................15

14. Mandibles shorter, stouter and more curved distally (Plate O13)……………. ...................................................................................................*brunneus* Hagen

14a. Mandibles longer, thinner and less so curved distally (Plate O14)……………. .........................................................................................*wallonensis* Wasmann

15. Labrum longish (>0.25 mm) (Plate O15)..................................*redemanni* Wasmann

15a. Labrum shorter (<0.25 mm) (Plate O16)...........................................*obesus* Rambur

**4.1.2.8 Key to the species from genus *Microcerotermes***

1. Smaller species: Head length to base of mandibles <1.0 mm and width <0.80 mm (Plate N1)........................................................................................*minor* Holmgren

1a. Larger species: Head length to base of mandibles <1.0 mm and width <0.80 mm.....................................................................................................................2

2. Mandibles shorter. Mandible index 0.46-0.56 (Plate N2).......................................... ..……………………………………………………………………......*pakistanicus*Akhtar

2a. Mandibles longer, index 0.53-0.67, labrum pentagonal (Plate N3)………….. ……………………………..……………….……*fletcheri* Holmgren and Holmgren

**4.1.2.9 Key to the species from genus *Microtermes***

1. Tip of labrum narrow (Plate M1)................................................*incertoides* Holmgren

1a. Tip of labrum comparartively wider (Plate M2)...................................*obesi* Holmgren

**4.1.2.10 Key to the species from genus *Nasutitermes***

1. Head without rostrum circular and rostrum is conical in shape (Plate S1).............. ..........………………………………………...………………*anamalaiensis* Snyder

1a. Head without rostrum pear shaped and rostrum narrow...............................................2

2. Mandibles without any spine like process, rostrum subcylindrical (Plate S2) ………………..……………………………………………………….*gardneri* Snyder

2a. Mandibles with spine like process.....................................................................3

3. Rostrum thin. Narrow and cylindrical (Plate S3)…………………………………. ...............................................................…………..*indicola* Holmgren and Holmgren

3a. Rostrum pale brown to deep brown basally (Plate S4)……………………………… …..…………………………………………………..*dunensis* Chatterjee and Thakur

#### 4.1.2.11 Key to the species from genus *Trinervitermes*

1. Smaller species: Head length with rostrum 1.78-2.00 mm, Head length without rostrum 1.10-1.20 (Plate R1)...............................................................*sensarmai* Bose

1a. Larger species: Head length with rostrum 2.15-2.55, Head length without rostrum 1.33-1.73 mm.................................................................................................2

2. Rostrum darker, blackish brown with paler apex and comparatively longer. Head bulge index 0.28-0.35 (Plate R2)………………………………………………….. ........................................................................*nigrirostris* Mathur and Sen-Sarma

2a. Antennae 12-14 segmented; in 14 segmented condition segment three slightly longer than two (Plate R3).............................................................*biformis* Wasmann

#### 4.1.2.12 Key to the species from genus *Eurytermes*

1. Larger species (head 2 mm long, 1.3 mm wide; mandibles 0.83-0.87 mm long) (Plate P1).............................................................................*assmuthi assmuthi* Wasmann

1a. Smaller species (head 1.7-2.0 mm long, 1.03-1.18 mm wide; mandibles 0.66-0.85 mm long) (Plate P2)......................................................................*buddha* Bose and Maiti

#### 4.1.2.13 Key to the species from genus *Dicuspiditermes*

1. Antero-lateral processes of head short and blunt (Plate J1)……………………….. …..………………………………………...................................*obtusus* Silvestri

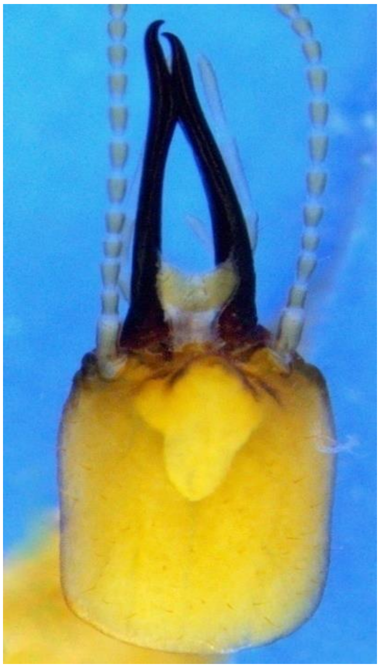

Plate I: *Angulitermes fletcheri*

Plate J1: *Dicuspiditermes obtusus*

Plate J2: *Dicuspiditermes gravelyi*

Plate J3: *Dicuspiditermes incola*

Plate K: *Pseudocapritermes fletcheri*

Plate L: *Labriocapritermes distortus*

Plate M1: *Microtermes incertoides*

Plate M2: *M. obesi*

Plate N1: *M. minor*

Plate N2: *M. pakistanicus*

Plate N3: *M. fletcheri*

Plate P1: *Eurytermes assmuthi assmuthi*

Plate P2: *Eurytermes buddha*

Plate Q: *Synhamitermes quadriceps*

Plate O1: *Odontotermes yadevi*

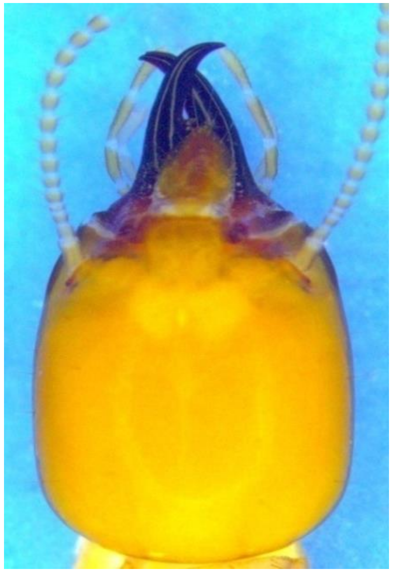

Plate O2: *O. anamallensis*

Plate O3: *O. horni*

Plate O4: *O. feae*

Plate O5: *O. bhagwatii*

Plate O6: *O. ceylonicus*

Plate O7: *O. assmuthi*

Plate O8: *O. boveni*


Plate O9: *O. globicola*


Plate O10: *O. vaishno*


Plate O11: *O. peshawarensis*


Plate O12: *O. bellahunisensis*


Plate O13: *O. brunneus*


Plate O14: *O. wallonensis*


Plate O15: *O. redemanni*


Plate O16: *O. obesus*

Plate R1: *Trinervitermes sensarmai*

Plate R2: *T. nigrirostris*

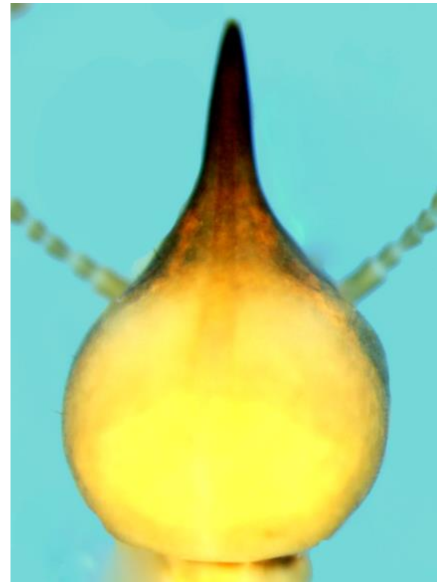

Plate R3: *T. biformis*

Plate S1: *N. anamalaiensis*

Plate S2: *N. gardneri*

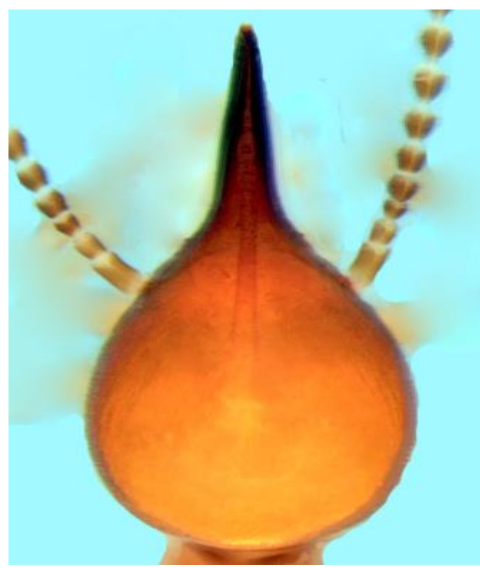

Plate S3: *N. indicola*

Plate S4: *N. dunensis*

1a. Antero-lateral processes of head horn like or long and pointed…………………….....2

2. Head smaller (length 1.85-2.10, head width 1.15-1.30mm). Side base of labrum with serrations (Plate J2)…..........................................................................*gravelyi* Silvestri

2a. Head larger (length 2.08-2.40, head width 1.33-1.50 mm). Antennal segments thicker (Plate J3).......................................................................................*incola* Wasmann

The remaining genera were represented by single species and are represented below.

#### 4.1.2.14 Key to the species from genus *Synhamitermes*

Outer margin of mandibles incurved near middle and apical half of mandibles weakly incurved (Plate Q)..................................................................*quadriceps* Wasmann

#### 4.1.2.15 Key to the species from genus *Angulitermes*

Head with long, conical, sharply pointed frontal projection. Antero-lateral angles of head not prominent and sharp and frontal projection not raised at tip (Plate I) ...........................................................................................*fletcheri* Holmgren and Holmgren

#### 4.1.2.16 Key to the species from genus *Pseudocapritermes*

Smaller species: Head length to base of mandibles 1.0-1.80. Max. width of head 0.90-1.03 mm. Left mandible strongly twisted much shorter than head length (Plate K) ...........................................................................................*fletcheri* Holmgren and Holmgren

#### 4.1.2.17 Key to the species from genus *Labriocapritermes*

Head capsule reddish yellow antennae pale brownish, labrum transluscent to yellowish (Plate L)............................................................................*distortus* Silvestri

### 4.1.4 Species description

The detailed description of identified species collected from different parts of Western Ghats is given below.

**Family: Termitidae**

**Subfamily: Macrotermitinae**

***Odontotermes anamallensis*** Holmgren and Holmgren

*Odontotermes (Odontotermes) anamallensis* Holmgren and Holmgren, 1917: 157-158.
*Odontotermes anamallensis* Holmgren and Holmgren: Krishna *et al*., 2013: 1134-1135.

**Description**:

**General appearance:** Head pale yellow to brown; labrum a little paler than head; antennae and legs pale yellow to brownish yellow; mandibles dark brown, paler basally; body creamish to yellow.

**Head:** Head–capsule sub-rectangular, sides weakly convex and somewhat converging in front (length to base of mandibles 2.23 (Table 2), max. width 1.83, width at base of mandibles 1.18mm); width 2/3 to a little more than ¾ of max. width (index max. width/length 0.82). Antennae 17-segmented ones segment 2 twice as long as 3, the latter shortest. Labrum tongue-shaped, anteriorly triangularly pointed. Mandibles sabre-shaped, strong and stout; length (1.30 mm) a little more than half of head-length. Left mandible with a prominent tooth at about middle (index tooth-distance from tip/mandible-length 0.49). Right mandible with a minute tooth at middle.Postmentum subrectangular, widest in anterior third (length 1.39, max. width 0.51 mm).

**Thorax:** Pronotum saddle-shaped (length 0.77, width 1.40 mm); anterior margin round, with a weak median notch; posterior margin weakly convex with a shallow, median depression. Mesonotum narrower than pronotum, distinctly emarginate posteriorly; metanotum as wide as or slightly wider than pronotum, posterior margin weakly convex.

**Material examined**: INDIA: Karnataka: *Agumbe, $13^0$29.263'N $075^0$04.26'E, 15.xi.2013, *ex* Deadwood, Vidyashree, A.S.; Near Agumbe, $13^0$31.468'N $75^0$06.135'E, 15.xi.2013, *ex* Deadwood, Vidyashree, A.S.: Maharashtra: Pratapgarh, $17^0$56.93'N, $73^0$37.304'E, 18.viii.2015, *ex* Soil nest, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 2.

**Distribution:** Karnataka and Maharashtra.

***Odontotermes assmuthi*** Holmgren

*Odontotermes (Odontotermes) Assmuthi/assmuthi* Holmgren, 1913: 112-113.

**Description:**

**General appearance:** Head capsule, antenna and labrum pale yellow to pale brown; antenna uniformly coloured; mandibles brown to blackish brown; body straw yellow to pale yellowish brown.

**Head:** Head-capsule sub rectangular (length to base of mandibles 1.62, range 1.44-1.70, max. width 1.35) (Table 2); anteriorly very slightly converging at base of mandibles (width at base of mandible-0.90). Antenna with 16 segments; segment $4^{th}$ shortest. Labrum tongue shaped (length 0.32, width 0.29 mm); anteriorly narrowly rounded at tip. Mandibles stout and short (length 0.90, range 0.77-0.95 mm, mandible index–length/head-length 0.56). Left mandible with a prominent, anteriorly directed tooth a little behind apical third, tooth distance 0.32 mm, index tooth 0.35. Right mandible with a weak denticle a little below level of tooth in left mandible. Postmentum is subrectangular (length 1.04 mm; width 0.56mm).

**Thorax:** Pronotum saddle shaped with a length of 0.51 mm and width 0.92 mm; anterior margin distinctly and posterior margin weakly notched.

**Material examined:** INDIA: Karnataka: VTU Campus, Panaji road, $15^0$47.45'N $74^0$27.471'E, 13.viii.2015, *ex* Arboreal nest, Vidyashree, A.S.; Karnataka: Navile, Shivamogga, $13^0$58.246'N; $75^0$34.435'E, 18.ix.2013, *ex* Silver oak, Adarsha.; Navile, Shivamogga, $13^0$58.251'N $75^0$34.439'E, 18.ix.2013, *ex*. Soil galleries on Eucalyptus, Adarsh.; Navile, Shivamogga; $13^0$58.245'N $75^0$34.434'E, 18.ix.2013, *ex* Neem, Adarsh.; Santhaveri, $13^0$32.501'N $75^0$49.272'E, 31.i.2014, *ex* Nest in soil, Kavitha.; Halladi, Shankarapura, $13^0$33.248'N $74^0$48.387'E, 13.xii.2013, *ex* Dead wood, Swetha.; *Ganadahole, Sakleshpura, $12^0$57.25'N $75^0$44.34'E, 04.x.2013, *ex* Dead wood, Kavyashree.; Agumbe, Vishanthi Dhama, $13^0$27.272'N $75^0$04.278'E, 15.xi.2013, *ex* Dead wood, Chaithra.; Agumbe, $13^0$29.263'N $75^0$04.26'E, 15.xi.2013, *ex* On bark of forest tree, Adarsh.; Kudremukha, 13$^0$11.448'N 75$^0$17.885'E, 08.xi.2014, *ex* Dead wood, Vidyashree, A.S.; Kudremukha, 13$^0$12.857' N 75$^0$15.166'E, 08.xi.2014, *ex* Dead wood, Adarsh.; Kagganalla, Balehonnur, 13$^0$15.645'N; 75$^0$27.102'E, 08.xi.2014, *ex* Dead wood, Nandini.; Talavata, Sagara, 14$^0$13.33'N 74$^0$52.314' E, 06.xii.2013, *ex* Dead wood, Vidyashree A.S.; Chikjeni, Hosanagara, 13$^0$57.536'N 75$^0$12.105'E, 27.iv.2014, *ex* Soil gallery on Teak tree; Vidyashree, A.S.; Near Karkala: 13$^0$18.453'N 74$^0$59.251'E, 22.vi.2014, *ex* Cowdung, Vidyashree, A.S.; KVK, Chamarajnagar, 10$^0$17.41'N; 77$^0$12.44'E, 30.xii.2015, *ex* Dead wood; Vidyashree, A.S.; Pura, Sagara; 14$^0$10.492'N 74$^0$56.461'E, 23.viii.2014, *ex* Dead wood, Vidyashree, A.S.; Kerala: IISR, Calicut, 11$^0$18.54'N 75$^0$50.35'E, 21.vi.2014, *ex* Cowdung, Adarsh.; IISR, Calicut, 11$^0$18.29'N 75$^0$50.279' E, 21.vi.2014, *ex* Dead wood; Vidyashree, A.S.; IISR, Calicut, 11$^0$17.591'N 75$^0$50.262'E, 21.vi.2014, *ex* At the base of jack fruit tree, Vidyashree.; IISR, Calicut, 11$^0$17.583'N 75$^0$50.262' E 21.vi.2014, *ex* Dead wood, Vidyashree.; IISR, Calicut, 11$^0$18'N 75$^0$50.277'E, 21.vi.2014, *ex* Dead wood, Vidyashree.; CPCRI, Kasaragod; 13$^0$58.262'N 75$^0$34.437'E, 24.xii.2014, *ex* Gallery on coconut tree; Vidyashree.; CPCRI, Kasaragod; 13$^0$58.262'N 75$^0$34.437'E, 24.xii.2014, *ex* Nest in Soil, Adarsh.; Goa: Mollem, near dudhsagar falls, 15$^0$19.21'N 74$^0$10.362'E, 13.ii.2016, *ex* Deadwood, Adarsh.; Valpoi, 15$^0$31.552'N; 74$^0$05.472'E, 10.ii.2016, *ex* Soil gallery on forest tree; Vidyashree.; Gauttomn, 15$^0$32.495'N 74$^0$0.55'E, 10.ii.2016, *ex* Dead wood; Vidyashree.; Maharashtra: Poladhpur, 18$^0$.249' N 73$^0$28.49'E, 17.viii.2015, *ex* Soil nest, Adarsh.; Amboli forest, 15$^0$56.28'N 73$^0$58.06'E, 14.viii.2015, *ex* Dead wood; Vidyashree.; Amboli ghat, 16$^0$59'N 74$^0$03.18'E, 14.viii.2015, *ex* Cowdung, Adarsh.; Pondaghat, 16$^0$21.46'N 73$^0$49.244'E, 15.viii.2015, *ex* Dead wood, Vidyashree.; Kankavali, 16$^0$17.41'N 74$^0$24.21'E, 15.viii.2015, *ex* Dead wood, Pavithra.; Raigad, 18$^0$07.33'N 73$^0$24.06' E, ex. Cowdung, Adarsh.; Radhanagari, Kholapur, 16$^0$25.585'N 74$^0$02.362'E, 15.viii.2015, *ex* Nest in soil, Pavithra.; Satara, 17$^0$42.879'N 73$^0$48.78.3''E, 19.viii.2015, *ex* Dead wood, Kavitha.; Gujarath: Parnera pardi: Valsad, 20$^0$34.366'N 72$^0$57.258' E, 23.v.2016, *ex* Dead wood, Vidyashree, A.S.; Banaskantha, 24$^0$20.246'N 71$^0$46.204'E, 24.v.2016, *ex* Nest in soil, Vidyashree, A.S.; Sindhai, 20$^0$51.526'N 73$^0$18.577'E; 25.v.2016, *ex* Dead wood, Vidyashree, A.S.

**Distribution:** Karnataka, Kerala, Goa, Maharashtra and Gujarath.

***Odontotermes bellahunisensis*** Holmgren and Holmgren

*Odontotermes (Cyclotermes) bellahunisensis* Holmgren and Holmgren, 1917: 150-151.
*Odontotermes bellahunisensis* Holmgren and Holmgren: Roonwal and Bose, 1961: 580-588.

**Description:**

**General appearance:** Head capsule pale yellowish brown to dark castaneous brown; antennae yellowish brownish, darker distally; mandibles reddish brown, paler basally.

**Head:** Head broadly oval, broadest posteriorly and narrowed in front (length to base of mandibles 1.13 (Table 2), max. width 0.98, width at the base of mandibles 0.64, index width/length 0.87) antennae with 17 segments; segment 3 shortest in 17 segmented antennae. Labrum tongue shaped, apically converging into somewhat pointed tip (length 0.35, width 0.24). Mandibles short, stout, sickle shaped and strongly incurved distally (length 0.63, range 0.60-0.73 mm, mandible index–length/head-length 0.56). Left mandible with a large pointed tooth at distal third (Tooth distance from tip 0.21, tooth index 0.33). Right mandible with a minute tooth a little above middle. Postmentum is subrectangular with weakly convex sides length 0.69, width 0.50 mm.

**Thorax:** Pronotum saddle shaped (length-0.53 and width-0.83); anteriorly weakly notched and posteriorly substraight. Mesonotum narrower and metanotum wider than pronotum; both without any emargination posteriorly.

**Material examined:** INDIA: Karnataka: Edalli, Siddapur forest, Gokarna road, $14^{0}$15.145' N $74^{0}$47.256' E, 08.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Kukunjaru road, $13^{0}$23.67'N $74^{0}$54.928' E, 14.xii.2013, *ex* Closed mound, Vidyashree, A.S.; Near Gopalaswamy betta, Gundlupet, $11^{0}$43.377'N $76^{0}$37.37'E, 04.x.2014, *ex* Nest in soil (below stone), Vidyashree, A.S.; Near Agumbe, $13^{0}$31.468'N $75^{0}$06.135'E, 15.xi.2013, *ex* Closed mound, Vidyashree, A.S.; Near Gopalaswamy betta, Gundlupet;$11^{0}$43.383'N $76^{0}$36.581'E, 04.x.2014, *ex* Nest in soil, Vidyashree, A.S.; Aayanur, Shivamogga, $13^{0}$59.05'N $75^{0}$22.240' E, 02.ix.2014, *ex* Closed mound, Vidyashree, A.S.; Kerala: KFRI, Peechi, $10^{0}$02.591'N $76^{0}$43.414'E, 27.xii.2015, *ex* Dead wood, Vidyashree, A.S.; Chinnar wildlife sanctuary, 10$^{0}$18.43'N, 77$^{0}$11. 235'E, 27.xii.2015, *ex* Elephant dung, Vidyashree, A.S.; Attukad, 10$^{0}$03.103'N 77$^{0}$03.333'E, 27.xii.2015, *ex* Dead wood, Vidyashree, A.S.; Palanadu, 10$^{0}$13'497'N 77$^{0}$68.194'E, 27.xii.2015, *ex* Gallery on teak tree, Vidyashree, A.S.; Palanadu, 10$^{0}$13'497'N 77$^{0}$68.194'E, 27.xii.2015, *ex* Gallery on teak tree, Vidyashree, A.S.; Tamil Nadu: Upasi Tea research Institute, Valporai, 10$^{0}$15.536'N 76$^{0}$58.07'E, 06.x.2014, *ex* Leaf litter; Vidyashree, A.S.; Mulli, 11$^{0}$13.949'N 76$^{0}$43.298'E, 06.x.2014, *ex* Leaf litter, Vidyashree, A.S.; Thaisara, 11$^{0}$13.323'N 76$^{0}$36.569' E, 07.x.2014, *ex* Leaf litter, Vidyashree, A.S.; Near Manjur, 11$^{0}$15.195' N 76$^{0}$39.359'E, 07.x.2014, *ex* Leaf litter, Vidyashree, A.S.; Upasi Tea Research Institute, Valporai, 10$^{0}$16.101'N 76$^{0}$58.670'E, 06.x.2014, *ex* Leaf litter, Vidyashree, A.S.; Upasi Tea Research Institute, Valporai, 10$^{0}$15.536'N 76$^{0}$58.790'E, 06.x.2014, *ex* Leaf litter; Vidyashree, A.S.; Sethumudai, 10$^{0}$30.392'N 76$^{0}$52.364'E, 07.x.2014, *ex* Leaf litter, Vidyashree, A.S.; Sethumudai, 10$^{0}$30.392'N 76$^{0}$52.364'E, 07.x.2014, *ex* Soil galleries on forest tree, Vidyashree, A.S.; Emerald,11$^{0}$17.591' N 76$^{0}$34.275'E, 07.x.2014, *ex* Cowdung, Vidyashree, A.S.; Emerald, 11$^{0}$17.591'N 76$^{0}$34.275'E, 07.x.2014, *ex* Dead wood: Vidyashree, A.S.; Sethumudai, 10$^{0}$30.392'N 76$^{0}$52.364'E,07.x.2014, *ex* Cowdung, Vidyashree, A.S.; Mulli, 11$^{0}$13.949'N 76$^{0}$43.298'E, 06.x.2014, *ex* Leaf litter, Vidyashree, A.S.; Thaisara, 11$^{0}$13.323'N 76$^{0}$36.569' E, 08.x.2014, *ex* Leaf litter, Vidyashree, A.S.; Palanighat area, 10$^{0}$22.384' N 77$^{0}$31.76'E, 05.x.2014, *ex* Dead wood, Vidyashree, A.S.; Palanighat area, 10$^{0}$22.383' N 77$^{0}$31.76'E, 05.x.2014, *ex* Cowdung, Vidyashree, A.S.; Goa: Pollem, 14$^{0}$54.451' N 74$^{0}$04.487'E, 09.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Pollem, 14$^{0}$54.464' N 74$^{0}$04.48' E, 09.ii.2016, *ex* Soil Gallery on forest tree, Vidyashree, A.S.; Pollem, 14$^{0}$54.49'N 74$^{0}$04.475'E, 09.ii.2016, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Mhadei wildlife sanctuary, 15$^{0}$36.171'N 74$^{0}$06.103'E, 10.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Mhadei wildlife sanctuary, 15$^{0}$36.171'N 74$^{0}$06.103' E, 10.ii.2016, *ex* Dead wood, Vidyashree, A.S.;Mhadei wildlife sanctuary, 15$^{0}$36.171'N 74$^{0}$06.103' E, 10.ii.2016, *ex* Dead wood; Vidyashree, A.S.; Mollem, Near dudhsagar waterfalls live forest tree, 15$^{0}$19.21'N 74$^{0}$10.362'E, 13.ii.2016, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Collem: 14$^{0}$54.451'N 74$^{0}$04.487' E, 09.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Valpoi: 15$^{0}$31.552'N 74$^{0}$05.472'E, 10.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Sanguem: 15$^{0}$22.413'N 74$^{0}$13.496'E, *ex* Closed mound, Vidyashree,

**Table 2. Measurements of different morphological characters in species belonging to genus *Odontotermes***

| Sl. No. | Measurement parameters#* | *Odontotermes* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ***anamallensis*** | ***assmuthi*** | ***bellahunisensis*** | ***bhagwatii*** | ***boveni*** | ***brunneus*** | ***ceylonicus*** | ***feae*** |
| 1 | Number of antennal segments | 17 | 16 | 17 | 17 | 15 | 17 | 16 | 17 |
| 2 | Head length with mandibles | 3.53 | 2.53 | 1.84 | 1.98 | 2.36 | 2.63 | 2.87 | 3.31 |
| 3 | Head length without mandibles | 2.23 | 1.62 | 1.13 | 1.38 | 1.53 | 1.69 | 1.78 | 2.30 |
| 4 | Head width | 1.83 | 1.35 | 0.98 | 1.15 | 1.31 | 1.40 | 1.48 | 1.88 |
| 5 | Head width at base of mandibles | 1.18 | 0.90 | 0.64 | 0.66 | 0.80 | 0.81 | 1.38 | 1.25 |
| 6 | Mandible length | 1.30 | 0.90 | 0.63 | 0.88 | 0.79 | 1.02 | 1.14 | 1.28 |
| 7 | Tooth distance from tip | 0.49 | 0.32 | 0.21 | 0.55 | 0.25 | 0.42 | 0.52 | 0.62 |
| 8 | Labrum length | 0.60 | 0.32 | 0.35 | 0.28 | 0.26 | 0.29 | 0.34 | 0.41 |
| 9 | Labrum width | 0.47 | 0.29 | 0.24 | 0.32 | 0.25 | 0.29 | 0.32 | 0.38 |
| 10 | Pronotum length | 0.77 | 0.51 | 0.53 | 0.48 | 0.49 | 0.00 | 0.70 | 0.78 |
| 11 | Pronotum width | 1.40 | 0.92 | 0.83 | 0.88 | 0.82 | 0.00 | 1.12 | 1.41 |
| 12 | Postmentum length | 1.39 | 1.04 | 0.69 | 0.98 | 0.78 | 0.98 | 1.23 | 1.41 |
| 13 | Postmentum width | 0.51 | 0.56 | 0.50 | 0.56 | 0.60 | 0.56 | 0.46 | 0.75 |
| 14 | Mandible index | 0.58 | 0.56 | 0.56 | 0.63 | 0.58 | 0.60 | 0.64 | 0.56 |
| 15 | Head index | 0.82 | 0.83 | 1.00 | 0.83 | 0.85 | 0.83 | 0.83 | 0.82 |
| 16 | Labrum index | 0.78 | 0.91 | 0.69 | 1.14 | 0.98 | 1.01 | 0.94 | 0.93 |
| 17 | Tooth index | 0.38 | 0.35 | 0.33 | 0.55 | 0.32 | 0.41 | 0.45 | 0.48 |
| 18 | Postmentum index | 0.43 | 0.54 | 0.72 | 0.57 | 0.77 | 0.57 | 0.37 | 0.53 |

# Average of 5 specimens; * Length and width in mm.

A.S.; Maharashtra: Kumbeshwar: $15^0$56.360'N $73^0$57.595'E, 14.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Kumbeshwar: $15^0$56.40'N $73^0$56.070'E, 14.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Raigad: $18^0$07.33'N $73^0$24.60'E, 17.viii.2015, *ex* Dead wood: Vidyashree, A.S.; Radhanagari, Kholapur: $16^0$25.585'N $74^0$02.362' E, 15.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Satara: $17^0$42.879' N $73^0$48.783'E, 19.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Mausi: $17^0$47.68'N $73^0$43.366'E, 19.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Radhanagari, Kholapur: $16^0$25.584'N $74^0$02.331' E, 15.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Gujarath: Damo kund, Junagad forest tree: $21^0$31.354'N $70^0$29.290'E, 23.v.2016, *ex* Soil gallery on live tree, Vidyashree, A.S.; Hasnapur, Junagad, $21^0$33.567'N $70^0$31.331'E, 24.v.2016, *ex* Deadwood, Vidyashree, A.S.; Saputara: $20^0$34.409'N $73^0$44.167'E, 26.v.2016, *ex* Dead wood, Vidyashree, A.S.

**Distribution:** Karnataka, Tamil Nadu, Kerala, Goa, Gujarath and Maharashtra.

***Odontotermes bhagwatii*** Chatterjee and Thakur

*Odontotermes bhagwatii* Chatterjee and Thakur, 1981: 4, 11, 13, 25-30.

**Description:**

**General appearance:** Head pale yellow to yellowish brown; antennae uniformly coloured, paler than head; mandibles pale reddish brown to dark brown.

**Head:** Head-capsule subrectangular, wider posteriorly (length to base of mandibles was 1.38 mm, max. width was 1.15 mm, index width/length 0.83). Antennae 15-17 segmented (Table 2); segment 2 equal to 3 and 4 combined, 4 shortest. Labrum tongue-shaped; anteriorly narrowed to a pointed tip.Mandibles sabre-shaped, a little longer than half of head-length (length 0.88 mm, index left mandible-length/head-length 0.63); left mandible with a small tooth, situated a little above basal one third (tooth index *i.e*. Tooth-distance from tip/mandible-length 0.55); right mandible without any tooth.Postmentum subrectangular (length 0.98, width 0.56 mm); sides behind widest point (at distal ¼) substraight.

**Thorax:** Pronotum saddle-shaped (length 0.48, width 0.88 mm); anterior margin distinctly notched; posterior margin weakly to distinctly emarginated. Mesonotum narrower and metanotum wider than pronotum; both substraight at posterior margin.

**Material examined:** INDIA: Karnataka: KVK, Chamarajnagar, $10^0$17.41'N $77^0$12.44'E, 30.xii.2015, *ex* Soil nest, Pavithra.

**Distribution:** Karnataka.

***Odontotermes boveni*** Thakur

*Odontotermes boveni* Thakur, 1981: 30-33.

**Description:**

**General appearance:** Head-capsule yellowish to dark brown; antennae uniformly pale yellow and labrum pale yellowish brown; mandibles reddish brown; thorax and abdomen creamy yellow.

**Head:** Head-capsule oval, a little longer than wide (head length to base of mandibles-1.53 mm, max. width 1.31 mm (Table 2), width at base of mandibles 0.80 mm, index max. width/length 0.85. Antennae with 15 segments; segment 3 shortest, 4 a little longer than 3. Mandibles short, thick and stout; much shorter than head (length 0.79 mm, index left mandible-length/head-length 0.58 mm); left mandible with a sharp, acute tooth at apical third (index tooth-distance/mandible-length 0.32); right mandible with a small, rudimentary tooth a little below level of tooth in left mandible. Postmentum swollen and arched at middle (length 0.78, max. width 0.60mm, index width/length 0.60 mm).

**Thorax:** Pronotum saddle-shaped; anterior lobe triangular and deeply notched medially; posterior margin weakly to markedly emarginated medially. Mesonotum a little narrow and metanotum a little wider than pronotum; both substraight at posterior margin.

**Material Examined:** INDIA: Karnataka: Halladi, Shankarapura, $13^0$33.248'**N** $74^0$48.387'E, 13.xii.2013, *ex* Gallery on live tree, Vidyashree, A.S.; Bandipur national park: $11^0$39.576'N $76^0$37.414'E, 04.x.2014, *ex* Dead wood, Vidyashree, A.S.; Kerala:

*Charukara: $10^{0}$55.529'N $76^{0}$13.375'E, 27.xii.2015, *ex* Gallery on live tree, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 2.

**Distribution:** Karnataka and Kerala.

***Odontotermes brunneus*** (Hagen)

*Termesbrunneus* Hagen, 1858: 133-135.
*Odontotermes brunneus* (Hagen): Thakur, 1981: 10, 12, 33-37.
*Odontotermes mathadi* Roonwal and Chhotani, 1964: 45-48.

**Description:**

**General appearance:** Head pale brown to reddish brown; antennae brown, darker distally; labrum and body rusty yellow.

**Head:** Head capsule subrectangular oval, very slightly converged in front of antennae (length to base of mandibles 1.69, max, width 1.40 mm, index width/length 0.83, Table 2). Antennae with 17 segments; segment 3 shortest; 4 shorter than 2: 5 shorter than 4.Labrum tongue–shaped, with rounded anterior margin. Mandibles thick, stout and short; strongly incurved anteriorly (length 1.02 mm); shorter than head (index-mandible length/head–length 0.60). Left mandible with a large prominent teeth below distal third (tooth-distance 0.42, index tooth distance/mandible-length 0.41). Right mandible with a small tooth situated almost at middle. Postmentum subrectangular (length 0.98, max. width 0.56 mm).

**Thorax:** Pronotum saddle shaped; anterior margin strongly notched and posterior margin weakly to deeply emarginated medially.

**Materials examined:** INDIA: Karnataka: Gopalaswamybetta, Gundlupet: $11^{0}$43.377' N $76^{0}$37.370'E, 04.x.2014, *ex* Cowdung, Vidyashree, A.S.; Kerala: Munnar, $10^{0}$03.056'N 76057.138'E, 27.xii.2015, *ex* Dead wood, Kavitha.; Tamil Nadu: *Annamalai Tiger Reserve forest, $10^{0}$28.280'N $76^{0}$57.522' E, 06.x.2014, *ex* Open mound, Vidyashree, A.S.; Udumalpet road, $10^{0}$19'41'N $77^{0}$12'43.90'E *ex* Gallery on live tree, Vidyashree, A.S.; Maharashtra: COA, Kholapur (Dist): $16^{0}$41.108'N $74^{0}$16.290'E, 16.viii.2015, *ex* Dead wood, Pavithra; Gujarath: Chimer, 21$^0$01.536'N 73$^0$43.157'E, 26.v.2016, *ex* Dead wood, Vidyashree, A.S.

*Measurement of different morphological characters is given in table 2.

**Distribution:** Karnataka, Kerala, Tamil Nadu, Maharashtra and Gujarath.

***Odontotermes ceylonicus*** (Wasmann)

*Termes ceylonicus* Wasmann, 1902: 112-113.
*Odontotermes* (*Odontotermes*) *ceylonicus* (Wasmann): Roonwal and Chhotani, 1967: 243-244.
*Odontotermes meturensis* Roonwal and Chhotani: 1959: 325-326. Person synonymised.

**Description:**

**General appearance:** Head yellowish to brownish yellow; antennae uniformly yellow; mandibles blackish brown, basally dark brown; body whitish to pale yellow.

**Head:** Head-capsule subrectangular, sides substraight or faintly convex and very slightly converged in front of antennae (length to base of mandibles 1.78, max. width 1.48, width at base of mandibles 1.38 mm (Table 2), index max. width/length 0.83. Antennae with 16 segments; segment 4 shortest in 16-segmented antennae. Labrum subtriangular, with tip somewhat pointed. Mandibles strong, stout, sabre-shaped, Incurved at tips (length 1.14 mm); less than 2/3 of head-length (index mandible-length 0.64). Left mandible with a large, sharp, pointed tooth at middle making an angle of about 90 (Tooth-distance 0.52, index tooth-distance/mandible-length 0.45).Right mandible with a rudimentary tooth at middle.Postmentum long, subrectangular (length-1.23, max. width-0.46 mm).

**Thorax:** Pronotum saddle-shaped, anterior and posterior margin deeply emarginated in middle (length 0.70, width 1.22 mm).

**Materials examined:** INDIA: Tamil Nadu: Valparai road, 10$^0$29.175'N 76$^0$58.186'E, 06.x.2014, *ex* Nest in soil, Vidyashree, A.S.; Annamalai tiger reserve forest, 10$^0$28.280'N 76$^0$57.522'E, 06.x.2014, *ex* Dead wood, Kumar.; TNAU campus, 11$^0$01.373'N 76$^0$56'40'E, 05.x.2014, *ex* Dead wood, Adarsha.; *Udumalpet Road, 10$^0$19.410'N 77$^0$12.439'E, 29.xii.2015, *ex* Gallery on live tree, Vidyashree, A.S.; Kerala: Charukara, 10$^0$57.529'N 76$^0$13.357'E, 27.xii.2015, *ex* Gallery on live tree, Pavithra.

* Measurement of different morphological characters is given in table 2.

**Distribution:** Kerala and Tamil Nadu.

***Odontotermes feae*** (Wasmann)

*Termes feae* Wasmann: 1896:625, 626.
*Odontotermes feae* (Wasmann): 1912: 786, 787.
*Odontotermes indicus* Thakur: 1981, 70-75. Person synonymised.

**Description:**

**General appearance:** Head yellow to reddish brown; antennae, labrum and legs paler; mandibles blackish, basally reddish brown; thorax and abdomen creamy yellow pale rust yellow.

**Head:** Head-capsule sub rectangular, longer than wide (length to base of mandibles 2.30, range 2.25-3.10, max. width 1.88, Table 2) widest in posterior region, width morethan 3/4$^{th}$ of length; antennae with 17 segments; segment 3 shortest; 4 longer than 5. Labrum tongue shaped, narrowed in front to a pointed tip. Mandibles stout, strong, sabre shaped (length 1.28, range 1.20-1.65 mm, mandible index–length/head-length 0.56). Left mandible with a medium sized tooth near middle (index tooth-0.48). Right mandible with a minute tooth at basal third. Postmentum is subrectangular, swollen near basal third (length 1.41; width 0.75).

**Thorax:** Pronotum saddle shaped with a length of 0.78 and width 1.41 (Table 2); anterior margin with a weak median notch; posterior margin weakly to deeply notched. Mesonotum and metanotum with sub straight posterior margin.

**Materials examined:** INDIA: Karnataka: Kyamanahalli, Sakleshpur, 12$^0$57.54'N 75$^0$43.44'E, 06.x.2013, *ex* Dead wood, Vidyashree, A.S.; Anemal, Sakleshpura, 12$^0$55.54'N 75$^0$45.46'E, 05.x.2013, *ex* Dead wood, Vidyashree, A.S.; Rakshidi, Sakleshpura, 12$^0$57'45''N 75$^0$44'12''E,05.x.2013, *ex* Dried wood pieces, Vidyashree, A.S.; Hettur, Sakleshpur, 12$^0$50'57''N 75046'42''E, 06.x.2013, *ex* Dead wood, Vidyashree, A.S.; Hettur, Sakleshpur, 12$^0$50'57''N 75046'39''E, 06.x.2013, *ex* Dead wood, Vidyashree, A.S.; Sakraypatna, Chikmaglur, 13$^0$28'12''N 75$^0$55'55''E, 04.x.2013, *ex* Unidentified forest tree, Vidyashree, A.S.; Sakraypatna, Chikmaglur, 13$^0$28'11''N

75$^{0}$55’54’’E, 04.x.2013, *ex* Dead wood, Vidyashree, A.S.; Sakraypatna, Chikmaglur, 13$^{0}$28’12’’N 75$^{0}$55’55’’ E, 04.x.2013, *ex* Fallen Coconut frond, Vidyashree, A.S.; Hiregouja, Chikmaglur, 13$^{0}$22’44’’N 75$^{0}$52’25’’ E, 04.x.2013, *ex Santalum album*, Vidyashree, A.S.; ZARS, Mudigere, 13$^{0}$07’8.60’’N 75$^{0}$37’37.70’’ E, 01.ii.2014, *ex* Silver oak, Vidyashree, A.S.; ZARS, Mudigere, 13$^{0}$06’51.1’’N 75$^{0}$37’55.20’’ E, 01.ii.2014, *ex* In decomposing material, Vidyashree, A.S.; COH, Mudigere, 13$^{0}$06’51.1’’N 75$^{0}$37’55.20’’ E, 01.ii.2014, *ex* Nest in soil, Vidyashree, A.S.; Giridarshini, Matthavara, Chikmaglur,13$^{0}$16’39.4’’ 75$^{0}$43’35.30’’ E, 31.i.2014, *ex* Soil galleries on forest tree, Vidyashree, A.S.; Salekoppa, Sagara, 14$^{0}$09’44.90’’N 74056’25.30’’ E, 06.xii.2013, *ex* Dead wood, Vidyashree, A.S.; Pura, Sagara, 14$^{0}$10’49.2’’N 74$^{0}$56’46.10’’E, 23.viii.2014, *ex* Dead wood, Vidyashree, A.S.; Aayanur,13$^{0}$59’05’’N75$^{0}$22’24’’E,02.ix.2014, *ex* Dead wood, Vidyashree, A.S.; Sigandoor,14$^{0}$04’4.10’’N 74$^{0}$53’37’’ E, 11.i.2014, *ex* Dead wood, Vidyashree, A.S.; Jannehaklu, 14$^{0}$11’8.10’’N 74057’49’’ E, 11.i.2014, *ex* Soil galleries on Mango tree, Vidyashree, A.S.; Talavani, Shivamogga, 13$^{0}$40’41.60’’N 75$^{0}$11’58.40’’E, 16.ix.2013, *ex* Dead wood, Vidyashree, A.S.; Salekoppa, Sagara,14$^{0}$09’44.90’’N 74$^{0}$56’25.30’’ E, 23.viii.2014, *ex* Dead wood, Vidyashree, A.S.; Talavani, Shivamogga, 13$^{0}$40’41.60’’N 75$^{0}$11’58.40’’ E, 16.ix.2013, *ex* Dead wood, Vidyashree, A.S.; Aldur, 13$^{0}$15’12.80’’N 75$^{0}$39’43.80’’ E, 16.ix.2013, *ex* Cowdung, Vidyashree, A.S.; Kukunjaru road, bhramavara, 13$^{0}$23’67.0’’N 74$^{0}$54’92.80’’E, 14.xii.2013, *ex* Closed mound, Vidyashree, A.S.; KVK, Brahmavara, 13$^{0}$25’46.20’’N 74$^{0}$45’47.0’’ E, 14.xii.2014, *ex* FYM, Vidyashree, A.S.; Salekoppa, Sagara: 15$^{0}$09’44.90’’N 74$^{0}$56’24.30’’ E, 23.viii.2014, *ex* Dead wood, Vidyashree, A.S.; Keladi: 14$^{0}$12’19.60’’N 75$^{0}$01’14.50’’ E, 29.ix.2013, *ex* Dead wood, Vidyashree, A.S.; Malaya Marutha, Mudigere, 13$^{0}$07’8.20’’N 75$^{0}$30’17.80’’E, 31.i.2014, *ex* Dead wood, Vidyashree, A.S.; Kudremukha, 13$^{0}$11’44.80’’N 75$^{0}$17’88.5’’ E, 08.xi.2014, *ex* Dead wood, Vidyashree, A.S.; Kudremukha, 13$^{0}$12’75.15’’N 75$^{0}$15’16.6’’ E, 08.xi.2014, *ex* Dead wood, Vidyashree, A.S.; Kudremukha, 13$^{0}$12’69’’N 75$^{0}$11’21.8’’ E, 08.xi.2014, *ex* Soil gallery on Silver oak, Vidyashree, A.S.; Horanadu, 13$^{0}$15’57.2’’N 75$^{0}$20’81.4’’E, 09.xi.2014, *ex* Soil galleries in Teak, Balehonnur, 13$^{0}$20’71.5’’N 75$^{0}$26’14.7’’E, 09.xi.2014, *ex* Dead wood, Vidyashree, A.S.; CCRI, Ballehonnur, 13$^{0}$22’4.80’’N 75$^{0}$25’24.2’’E, 09.xi.2014, *ex* Dead wood, Vidyashree, A.S.; Kagganalla, Balehonnur,

$13^{0}$15’64.5’’N $75^{0}$27’10.2’’ E, 08.xi.2014, *ex* Dead wood, Vidyashree, A.S.; Kagganalla, Ballehonnur, $13^{0}$15’62.4’’N $75^{0}$27’92’’ E, 08.xi.2014, *ex* Soil gallery on a live forest tree, Vidyashree, A.S.; Tupiru, Sagara road, $14^{0}$04’59.6’’N $75^{0}$18’15.1’’E, 23.viii.2014, *ex* Dead wood, Vidyashree, A.S.; Bannadakoppa, Near Sagara, $14^{0}$08’56.9’’N $75^{0}$05’11.2’’ E, 23.viii.2014, *ex* Dead wood, Vidyashree, A.S.; Surulihulli, Hosanagara, $13^{0}$57’18.1’’N $75^{0}$11’37.90’’ E, 02.ix.2014, *ex* Dead wood, Vidyashree, A.S.; Pilikola Nisargadhama, Mangalore, $12^{0}$55’32.4’’N $74^{0}$54’2.60’’E, 22.vi.2014, *ex* Soil gallery, Vidyashree, A.S.; KVK, Chamarajnagar, $10^{0}$19’41’’N $77^{0}$12’44’’ E, 30.xii.2015, *ex* Nest in soil, Vidyashree, A.S.; KVK, Chamarajnagar, $10^{0}$19’41’’N $77^{0}$12’44’’ E, 30.xii.2015, *ex* Dead wood, Vidyashree, A.S.; KVK, Chamarajnagar, $10^{0}$19’41’’N $77^{0}$12’44’’ E, 30.xii.2015, *ex* Nest in soil, Vidyashree, A.S.; KVK, Chamarajnagar, $10^{0}$19’41’’N $77^{0}$12’44’’ E,30.xii.2015, *ex* Gallery on silver oak tree, Vidyashree, A.S.; Near Agumbe, $13^{0}$29’26.3’’N $75^{0}$04’26’’E, 15.xi.2013, *ex* Closed Mound, Vidyashree, A.S.; *Hiregouja, Chikmaglur,$13^{0}$22’44’’N $75^{0}$52’25’’ E, 04.x.2013, *ex Ficus religiosa*, Vidyashree, A.S.; Panaji road, Belgavi, $15^{0}$47’4.50’’N$74^{0}$27’47.10’’E, 13.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Kerala: IISR, Calicut, $11^{0}$18’5.40’’N $75^{0}$50’35’’E, 21.vi.2014, *ex* Dead wood, Vidyashree, A.S.; IISR, Calicut, $11^{0}$18’5.10’’N $75^{0}$50’28.8’’ E, 21.vi.2014, *ex* Small closed mound, Vidyashree, A.S.; IISR, Calicut, $11^{0}$18’’N $75^{0}$50’32.4’’E, 21.vi.2014, *ex* Dead wood, Vidyashree, A.S.; IISR, Calicut, $11^{0}$18’2.90’’N $75^{0}$50’27.9’’E, 21.vi.2014, *ex* Dead wood, Vidyashree, A.S.; CPCRI, Kasargod, $13^{0}$58’26.2’’N $75^{0}$34’43.7’’ E, 24.xii.2015, *ex* Nest in soil, Vidyashree, A.S.; CPCRI, Kasargod, $13^{0}$58’26.2’’N $75^{0}$34’43.7’’ E, 24.xii.2015, *ex* Nest in soil, Vidyashree, A.S.; CPCRI, Kasargod,$13^{0}$58’26.2’’N $75^{0}$34’43.7’’E, 24.xii.2015, *ex* Dead wood, Vidyashree, A.S.; CPCRI, Kasargod, $13^{0}$58’26.2’’N $75^{0}$34’43.7’’E, 24.xii.2015, *ex* Nest in soil, Vidyashree, A.S.; Charukara,$10^{0}$55’52.90’’N $76^{0}$13’35.70’’ E, 27.xii.2015, *ex* Leaf litter, Vidyashree, A.S.; Charukara, $10^{0}$55’52.90’’N $76^{0}$13’35.70’’E, 27.xii.2015, *ex* Deadwood, Vidyashree, A.S.; Charukara, $10^{0}$55’52.90’’N $76^{0}$13’35.70’’E, 27.xii.2015 *ex* Dead wood, Vidyashree, A.S.; Chinnar wildlife sanctuary, $10^{0}$18’43’’N $77^{0}$11’23.50’’E, 27.xii.2015, *ex* Dead wood, Vidyashree, A.S.; Munnar, $10^{0}$03’5.60’’N $76^{0}$57’13.80’’E, 27.xii.2015, *ex* Nest in soil, Vidyashree, A.S.; Munnar, $10^{0}$03’5.60’’N $76^{0}$57’13.80’’E, 27.xii.2015, *ex* Nest in Soil, Vidyashree, A.S.; Palanadu, $10^{0}$13’49.7’’N 77008’19.40’’E, 27.xii.2015*ex* Gallery on Teak, Vidyashree, A.S.; Marayoor Forest Division, 10$^0$14’36.6’’N 77$^0$08’19.40’’E, 29.xii.2015, *ex* Gallery on Teak, Vidyashree, A.S.; Goa: Mhadei wildlife sanctuary, 15$^0$36’17.1’’N 74$^0$06’10.3’’E, 10.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Curtorim, 15$^0$16’02’’N 74$^0$01’12.90’’E, 12.ii.2016, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Valpoi,15$^0$31’55.2’’N 74$^0$05’47.2’’E, 10.ii.2016, *ex* Soil gallery on live tree, Vidyashree, A.S.; Valpoi, 15$^0$31’55.2’’N 74$^0$05’47.2’’ E, 10.ii.2016, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Mandovi guest house, 15$^0$22’41.2’’N 74$^0$13’49.6’’E, 09.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Maharashtra: Pratapgarh, 17$^0$56’9.30’’N 73$^0$37’30.4’’E, 18.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Poladhpur, 18$^0$00’24.9’’N 73$^0$28’4.90’’E, 17.viii.2015, *ex* Dead wood, Vidyashree, A.S.;Poladhpur, 18$^0$00’26.8’’N 73$^0$28’3.70’’E, 17.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Poladhpur, 18$^0$00’24.9’’N 73$^0$28’4.90’’E, 17.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Poladhpur, 18$^0$00’26.6’’N 73$^0$28’3.80’’E, 17.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Gujarath: Sholapaneshwar wildlife sanctuary, 21$^0$45’19.22’’N 73$^0$47’39.75’’ E, 23.v.2016, *ex* Dead wood, Vidyashree, A.S.; Manekpur, 20$^0$51’41.16’’N 73$^0$01’13.95’’ E, 24.v.2016, *ex* Dead wood, Vidyashree, A.S.; Shravaniya, 21$^0$01’57.91’’N 73$^0$41’18.74’’ E, 25.v.2016, *ex* Dead wood, Vidyashree, A.S.; Amthava, 21$^0$01’38.31’’N 73$^0$39’26.71’’ E, 23.v.2016, *ex* Dead wood, Vidyashree, A.S.; Machhi, 21$^0$17’1.50’’N 73$^0$03’48.76’’ E, 24.v.2016, *ex* Nest in soil, Vidyashree, A.S.; Ratnapur, 22$^0$24’25.64’’N 70$^0$47’36.51’’ E, 26.v.2016, *ex* Soil gallery on wood, Vidyashree, A.S.; Tamil Nadu: Sethumudai, 10$^0$30’39.29’’N 76$^0$52’36.40’’E, 07.x.2014, *ex* Dead wood, Vidyashree, A.S.; Valporai road, 10$^0$29’17.50’’N 76$^0$58’18.60’’ E, 06.x.2014, *ex* Dead wood, Vidyashree, A.S.; Annamalai tiger reserve forest, 10$^0$28’2.80’’N 76$^0$57’52.20’’E, 06.x.2014, *ex* Nest in soil, Vidyashree, A.S.; TNAU campus, 11$^0$00’37.30’’N 76$^0$56’0.40’’E, 05.x.2014, *ex* Soil gallery on wood, Vidyashree, A.S.; TNAU campus, 11$^0$00’34.60’’N 76$^0$55’58.70’’E, 05.x.2014, *ex* Nest in soil, Vidyashree, A.S.; Nelliyampathy, 10$^0$32’2.98’’N 76$^0$41’46.50’’E, 08.x.2014, *ex* Decomposing material, Vidyashree, A.S.; Maharashtra: Lodwick point, Mahabaleshwara, 17$^0$56’21.0’’N 73$^0$38’05’’ E, 18.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Mahabaleshwar, 17$^0$55’25.5’’N 73$^0$37’55’’E, 18.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Kankavali, 16$^0$17’41.0’’N 74$^0$24’21’’E, 14.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Raigad, 18$^0$07’33.0’’N 73$^0$24’06’’E, 17.viii.2015, *ex*Dead wood, Vidyashree, A.S.; Raigad, $18^{0}$07’34.70’’N $73^{0}$24’06.8’’E,17.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Hiranyakesh Ugam, $15^{0}$57’20.10’’N $74^{0}$01’35.30’’E, 14.viii.2015, *ex* Dead wood, Vidyashree, A.S.

*The specimens on which description and measurement was given (Table 2).

**Distribution:** Karnataka, Kerala, Tamil Nadu, Maharashtra, Goa and Gujarath.

***Odontotermes globicola*** (Wasmann)

*Microtermes globicola* Wasmann, 1902: 116-117.
*Termes* (*Termes*) *dehraduni* Synder: 1933, 82 (6): 6-7. Person Synonymised.

**Description:**

**General appearance:** Head-capsule yellowish to dark golden brown; antennae yellowish to brownish, paler than head and paler apically; mandibles dark brown, paler basally; body whitish to pale yellow.

**Head:** Head-capsule roundly oval, converging anteriorly; widest behind middle (length to base of mandibles 1.02, max. width 0.95, width at mandible-base 0.56 mm, index max. width/length 0.93) (Table 3). Antennae 15 segmented; segment 2 equal to 3+4, the latter shortest; in type soldier (antennae broken) segment 3 shortest, 4 longer than 5. Labrum triangular, pointed in front; longer than wide (length 0.28, width 0.32 mm). Mandibles thin, long and slender; straight and weakly incurved near distal end (length 0.63 mm); shorter than head (index mandible-length/head-length 0.63). Left mandible with a prominent tooth near tip, tooth distance from tip 0.15 mm (index tooth-distance/mandible-length 0.24).Right mandible with a small tooth at about distal third.Postmentum short, broad and arched, sides convex, anteriorly converging (length 0.48, max. width 0.38 mm).

**Thorax:** Pronotum saddle shaped; weakly to markedly notched at anterior margin; posterior margin slightly emarginated; length 0.42, width 0.60 mm. Mesonotum narrower and metanotum as wide as pronotum.

**Material examined:** INDIA: Kerala: Chinnar wildlife sanctuary, 10$^{0}$18'43''N, 77.11'23.50''E, 27.xii.2015, *ex* Dead wood, Vidyashree, A.S.

**Distribution:** Kerala.

***Odontotermes horni*** (Wasmann)

*Termes horni* Wasmann, 1902: 111-112.
*Termes peradeniyae* Holmgren: 1911, 197.
*Odontotermes horni* var *hutsoni* Kemner: 1926, 384-385.
*Odontotermes horni* var. *minor* Kemner: 1926: 385-386.

**Description:**

**General appearance:** Head-capsule yellow to reddish brown; antennae, labrum, pronotum and legs pale yellowish brown; abdomen creamish white to pale yellow. Head sparsely and body fairly hairy.

**Head:** Head-capsule subrectangular; sides substraight very slightly converged in front of antennae (length to base of mandibles 2.48, max. width 1.85 (Table 3). Antennae with 17 segments; segment 3 much shorter than 2; 4 almost as long as 2; 5 shorter than 4. Labrum tongue- shaped; anteriorly with bluntly rounded tip. Mandibles strong, stout, sabregene-shaped (length 1.38 mm, index mandible-Length/head- length 0.55); left mandible with a large, prominent tooth near base of middle third (tooth-distance 0.80 mm, index tooth-distance/mandible-length 0.57); right mandible with a minute tooth a little below level of tooth on left mandible. Postmentum subrectangular; sides bulging out in proximal third (length 1.65, max. width 0.85 mm).

**Thorax:** Pronotum saddle-shaped (length 0.90, width 0.78 mm); anterior margin with weak to fairly marked median notch; posterior margin fairly distinctly notched.

**Material examined:** Karnataka: CCRI, Balehonnur: 13$^{0}$22'48''N, 75.25'24.2''E, 08.xi.2014, *ex* Soil nest, Vidyashree, A.S.

**Distribution:** Karnataka.

**Table 3. Measurements of different morphological characters in species belonging to genus *Odontotermes***

| Sl. No. | Measurement parameters#* | *Odontotermes* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ***globicola*** | ***horni*** | ***obesus*** | ***peshawarensis*** | ***redemanni*** | ***vaishno*** | ***wallonensis*** | ***yadevi*** |
| 1 | Number of antennal segments | 15 | 17 | 17 | 15 | 17 | 16 | 17 | 17 |
| 2 | Head length with mandibles | 2.06 | 2.98 | 2.08 | 1.69 | 1.90 | 1.58 | 2.52 | 3.87 |
| 3 | Head length without mandibles | 1.02 | 2.48 | 1.23 | 1.08 | 1.25 | 1.00 | 1.76 | 2.35 |
| 4 | Head width | 0.95 | 1.85 | 1.14 | 0.94 | 1.02 | 0.95 | 1.38 | 2.00 |
| 5 | Head width at base of mandibles | 0.56 | 1.80 | 0.67 | 0.68 | 0.64 | 0.54 | 0.88 | 1.34 |
| 6 | Mandible length | 0.63 | 1.38 | 0.76 | 0.78 | 0.85 | 0.64 | 1.05 | 1.36 |
| 7 | Tooth distance from tip | 0.15 | 0.80 | 0.28 | 0.27 | 0.29 | 0.22 | 0.45 | 0.63 |
| 8 | Labrum length | 0.28 | 0.45 | 0.34 | 0.25 | 0.30 | 0.24 | 0.38 | 0.54 |
| 9 | Labrum width | 0.32 | 0.39 | 0.26 | 0.24 | 0.24 | 0.20 | 0.41 | 0.50 |
| 10 | Pronotum length | 0.42 | 0.90 | 0.50 | 0.36 | 0.41 | 0.43 | 0.59 | 0.77 |
| 11 | Pronotum width | 0.60 | 0.78 | 0.86 | 0.66 | 0.82 | 0.65 | 1.03 | 1.51 |
| 12 | Postmentum length | 0.48 | 1.65 | 0.74 | 0.63 | 0.61 | 0.65 | 0.95 | 1.52 |
| 13 | Postmentum width | 0.38 | 0.85 | 0.48 | 0.40 | 0.44 | 0.44 | 0.53 | 0.84 |
| 14 | Mandible index | 0.63 | 0.55 | 0.62 | 0.72 | 0.77 | 0.64 | 0.60 | 0.58 |
| 15 | Head index | 0.96 | 0.75 | 0.93 | 0.87 | 0.82 | 0.95 | 0.78 | 0.85 |
| 16 | Labrum index | 1.14 | 0.87 | 0.76 | 0.97 | 0.80 | 0.83 | 0.97 | 0.93 |
| 17 | Tooth index | 0.24 | 0.57 | 0.37 | 0.35 | 0.35 | 0.34 | 0.39 | 0.46 |
| 18 | Postmentum index | 0.79 | 0.51 | 0.65 | 0.64 | 0.72 | 0.67 | 0.56 | 0.55 |

# Average of 5 specimens; * Length and width in mm.

***Odontotermes obesus*** (Rambur)

*Termes obesus* Rambur: 1842. 304.
*Odontotermes obesus* (Rambur): 1965, 24-25.
*Termes obesus* (*Cyclotermes*) *orissae* Snyder: 1934, 10-11. Person synonymised.

**Description:**

**General appearance:**Head capsule pale yellow to castaneous brown; antennae pale yellow to yellowish brown, darker distally; mandibles light brown to deep reddish brown; body pale yellow to pale yellowish.

**Head:** Head capsule oval (length to base of mandibles 1.23, max. width 1.14 (Table 3), index width/length 0.93) antenna 17 segmented, segment 3 was shortest. Labrum tongue shaped, with broadly rounded anterior margin. Mandibles long slender and sabre shaped (length 0.76, mandible index length/head length 0.62). Left mandible with a sharp prominent tooth at distal 1/3 (tooth distance from tip 0.28, index tooth-distance/ mandible length 0.37). Right mandible with a minute tooth a little below level of tooth on left mandible.Post mentum subrectangular (length 0.74, width 0.48).

**Thorax:** Pronotum saddle shaped (length, 0.50 and width 0.86 mm).

**Materials examined:** INDIA: Karnataka: Humchadakatte, 13$^{0}$51’22’’N 75$^{0}$13’30’’E, 02.ix.2013, *ex* Teak, Vidyashree, A.S.; Humcha, 13$^{0}$52’16.87’’N 75$^{0}$13’9.42’’E, 02.ix.2013, *ex* Dead wood, Vidyashree, A.S.; Humcha,13$^{0}$59’59.39’’N 75$^{0}$18’58.83’’E, 02.ix.2013, *ex* Cowdung, Vidyashree, A.S.; Humcha, 13$^{0}$59’50.03’’N 75$^{0}$22’24.86’’E, 02.ix.2013, *ex* Dead wood, Vidyashree, A.S.; Kyanahalli, Sakleshpura, 12$^{0}$53’39’’N 75$^{0}$45’30’’E, 05.x.2013, *ex* Dead wood, Vidyashree, A.S.; Kyanahalli, Sakleshpura, 12$^{0}$53’44’’N 75$^{0}$45’05’’E, 05.x.2013, *ex* Closed mound, Vidyashree, A.S.; Kyanahalli, Sakleshpura, 12$^{0}$53’42’’N 75$^{0}$45’04’’E, 05.x.2013, *ex* Closed mound, Vidyashree, A.S.; Kadumane, Sakleshpura, 12$^{0}$57’55’’N 75$^{0}$43’80’’E, 06.x.2013, *ex* Unidentified forest tree, Vidyashree, A.S.; Kadumane, Sakleshpura, 12$^{0}$55’54’’N 75$^{0}$45’46’’E, 06.x.2013, *ex* Fallen and dried Coconut frond, Vidyashree, A.S.; Kadumane, Sakleshpura, 12$^{0}$56’18’’N 75$^{0}$45’39’’E, 06.x.2013, *ex* Closed mound, Vidyashree, A.S.; ARS, Theerthahalli, 13$^{0}$41’55’’N 75$^{0}$13’59’’E, 16.ix.2013, *ex* Unidentified forest tree, Vidyashree, A.S.; ARS, Theerthahalli, 13$^0$41$^{’}$55’’N 75$^0$13$^{’}$59’’E, 16.ix.2013, Dead wood, Vidyashree, A.S.; ARS, Theerthahalli, 13$^0$41$^{’}$55’’N 75$^0$13$^{’}$59’’E, 16.ix.2013, *ex* Dead wood, Vidyashree, A.S.; Bisle, Sakleshpura, 12$^0$42’39’’N 75$^0$41’31’’E, 05.x.2013, *ex* Dead wood, Vidyashree, A.S.; Bommanakere, Sakleshpura, 12$^0$48’59’’N 75$^0$46’35’’E, 06.x.2013, *ex* Dead wood, Vidyashree, A.S.; Bommanakere, Sakleshpura, 12$^0$50’55’’N 75$^0$46’35’’E, 06.x.2013, *ex* Dead wood, Vidyashree, A.S.; Garthikere, 13$^0$54’01’’N 75$^0$01’4.23’’E, 29.ix.2013, *ex* Acasia, Vidyashree, A.S.; Rippenpet, 13$^0$56’16’’N 75$^0$12’10’’E, 29.ix.2013, *ex Tectona grandis*, Vidyashree, A.S.; Rippenpet, 13$^0$56’16’’N 75$^0$12’10’’E, 29.ix.2013, *ex* Closed mound, Vidyashree, A.S.;Santhaveri : 13$^0$32’50.1’’N 75$^0$49’27.2’’E, 31.i.2014, *ex* Closed mound, Vidyashree, A.S.;Kukunjaru road, 13$^0$23’67’’N 74$^0$54’92.8’’E, 14.xii.2013, *ex* Closed mound, Vidyashree, A.S.; Matthavara, Chikmaglur, 13$^0$16’39.4’’N 75$^0$43’35.3’’E, 31.i.2014, *ex* Soil galleries on forest tree, Vidyashree, A.S.;Siddinakai, Sagara. 14$^0$09’13.2’’N 74056’37.9’’E, 23.viii.2014, *ex* Closed mound, Vidyashree, A.S.; Kabbinamane, Sagara, 14$^0$06’46.4’’N 75$^0$58’58.1’’E, 23.viii.2014, *ex* Closed mound, Vidyashree, A.S.; Bheemanakone, Sagara. 14$^0$07’35.5’’N 75$^0$03’28’’E, 23.viii.2014, *ex* Closed mound, Vidyashree, A.S.; Kabbinamane, Sagara. 14$^0$06’46.4’’N 75058’58.1’’E, 23.viii.2014, *ex* Closed mound, Vidyashree, A.S.; Pura, Sagara, 14$^0$10’59.2’’N 74$^0$56’46.4’’E, 23.viii.2014, *ex* Soil, Vidyashree, A.S.; Talavani, Thirthahalli. 13$^0$40’41.6’’N 75$^0$11’58.4’’E, 16.ix.2013, *ex* Soil galleries on Acasia, Vidyashree, A.S.; Thalavani, Theerthahalli 13$^0$40’41.1’’N 75$^0$11’58.8’’E, 16.ix.2013, *ex* Soil galleries on forest tree, Vidyashree, A.S.; Talavani, Thirthahalli, 13$^0$40’41.1’’N 75$^0$11’58.4’’E, 16.ix.2013, *ex* Soil galleries on forest tree, Vidyashree, A.S.; Halladi, Shankarapura. 13$^0$33’24.8’’N 74$^0$48’38.7’’E,13.xii.2013, *ex* Closed mound, Vidyashree, A.S.; Jogfalls, 14$^0$13’31.3’’N 74$^0$48’29.5’’E, 23.viii.2014, *ex* Soil galleries on forest tree, Vidyashree, A.S.; Jogfalls, 14$^0$12’30.7’’N 74$^0$51’3.80’’E, 23.viii.2014, *ex* Closed mound, Vidyashree, A.S.; Kakanahasudi, 13$^0$45’11.2’’N 75$^0$33’21.1’’E, 20.xi.2013, *ex* Closed mound, Vidyashree, A.S.; Kakanahasudi, 13$^0$45’11.3’’N 75$^0$33’20.9’’E, 20.xi.2013, *ex* Dead wood, Vidyashree, A.S.; Kakanahasudi, 13$^0$45’11.2’’N 75$^0$33’21.1’’E, 20.xi.2013, *ex* Dead wood, Vidyashree, A.S.; Agumbe vishranthi dhama. 13$^0$27’27.2’’N 75$^0$04’27.8’’E, 15.xi.2013, *ex* Closed mound, Vidyashree, A.S.; Agumbe vishanthi dhama, 13$^0$29’53.4’’N 75$^0$04’58.3’’E, 15.xi.2013, *ex* Small closed mound, Vidyashree, A.S.;

Hebri. $13^{0}$27’82.3’’N $74^{0}$59’93’’E, 20.xi.2013, *ex* Dead wood, Vidyashree, A.S.; Sirimane, $13^{0}$23’13.8’’N $75^{0}$10’39.2’’E, 20.xi.2013, *ex* Dead wood, Vidyashree, A.S.; Sirimane, $13^{0}$23’14.2’’N $75^{0}$10’38.7’’E, 20.xi.2013, *ex* Dead wood, Vidyashree, A.S.; Koppa. $13^{0}$31’23.6’’N $75^{0}$19’52.1’’E, 20.xi.2013, *ex* Closed mound, Vidyashree, A.S.; Koppa. $13^{0}$31’23.6’’N $75^{0}$19’52.1’’E, 20.xi.2013, *ex* Soil galleries on forest tree, Vidyashree, A.S.; KVK, Brahmavara, $13^{0}$25’46.2’’N $74^{0}$45’47’’E, 14.xii.2013, Dead wood, Vidyashree, A.S.; KVK, Brahmavara, $13^{0}$25’46.2’’N $74^{0}$45’46’’E, 14.xii.2013, *ex* Closed mound, Vidyashree, A.S.; Near Hariharapura, $13^{0}$31’23.3’’N $75^{0}$19’50.6’’E, 14.xii.2013, *ex* Dead stump of Forest tree, Vidyashree, A.S.; Someshwara, $13^{0}$29’18.6’’N $75^{0}$03’45.5’’E, 02.ix.2014, *ex* Dead wood, Vidyashree, A.S.; Amberagodlu, $14^{0}$04’40.9’’N $74^{0}$55’33.1’’E, 11.i.2014, *ex* Closed mound, Vidyashree, A.S.; Amberagodlu, Sigandoor, $14^{0}$04’4.1’’N $74^{0}$53’37’’E, 11.i.2014, Dead wood, Vidyashree, A.S.; Near Agumbe, $13^{0}$31’46.8’’N $75^{0}$06’13.5’’E, 15.xi.2013, *ex* Closed mound, Vidyashree, A.S.; Agumbe vishranti dhama, $13^{0}$29’27.2’’ $75^{0}$04’27.8’’, 15.xi.2013, *ex* Closed mound, Vidyashree, A.S.; Agumbe, $13^{0}$29’26.3’’N $75^{0}$04’26’’E, 15.xi.2013, *ex* Deadwood, Vidyashree, A.S.; Near Agumbe, $13^{0}$31’46.8’’N $75^{0}$06’13.5’’E, 15.xi.2013, *ex* Closed mound, Vidyashree, A.S.; Sigandhoor, $14^{0}$04’4.20’’N $74^{0}$53’37’’E, 11.i.2014, *ex* Dead wood, Vidyashree, A.S.;Sigandhoor, $14^{0}$04’4.20’’N $74^{0}$53’37.2’’E, 11.i.2014, *ex* Dead wood, Vidyashree, A.S.; Sigandhoor, $14^{0}$04’4.60’’N $74^{0}$53’34.9’’E, 11.i.2014, *ex* Closed mound, Vidyashree, A.S.;Sigandhoor, $14^{0}$04’5.50’’N $74^{0}$53’20.3’’E, 11.i.2014, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Keladi, $14^{0}$12’19.6’’N $75^{0}$01’14.5’’E, 11.i.2014, *ex* Dead wood, Vidyashree, A.S.; Kudremukha. $13^{0}$11’44.8’’N $75^{0}$17’88.5’’E, 08.xi.2014, *ex* Dead wood, Vidyashree, A.S.; Kudremukha, $13^{0}$12’75.15’’N $75^{0}$15’16.6’’E, 08.xi.2014, *ex* Soil gallery on a forest tree, Vidyashree, A.S.; Kudremukha, $13^{0}$12’69’’N $75^{0}$11’21.8’’E, 08.xi.2014, *ex* Nest in soil, Vidyashree, A.S.; Horanadu, $13^{0}$15’57.2’’N $75^{0}$20’81.4’’E, *ex* Leaf litter, Vidyashree, A.S.; Kagganalla, Kalasa road, Balehonnur.$13^{0}$15’64.5’’N $75^{0}$27’10.2’’E, 08.xi.2014, *ex* Small closed mound, Vidyashree, A.S.; Kagganalla, Kalasa road, Balehonnur $13^{0}$15’62.4’’N $75^{0}$27’92’’E, 08.xi.2014, *ex* Soil gallery on a forest tree, Vidyashree, A.S.; Kagganalla, Kalasa road, Balehonnur. $13^{0}$15’62.8’’N $75^{0}$27’88’’E, 08.xi.2014, Soil gallery on teak tree, Vidyashree, A.S.; Talavata, Sagara, $14^{0}$13’33’’N $74^{0}$52’31.4’’E, 06.xii.2013, *ex*

Closed mound, Vidyashree, A.S.; Iginbayalu, near Sagara, 14$^{0}$06’43.4’’N 75$^{0}$09’12.1’’E, *ex* Dead wood, Vidyashree, A.S.; Iginbayalu, near Sagara, 14$^{0}$06’43.4’’N 75$^{0}$09’10.8’’E, 06.xii.2013, *ex* Dead wood, Vidyashree, A.S.; Bannadakoppa, near Sagara, 14$^{0}$08’56.9’’N 75$^{0}$05’11.2’’E, 06.xii.2013, *ex* Decomposing material, Vidyashree, A.S.; Near Talaguppa, Sagara, 14$^{0}$13’33.1’’N 74$^{0}$52’31.5’’E, 06.xii.2013, *ex* Nest in soil, Vidyashree, A.S.; Iginbayalu, near Sagara, 14$^{0}$06’43.3’’N 75$^{0}$09’10.6’’E, 06.xii.2013, *ex* Closed mound, Vidyashree, A.S.; Bannadakoppa, near Sagara, 14$^{0}$08’56.8’’N 75$^{0}$05’11.2’’E, 06.xii.2013, *ex* Nest in soil, Vidyashree, A.S.; Near Hosur, Sagara, 14$^{0}$05’31.6’’N 75$^{0}$11’19.8’’E, 06.xii.2013, *ex* Closed mound, Vidyashree, A.S.; Devagange, Hosanagara, 13$^{0}$50’0.3’’N 75$^{0}$01’1.80’’E, 02.ix.2014, *ex* Closed mound, Vidyashree, A.S.; Chikjeni, Hosanagara, 13$^{0}$57’53.6’’N 75$^{0}$12’10.5’’E, 02.ix.2014, *ex* Closed mound, Vidyashree, A.S.; Kodur, Hosanagara, 13$^{0}$56’6.80’’N 75$^{0}$08’19.2’’E, 02.ix.2014, *ex* Closed mound, Vidyashree, A.S.; Shanthapura, Hosanagara, 13$^{0}$56’49.2’’N 75$^{0}$10’48.6’’E, 02.ix.2014, *ex* Closed mound, Vidyashree, A.S.; Kolluru, 13$^{0}$52’50.6’’N 74$^{0}$48’58.5’’E, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Pilikola Nisargadhama, Mangalore, 12$^{0}$55’32.4’’N 74$^{0}$54’2.6’’E, 22.vi.2014, *ex* Closed mound, Vidyashree, A.S.; Near Karkala, 13$^{0}$18’45.3’’N 74$^{0}$59’25.1’’E, 22.vi.2014, *ex* Closed mound, Vidyashree, A.S.; Near Gopalaswamy betta, Gundlupet, 11$^{0}$43’37.7’’N 76$^{0}$37’3.7’’E, 04.x.2014, *ex* Cowdung, Vidyashree, A.S.; Bandipur national park, 11$^{0}$39’57.6’’N 76$^{0}$37’41.4’’E, 04.x.2014, *ex* Closed mound, Vidyashree, A.S.; Siddapur forest, 14$^{0}$15’15.1’’N 75$^{0}$47’26.1’’E, 08.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Edalli, Siddapur forest, Gokarna road, UK(D), 14$^{0}$15’14.2’’N 74$^{0}$47’25.9’’E, 08.ii.2016, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Panji road, 15$^{0}$47’4.50’’N 74$^{0}$27’47.1’’E, *ex* Closed mound, Vidyashree, A.S.; KVK, Chamarajnagar, 10$^{0}$17’41’’N 77$^{0}$12’44’’E, 30.xii.2015, *ex* Nest in Soil, Vidyashree, A.S.; KVK, Chamarajnagar, 10$^{0}$17’41’’N 77$^{0}$12’44’’E, 30.xii.2015, *ex* Closed mound, Vidyashree, A.S.; KVK, Chamarajnagar, 10$^{0}$17’41’’N 77$^{0}$12’44’’E, 30.xii.2015, *ex* Closed mound, Vidyashree, A.S.; KVK, Chamarajnagar, 10$^{0}$17’41’’N 77$^{0}$12’44’’E, 30.xii.2015, *ex* Dead wood, Vidyashree, A.S.; KVK, Chamarajnagar, 10$^{0}$17’41’’N 77$^{0}$12’44’’E, 30.xii.2015, *ex* Dead wood, Vidyashree, A.S.; KVK, Chamarajnagar, 10$^{0}$17’41’’N 77$^{0}$12’44’’E, 30.xii.2015, *ex* Soil nest, Vidyashree, A.S.; KVK, Chamarajnagar, 10$^{0}$17’41’’N 77$^{0}$12’44’’E, 30.xii.2015, *ex*

Gallery on silver oak tree, Vidyashree, A.S.; Halladi, Shankarapura, 13$^{0}$33’24.8’’N 74$^{0}$48’38.7’’E, 13.xii.2013, *ex* Soil galleries on forest tree, Vidyashree, A.S.; Sirimane, 13$^{0}$23’13.8’’N 75$^{0}$10’93.2’’E, 20.xi.2013, *ex* Dead standing tree, Vidyashree, A.S.; Panaji road, 15$^{0}$47’4.5’’N 74$^{0}$27’47.1’’E, 13.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Santhaveri, 13$^{0}$32’50.1’’N 75$^{0}$49’27.2’’E, 31.i.2014, *ex* Closed mound, Vidyashree, A.S.; *Rakshidi, Sakleshpur, 12$^{0}$57’45’’N 75$^{0}$44’12’’E, 05.x.2013, *ex* Closed mound, Vidyashree, A.S.; Kerala: IISR, Calicut, 11$^{0}$18’5.4’’N 75$^{0}$50’35’’E, 21.vi.2014, *ex* Soil gallery on Coconut, Vidyashree, A.S.; IISR, Calicut, 11$^{0}$18’5.1’’N 75$^{0}$50’28.8’’E, 21.vi.2014, *ex* Small closed mound, Vidyashree, A.S.;IISR, Calicut, 11$^{0}$17’50.8’’N 75$^{0}$50’27’’E, 21.vi.2014, *ex* Dried coconut frond, Vidyashree, A.S.; IISR, Calicut, 11$^{0}$17’58.3’’N 75$^{0}$50’26.2’’E, 21.vi.2014, *ex* Dead wood, Vidyashree, A.S.; IISR, Calicut, 11$^{0}$18’00’’N 75$^{0}$50’27.7’’E, 21.vi.2014, *ex* Dead wood, Vidyashree, A.S.; IISR, Calicut, 11$^{0}$18’2.9’’N 75$^{0}$50’27.9’’E, 21.vi.2014, *ex* Dead wood, Vidyashree, A.S.; KFRI, Peechi, 10$^{0}$02’59.1’’N 76$^{0}$43’41.4’’E, 27.xii.2015, *ex* Closed mound, Vidyashree, A.S.; Perinthalmanna, 11$^{0}$18’1.1’’N 75$^{0}$50’33.6’’E, 27.xii.2015, *ex* Closed mound, Vidyashree, A.S.;Attukad, 10$^{0}$03’10.3’’N 77$^{0}$03’33.3’’E, 27.xii.2015, *ex* Closed mound, Vidyashree, A.S.;Attukad Falls, 10$^{0}$03’10.4’’N 77$^{0}$03’33.4’’E, 27.xii.2015, *ex* Dead wood**,** Vidyashree, A.S.; Attukad, 10$^{0}$03’10.3’’N 77$^{0}$03’33.3’’E, 27.xii.2015, *ex* Closed mound, Vidyashree, A.S.; Attukad, 10$^{0}$03’10.4’’N 77$^{0}$03’33.4’’E, 27.xii.2015, *ex* Nest in Soil, Vidyashree, A.S.; KFRI, Peechi, 10$^{0}$02’59.1’’N 76$^{0}$43’41.4’’E, 27.xii.2015, *ex* Closed mound, Vidyashree, A.S.;KFRI, Peechi, 10$^{0}$02’59.1’’N 76$^{0}$43’41.4’’E, 27.xii.2015, *ex* Closed mound, Vidyashree, A.S.;KFRI, Peechi, 10$^{0}$02’59.1’’N 76$^{0}$43’41.4’’E,27.xii.2015, *ex* Closed mound, Vidyashree, A.S.; KFRI, Peechi, 10$^{0}$02’59.1’’N 76$^{0}$43’41.4’’E, 27.xii.2015, *ex* Closed mound, Vidyashree, A.S.;IISR, Calicut, 11$^{0}$18’5.1’’N 75$^{0}$50’28.8’’E, 06.x.2014, *ex* Small closed mound, Vidyashree, A.S.; IISR, Calicut, 11$^{0}$18’5.4’’N 75$^{0}$50’35’’E, 06.x.2014, *ex* Small closed mound, Vidyashree, A.S.;Tamil Nadu: Balasamudram, 10$^{0}$23’54.23’’N 77$^{0}$30’36.3’’E, 08.x.2014, *ex* Dead wood, Vidyashree, A.S.; Gudalur, 11$^{0}$29’32.12’’N 76$^{0}$27’7.5’’E, 08.x.2014, *ex* Dead wood, Vidyashree, A.S.; Srimadurai, 11$^{0}$33’17.35’’N 76$^{0}$29’52.11’’E, 08.x.2014, *ex* Dead wood, Vidyashree, A.S.; Sethumudai, 10$^{0}$30’39.29’’N 76$^{0}$52’36.4’’E, 07.x.2014, *ex* Dead wood, Vidyashree, A.S.; Aliyar, 10$^{0}$29’7.42’’N 76$^{0}$58’2.50’’E, 08.x.2014, *ex*

Dead wood, Vidyashree, A.S.;Sethumudai, 10$^{0}$30’39.29’’N 76$^{0}$52’36.4’’E, 07.x.2014, *ex* Closed mound, Vidyashree, A.S.; Mulli, 11$^{0}$13’9.49’’N 76$^{0}$43’29.8’’E, 06.x.2014, *ex* Closed mound, Vidyashree, A.S.; Mullimalai, 11$^{0}$15’56.17’’N 76$^{0}$37’57.1’’E, 06.x.2014, *ex* Dead wood, Vidyashree, A.S.; Near manjur, 11$^{0}$15’19.52’’N 76$^{0}$39’35.9’’E, 08.x.2014, *ex* Dead wood, Vidyashree, A.S.; Melkunda, 11$^{0}$13’28.99’’N 76$^{0}$36’39.5’’E, 08.x.2014, *ex* Dead wood, Vidyashree, A.S.; Emerald 11$^{0}$17’59.1’’N 76$^{0}$34’27.5’’E**,** 08.x.2014, *ex* Dead wood, Vidyashree, A.S.; Upasi Tea Research Institute, Valparoi, 10$^{0}$15’53.5’’N 76$^{0}$58’07’’E,06.x.2014, *ex* Dead wood, Vidyashree, A.S.;Upasi Tea Research Institute, Valparoi, 10$^{0}$16’10.1’’N 76$^{0}$58’6.70’’E,06.x.2014, *ex* Leaf litter, Vidyashree, A.S.; Sethumudai, 10$^{0}$30’39.29’’N 76$^{0}$52’36.4’’E,07.x.2014, *ex* Closed mound, Vidyashree, A.S.; Nirar dam, Valparoi, 10$^{0}$16’27.7’’N 76$^{0}$59’1.1’’E, 06.x.2014, *ex*Closed mound, Vidyashree, A.S.; Aliyar reserve forest, 10$^{0}$28’47.94’’N 76$^{0}$56’30.6’’E, 08.x.2014, *ex* Soil gallery on Neem, Vidyashree, A.S.; Mulli, 11$^{0}$13’9.49’’N 76$^{0}$43’29.8’’E, 08.x.2014, *ex* Closed mound, Vidyashree, A.S.;Thaisara, 11$^{0}$13’32.31’’N 76$^{0}$36’56.9’’E, 07.x.2014, *ex* Closed mound, Vidyashree, A.S.; Near Manjur, 11$^{0}$15’19.52’’N 76$^{0}$39’35.9’’E, 08.x.2014, *ex* Closed mound, Vidyashree, A.S.; Gudalur 11$^{0}$29’32.12’’N 76$^{0}$27’7.50’’E, 08.x.2014, *ex* Leaf litter, Vidyashree, A.S.; Srimadurai, 11$^{0}$33’17.35’’N 76$^{0}$49’52.11’’E, 07.x.2014, *ex* Leaf litter, Vidyashree, A.S.; Thaisara, 11$^{0}$13’32.31’’N 76$^{0}$36’56.9’’E, 07.x.2014, *ex* Leaf litter Vidyashree, A.S.; Thaisara 11$^{0}$13’32.31’’N 76$^{0}$36’56.9’’E, 07.x.2014, *ex* Soil gallery on Teak, Vidyashree, A.S.; Goa: Poinguinim, 14$^{0}$58’43.2’’N 74$^{0}$06’12.6’’E**,** 09.ii.2016, *ex* Soil gallery on Teak, Vidyashree, A.S.; Poinguinim, 14$^{0}$58’43.8’’N 74$^{0}$06’12.3’’E**,** 09.ii.2016, *ex* Soil gallery on forest tree**,** Vidyashree, A.S.; Pollem, 13$^{0}$32’50.1’’N 75$^{0}$49’27.2’’E,09.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Pollem, 13$^{0}$32’50.1’’N 75$^{0}$49’27.2’’E, 09.ii.2016, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Quepem, 15$^{0}$12’14.1’’N 74$^{0}$12’51.5’’E**,** 12.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Bondla wildlife sanctuary, 15$^{0}$31’55.3’’N 74$^{0}$05’47.5’’E**,** 11.ii.2016, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Bondla wildlife sanctuary, 15$^{0}$27’37.2’’N 74$^{0}$05’20.3’’E, 11.ii.2016, *ex* Closed mound, Vidyashree, A.S.; Bandoli, 15$^{0}$17’59.1’’N 74$^{0}$08’7.1’’E, *ex* Closed mound, Vidyashree, A.S.; Mhadei wildlife sanctuary, 15$^{0}$36’17.1’’N 74$^{0}$06’10.3’’E, 10.ii.2016, *ex* Closed mound, Vidyashree, A.S.; Mhadei wildlife sanctuary, 15$^{0}$36’16.1’’N 74$^{0}$06’10’’E**,** 10.ii.2016, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Mhadei wildlife sanctuary, 15$^0$36’16.4’’N 74$^0$06’9.90’’E, 10.ii.2016, *ex* Closed mound, Vidyashree, A.S.; Mollem near dudhsagar waterfalls, 15$^0$19’21’’N 74$^0$10’36.2’’E, 13.ii.2016, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Mollem, near dudhsagar falls, 15$^0$19’21’’N 74$^0$10’37.2’’E, 13.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Mollem, near dudhsagar waterfalls, 15$^0$19’21.4’’N 74$^0$10’36.3’’E, 13.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Valpoi, 15$^0$31’55.2’’N 74$^0$05’47.2’’E, 10.ii.2016, *ex* Cowdung, Vidyashree, A.S.; Valpoi, 15$^0$31’57.5’’N 74$^0$05’45.2’’E, 10.ii.2016, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Valpoi, 15$^0$31’58.6’’N 74$^0$05’44.3’’E, 10.ii.2016, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Poinguinim, 14$^0$58’43.2’’N 74$^0$06’12.6’’E, *ex* Soil gallery on forest tree, Vidyashree, A.S.; Maharashtra: Pratapgarh Fort, 17$^0$56’9.5’’N 73$^0$37’22.1’’E, 18.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Pratapgarh, 17$^0$56’9.3’’N 73$^0$37’30.4’’E, 18.viii.2015, *ex* Closed mound, Vidyashree, A.S.; Pratapgarh, 17$^0$56’7.7’’N 73$^0$37’23.9’’E, 18.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Kumbeshwar, 15$^0$56’3.6’’N 73$^0$57’59.5’’E, 14.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Kumbeshwar, 15$^0$56’4.4’’N 73$^0$56’12’’E, 14.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Vennadhal, 17$^0$47’40.5’’N 73$^0$43’21’’E, 19.viii.2015, *ex* Closed mound, Vidyashree, A.S.; Mahabaleshwar, 17$^0$55’25.5’’N 73$^0$37’55’’E, 18.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Amba ghat, kholapur (D), 16$^0$53’42’’N 73$^0$58’42’’E, 14.viii.2015, *ex* Cow dung, Vidyashree, A.S.; Amboli ghat, 16$^0$00’5.9’’N 74$^0$03’1.8’’E, 14.viii.2015, *ex* Closed mound, Vidyashree, A.S.; Ambholi forest, 15$^0$56’2.8’’N 73$^0$58’0.6’’E, 14.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Ambaghat Forest, Kholapur (D), 16$^0$59’54.6’’N 73$^0$46’10.5’’E, 14.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Ambaghat Forest, Kholapur (D), 16$^0$59’57.5’’N 73$^0$46’6.9’’E, 14.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Pondaghat, 16$^0$21’46’’N 73$^0$49’24.4’’E, 15.viii.2015, *ex* Closed mound, Vidyashree, A.S.; Kankavali, 16$^0$17’41’’N 74$^0$24’21’’E, 15.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Kankovali, 16$^0$17’45.5’’N 73$^0$42’44.6’’E, 15.viii.2015, *ex* Cow dung, Vidyashree, A.S.; Kankavali, 16$^0$17’44.5’’N 73$^0$42’44.9’’E, 15.viii.2015, *ex* Closed mound, Vidyashree, A.S.; Kankavali, 16$^0$17’45.5’’N 73$^0$42’44.8’’E, 15.viii.2015, *ex* Bamboo, Vidyashree, A.S.; Raigad, 18$^0$07’33’’N 73$^0$24’6.0’’E, 17.viii.2015, *ex* Closed mound, Vidyashree, A.S.; Radhanagiri, 16$^0$25’58.5’’N 74$^0$42’36.2’’E, 15.viii.2015, *ex*Dead wood, Vidyashree, A.S.; Karanjari, 16$^0$57’53’’N 73$^0$34’38’’E, 16.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Karanjari , 16$^0$57’52.7’’N 73$^0$34’38.1’’E, 16.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Satara, 17$^0$42’87.9’’N 73$^0$48’78.3’’E, 19.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Mausi, 17$^0$47’68’’N 73$^0$43’36.6’’E, 19.viii.2015, *ex* Closed mound, Vidyashree, A.S.; Mausi, 17$^0$44’37.2’’N 73$^0$45’96.0’’E, 19.viii.2015, *ex* Closed mound, Vidyashree, A.S.; COA, Kholapur (D), 16$^0$41’10.8’’N, 74$^0$16’2.90’’E, 16.viii.2015, *ex* Closed mound, Vidyashree, A.S.;Chipnur, 17$^0$14’31’’N 73$^0$33’13.7’’E, 16.viii.2015, *ex* Closed mound, Vidyashree, A.S.;Chipnur, 17$^0$14’53.1’’N 73$^0$33’15.2’’E, 16.viii.2015, *ex* Closed mound, Vidyashree, A.S.;Radhanagari, Kholapur, 16$^0$25’58.5’’N 74$^0$02’36.2’’E, 15.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Vennadhal , 17$^0$47’40.5’’N 73$^0$43’21.8’’E, 19.viii.2015, *ex* Closed mound, Vidyashree, A.S.; Mahabaleshwar, 17$^0$55’25.5’’N 73$^0$37’55.5’’E, 18.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Amba Ghat, Kholapur, 16$^0$59’57.8’’N 73$^0$46’6.10’’E, 14.viii.2015, *ex* Cowdung, Vidyashree, A.S.; Amboli Ghat, 16$^0$59’54’’N 73$^0$46’10.3’’E, 14.viii.2015, *ex* Closed mound, Vidyashree, A.S.; Raigad,18$^0$07’33’’N 73$^0$24’6.0’’E, 17.viii.2015, *ex* Closed mound, Vidyashree, A.S.; Radhanagiri, 16$^0$25’59.8’’N 74$^0$02’30.3’’E, 15.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Radhanagiri, 16$^0$25’58.4’’N 74$^0$02’33.1’’E, 15.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Karanjari, 16$^0$57’52.5’’N, 73$^0$34’37.8’’E, 16.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Chipnur, 17$^0$14’53.2’’N, 73$^0$33’15.5’’E, 16.viii.2015, *ex* Dead wood, Vidyashree, A.S.;Gujarath: Manekpur, 20$^0$51’41.16’’N 73$^0$01’13.95’’E, 24.v.2016, *ex* Closed mound, Vidyashree, A.S.; Chimer, 21$^0$01’5.36’’N 73$^0$43’15.67’’E, 26.v.2016, *ex* Closed mound Vidyashree, A.S.; Galtheshwar, 21$^0$16’39.7’’N 74$^0$02’30.3’’E, 24.v.2016, *ex* Soil nest, Vidyashree, A.S.; Amthava, 21$^0$01’38.31’’N 73$^0$39’26.71’’E, 23.v.2016, *ex* Closed mound, Vidyashree, A.S.; Machhi, 21$^0$17’1.5’’N 73$^0$03’48.76’’E, 24.v.2016, *ex* Dead wood, Vidyashree, A.S.; Sawardakasad 20$^0$53’09.76’’N 73$^0$40’58.9’’E, 26.v.2016, *ex* Cowdung, Vidyashree, A.S.**;** Damo kund, Junagad, 21$^0$31’35.54’’N 70$^0$29’2.5’’E, 23.v.2016,*ex* Closed mound, Vidyashree, A.S.**;** Hasnapur, Junagad 21$^0$33’56.77’’N 70$^0$31’33.11’’E, 24.v.2016, *ex* Closed mound, Vidyashree, A.S.; Banaskantha-nearplace, 24$^0$20’24.63’’N 71$^0$46’2.04’’E, 24.v.2016, *ex* Soil nest, Vidyashree, A.S.; Saputara, 20$^0$34’40.96’’N 73$^0$44’16.72’’E, 26.v.2016, *ex* Closed mound, Vidyashree, A.S.; Vansad national park, 20$^0$41’30.56’’N 73$^0$32’25.33’’E, 23.v.2016, *ex* Dead wood, Vidyashree, A.S.; Chikar, $20^0$41'49''N $73^0$31'7.51''E, 26.v.2016, *ex* Cowdung, Vidyashree, A.S.; Dungrara, $20^0$47'41.15''N $73^0$29'5.03''E, 26.v.2016, *ex* Closed mound, Vidyashree, A.S.; Sindhai, $20^0$51'52.86''N $73^0$18'57.67''E, 25.v.2016, *ex* Closed mound, Vidyashree, A.S.; Sholapaneshwar wildlife sanctuary, $21^0$45'19.22''N $73^0$47'39.75''E, 23.v.2016, *ex* Soil nest, Vidyashree, A.S.; Vandari, $21^0$46'6.22''N $73^0$47'15.09''E, 25.v.2016, *ex* Closed mound, Vidyashree, A.S.; Chapadi, $21^0$45'47.43''N $73^0$50'58.12''E, 23.v.2016, *ex* Dead wood, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 3.

**Distribution:** Karnataka, Kerala, Tamil Nadu, Goa, Gujarath and Maharashtra.

***Odontotermes peshawarensis*** Akhtar

*Odontotermes peshawarensis* Akhtar: 1974, 44-46.

**Description:**

**General appearance:** Head brownish yellow to yellowish brown, slightly paler anteriorly; antennae smoky brown, brownish yellow basally; mandibles light reddish brown, paler basally: pronotum yellowish; abdomen and legs whitish yellow.

**Head:** Head subrectangularly oval, a little longer than wide (length to base of mandibles 1.08 (Table 3), maximum width 0.94, width at base of mandibles 0.68 mm, index max. width/length 0.87). Antennae 15-segmented; segment 2 twice as long as 3, latter shortest. Labrum tongue- shaped, roundly pointed anteriorly; with a row of hairs on either side. Mandibles long, slender, weakly incurved apically (length of left mandible Mandibles long, slender, weakly incurved apically (length of mandible 0.78 mm, index mandible-length/head-length 0.72). Left mandible with a small, anteriorly directed tooth at distal third (tooth- distance from tip 0.27 mm, index tooth-distance/mandible-length 0.35).Right mandible with a minute tooth a little below level of left mandibular tooth. Postmentum arched, with slightly convex sides; a little longer than wide, with maximum width at middle (length of postmentum 0.63, maximum width 0.40 mm).

**Thorax:** Pronotum saddle-shaped; anterior margin indistinctly notched, posterior margin weakly emarginate (length 0.36 and width 0.66 mm).

**Materials examined: Goa:** Quepem, 15$^{0}$12'14.10''N 74$^{0}$12'51.50''E, 11.ii.2016, *ex* Deadwood, Vidyashree, A.S.

**Distribution:** Goa.

***Odontotermes redemanni*** **(Wasmann)**

*Odontotermes redemanni* (Wasmann): Roonwal and Chhotani, 1967: 251-252.

**General appearance:** Head- capsule pale yellowish to dark yellowish brown; antennae brown, paler basally; labrum brownish; mandibles dark reddish black, paler basally.

**Head:** Head-capsule oval (length to base of Mandibles 1.25 (Table 3), max. width 1.02 mm) resembles *O. obesus* very much. Antennae 17-segmented, segment 3 in 17-segmented ones. Labrum tongue-shaped; anterior margin broadly rounded. Mandibles long, slender, sabre-shaped, incurved distally; length 0.85 mm; longer than half of head-length (index mandible-length/head-length 0.77.

**Thorax:** Pronotum saddle-shaped, weakly to deeply notched with a length of 0.41 mm and 0.82 mm of maximum width.

**Materials examined:** INDIA: Karnataka: *Thorehadlu, Near Shringeri, 13$^{0}$27'30.1''N 75$^{0}$16'29.70''E, 20.xi.2013, *ex* Dead wood, Vidyashree, A.S.; Koppa, 13$^{0}$31'23.6''N 75$^{0}$19'52.10''E, 20.xi.2013, *ex* Soil galleries on forest tree, Vidyashree, A.S.; Agumbe, 13$^{0}$29'26.3''N 75$^{0}$04'26''E, 15.xi.2013 *ex* Bark of forest tree, Vidyashree, A.S.; Muttinakoppa, 13$^{0}$45'18.3''N 75$^{0}$28'19.4''E, 20.xi.2013, *ex* Dead wood, Vidyashree, A.S.; Keladi, 14$^{0}$12'19.6''N 75$^{0}$01'14.5''E, 27.iv.2014, *ex* Nest in soil, Vidyashree, A.S.; Goa: Pollem, 14$^{0}$54'45.1''N 74$^{0}$04'48.7''E, 09.ii.2016, *ex* Closed mound, Vidyashree, A.S.; Mhadei wildlife sanctuary, 15$^{0}$36'17.1''N 74$^{0}$06'10.3''E, 10.ii.2016, *ex* Soil nest, Vidyashree, A.S.; Karmane, 15$^{0}$19'21.4''N 74$^{0}$10'36.3''E, 12.ii.2016, *ex* Leaf litter, Vidyashree, A.S.

**Distribution:** Karnataka and Goa.

***Odontotermes vaishno*** Bose

*Odontotermes vaishno* Bose: 1975: 161-164.

**Description:**

**General appearance:** Head and labrum brownish yellow; antennae pale yellow, darker apical; mandibles dark reddish brown; body light brownish yellow.

**Head:** Head-capsule oval, converging anteriorly; a little longer than wide (length to base of mandibles was 1 mm and had maximum width of 0.95 mm). Antennae with 16 segments (Table 3); segment 4 shortest, 3 and 5 subequal. Labrum tongue-shaped, anterior margin broad and rounded. Mandibles thin, long, slendar, sabre-shaped; very weakly incurved distally (length 0.64 mm); a little longer than half of head length; index mandible-length/head length 0.64. Left mandible with a sharp, laterally directed tooth at distal one third (tooth distance 0.22 mm); index tooth distance / mandible length 0.34). Right mandible with a minute tooth a little above middle.Postmentum subrectangular (length 0.65, max. width 0.44 mm).

**Thorax:** Pronotum saddle shaped, anterior margin deeply notched and posterior margin fairly incurved medially (length 0.43, width 0.65 mm).

**Materials examined:** INDIA: Karnataka: Near Gopalaswamy betta, Gundlupet, $11^{0}$43’37.7’’N $76^{0}$37’3.70’’E, 04.x.2014, *ex* Dead wood, Vidyashree, A.S.; Bandipur national park, $11^{0}$39’57.6’’N $76^{0}$37’41.4’’E, 04.x.2014, *ex* Dead wood, Vidyashree, A.S.; Kerala: *IISR, Calicut, $11^{0}$18’5.40’’N $75^{0}$50’35’’E, 21.vi.2014, *ex* Dead wood, Vidyashree, A.S.; IISR, Calicut, $11^{0}$18’2.90’’N $75^{0}$50’27.9’’E, 21.vi.2014, *ex* Dead wood, Vidyashree, A.S.; KFRI, Peechi, $10^{0}$22’59.1’’N $76^{0}$43’41.4’’E, 27.xii.2015, *ex* Deadwood, Vidyashree, A.S.; KFRI, Peechi, $10^{0}$22’59.1’’N $76^{0}$43’41.4’’E, 27.xii.2015, *ex* Deadwood, Vidyashree, A.S.; Tamil Nadu: Thaisara, $11^{0}$13’32.31’’N $76^{0}$36’56.9’’E, 07.x.2014, *ex* Nest in soil, Vidyashree, A.S.; Upasi tea research institute, Valparai, $10^{0}$15’53.6’’N $76^{0}$58’7.0’’E, 06.x.2014, *ex* Nest in soil, Vidyashree, A.S.; Upasi tea research institute, Valparai, $10^{0}$15’5.6’’N $76^{0}$58’5.6’’E, 06.x.2014, *ex* Nest in soil, Vidyashree, A.S.; Nelliyampathy, $10^{0}$32’2.98’’N $76^{0}$41’46.5’’E, 06.x.2014, *ex* Nest in soil, Vidyashree, A.S.; Maharashtra: Amba Ghat, Kholapur (Dt), $16^{0}$59’54.5’’N $73^{0}$46’10.3’’E, 14.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Hiranyakesh Ugam, $15^{0}$57’20.1’’N $74^{0}$01’35.3’’E, 14.viii.2015, *ex* Closed mound, Vidyashree, A.S.; Ambha ghat, $16^{0}53'42''$N $73^{0}58'4.2''$E,14.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Goa: Catigao wildlife sanctuary, $14^{0}58'59.9''$N $74^{0}07'14.9''$E, 12.ii.2016, *ex* Soil galleries on forest tree, Vidyashree, A.S.; Gujarath: Vandari, $21^{0}46'6.22''$N $73^{0}47'15.09''$E, 25.v.2016, *ex* Deadwood, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 3.

**Distribution:** Karnataka, Kerala, Tamil Nadu, Goa, Gujarath and Maharashtra.

***Odontotermes wallonensis*** (Wasmann)

*Termes obesus wallonensis*, Wasmann, 1902: 106-109.
*Odontotermes brunneus kushwahai* Roonwal and Bose: 1964, 33-36. Person Synonymised.

**Description:**

**General appearance:** Head pale yellow to brownish yellow; antennae yellow to pale brown distally and paler proximally; mandibles dark brown; body and legs whitish yellow.

**Head:** Head sub-rectangularly oval, sides faintly convex (length to base of mandibles 1.76, max. width 1.38, width at the base of mandibles was 0.88 mm were given in table 3, index max. width/length 0.78). Antennae 17 segmented, 2 longer than 3 and latter shortest and 4 longer than 5. Labrum broadly tongue shaped; anteriorly broadly rounded (length 0.38, width 0.41 mm). Mandibles long and fairly strongly incurved anteriorly; length about 2/3 of head-length (length 1.05, index left mandible-length/head-length 0.60); left mandible with a prominent tooth a little above middle point (tooth distance from tip 0.45, index tooth-distance/mandible length 0.43); right mandible with a small tooth at middle. Postmentum subrectangular, flat, widest at anterior ¼; behind sides slightly incurved (length 0.95, max. width 0.53 mm).

**Thorax:** Pronotum saddle shaped (length 0.59, width 1.03 mm); deeply notched both anteriorly and posteriorly. Mesonotum narrower than pronotum, posterior margin weakly to fairly incurved. Metanotum as wide as or broader than pronotum, posterior margin substraight or weakly incurved.

**Materials examined:** INDIA: Karnataka: *Near Gopalaswamy betta, Gundlupet, 11$^{0}$43’37.7’’N 76$^{0}$37’3.70’’E, 04.x.2014, *ex* Open mound, Vidyashree, A.S.; Near Gopalaswamy betta, Gundlupet, 11$^{0}$39’58.6’’N 76$^{0}$37’39.0’’E, 04.x.2014, *ex* Small closed mound, Vidyashree, A.S.; Near Gopalaswamy betta, Gundlupet, 11$^{0}$43’37.2’’N 76$^{0}$36’21.6’’E, 04.x.2014, Dead wood, Vidyashree, A.S.; Bandipur national park, 11$^{0}$39’57.6’’N 76$^{0}$37’41.4’’E, 04.x.2014, *ex* Small closed mound, Vidyashree, A.S.; Tamil Nadu: Sethumudai, 10$^{0}$30’39.29’’N 76$^{0}$52’36.4’’E, 07.x.2014, *ex* Dead wood, Vidyashree, A.S.; Gujarath: Manekpur, 20$^{0}$51’41.16’’N 73$^{0}$01’13.95’’E, 24.v.2016, *ex* Closed mound, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 3.

**Distribution:** Karnataka, Tamil Nadu and Gujarath.

***Odontotermes yadevi*** Thakur

*Odontotermes yadevi* Thakur, 1981: 122-125.

**Description:**

**General appearance:** Head capsule pale yellowish brown to brown; labrum and post clypeus dark brown; antennae uniformly colored (Table 3), yellowish brown to brown; mandibles blackish brown, deep reddish brown basally.

**Head**: Head capsule broadly oval, longer than wide and widest posteriorly (length to base of mandibles 2.35 mm, max. width 2.00 mm, index width/length 0.85) antennae 17 segmented, segment 2 longer than 3, 4 longer than 3 and 5 shortest. Labrum tongue shaped, longer than broad and pointed anteriorly into a hyaline tip. Mandibles short, thick, sabre shaped (length 1.36 mm, mandible index-length/head length 0.58). Left mandible with a large, acute tooth near mid-point (tooth distance from tip 0.63, index tooth-distance/ mandible length 0.46). Right mandible with a small, rudimentary tooth at middle.Postmentum subrectangular, sides weakly convex (length 1.52, width 0.84).

**Thorax:** Pronotum saddle shaped (length-0.77 and width 1.51 mm).

**Materials examined:** INDIA: Karnataka: Near Agumbe, $13^{0}$31’46.8’’N $75^{0}$06’13.5’’E, 15.xii.2013, *ex* Dead wood, Vidyashree, A.S.; Someshwara, $13^{0}$29’18.6’’N $75^{0}$03’45.5’’E, 02.ix.2014, *ex* Dead wood, Vidyashree, A.S.; Maharashtra: Kumbeshwar, $5^{0}$56’3.60’’N $73^{0}$57’59.5’’E, 14.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Kumbeshwar, $15^{0}$56’4.40’’N $73^{0}$56’1.20’’E, 14.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Ambha ghat, Kholapur, $16^{0}$53’42’’N $73^{0}$58’4.20’’E, 14.viii.2015, *ex* Gallery on Eucalyptus tree, Vidyashree, A.S.; Goa: Mandovi Guest House, $15^{0}$22’41.2’’N $74^{0}$13’49.6’’E, 09.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Margao, $15^{0}$16’13’’N $73^{0}$59’16.1’’E, 12.ii.2016, *ex* Coconut tree, Vidyashree, A.S.; Valpoi, $15^{0}$31’55.2’’N $74^{0}$05’47.2’’E, 10.ii.2016, *ex* Dead wood, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 3.

**Distribution:** Karnataka, Maharashtra and Goa.

***Microtermes obesi*** Holmgren

*Microtermes obesi* Holmgren: 1911: 787-788.
*Microtermes anandi* Holmgren: 1913: 114.
*Microtermes anandi f. curvignathus* Holmgren: 1913: 114.

**General appearance:** Head capsule yellowish to brownish yellow; antennae creamish white; labrum pale yellowish brown; body creamish white.

**Head:** Head capsule oval, a little longer than wide (length to base to mandibles 0.90, width 0.90); widest at middle of head (Table 4). Antennae with 14 segments; segment 2 subequal to 3+4; 4 shortest.Labrum long, lanceolate, reaching upto about 2/3 of mandibles; tip comparatively wider than in other species. Mandibles thin, delicate and weakly incurved apically (length 0.54) a little longer than half of head length. Mandible index (0.60). Postmentum little longer than wide and slightly arched; sides weakly convex (length 0.41, width 0.40 mm); anterior margin deeply notched; posterior margin weakly emarginated.

**Material examined:** INDIA: Karnataka: *Anemal, Sakleshpura, $12^{0}$55’54’’N $75^{0}$45’46’’E, 05.x.2013, *ex* Unidentified forest tree, Vidyashree, A.S.; Matthavara forest information centre, Chikmaglur, $13^{0}$16’39.4’’N $75^{0}$43’35.3’’E, 31.i.2014, *ex* Dead forest tree, Vidyashree, A.S.; Jogfalls, 14$^{0}$13’31.3’’N 74$^{0}$78’29.5’’E, 23.viii.2014, *ex* Nest in soil, Vidyashree, A.S.; Kudremukha, 13$^{0}$11’44.8’’N 75$^{0}$17’88.5’’E, 8.xi.2014, *ex* Dead wood, Vidyashree, A.S.; Kudremukha, 13$^{0}$12’85.7’’N 75$^{0}$15’16.6’’E, 08.xi.2014, *ex* Dead wood, Vidyashree, A.S.; Kagganalla, Kalasa road, Balehonnur, 13$^{0}$15’64.5’’N 75$^{0}$27’10.2’’E, 08.xi.2014, *ex* Dead wood, Vidyashree, A.S.; Talavata, Sagara, 14$^{0}$13’33’’N 74$^{0}$52’31.4’’E, 23.viii.2014, *ex* Nest in soil, Vidyashree, A.S.; Near Hosur, Sagara, 14$^{0}$05’31.6’’N 75$^{0}$11’19.8’’E, 23.viii.2014, *ex* Dead wood, Vidyashree, A.S.; Near Talaguppa, Sagara, 14$^{0}$13’33.1’’N 74$^{0}$52’31.5’’E, 23.viii.2014, *ex* Dead wood, Vidyashree, A.S.; Bacchagaru, Sagara, 14$^{0}$12’30.8’’N 74$^{0}$51’3.80’’E, 23.viii.2014, *ex* Dead wood, Vidyashree, A.S.; Talavata, Sagara, 14$^{0}$13’33’’N 74$^{0}$52’31.4’’E, 23.viii.2014, *ex* Dead wood, Vidyashree, A.S.; Near Hosur, Sagara, 14$^{0}$05’31.6’’N 75$^{0}$11’19.8’’E, 23.viii.2014, *ex* Dead wood, Vidyashree, A.S.;KVK, Chamarajnagar, 10$^{0}$17’41’’N 77$^{0}$12’44’’E, 30.xii.2015, *ex* Dead wood, Vidyashree, A.S.; KVK, Chamarajnagar, 10$^{0}$17’41’’N 77$^{0}$12’44’’E, 30.xii.2015, *ex* Dead wood, Vidyashree, A.S.; Shanthapura, Hosanagara, 13$^{0}$56’49.2’’N 75$^{0}$10’48.6’’E, 27.iv.2014, *ex* Soil gallery on forest tree**,** Vidyashree, A.S.; Ammanaghatta, Kodachadri, 13$^{0}$57’47.3’’N 75$^{0}$18’11.2’’E, 26.i.2015, *ex* Closed mound, Vidyashree, A.S.; Kerala: IISR, Calicut, 11$^{0}$18’5.40’’N 75$^{0}$50’35’’E, 21.vi.2014, *ex* Dead wood, Vidyashree, A.S.; Tamil Nadu: Annamalai tiger reserve forest, 10$^{0}$28’2.8’’N 76$^{0}$57’52.2’’E, 06.x.2014, *ex* Dead wood, Vidyashree, A.S.; Maharashtra: Raigad, 18$^{0}$07’33’’N 73$^{0}$24’06’’E, 17.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Mausi, 17$^{0}$47’68’’N 73$^{0}$43’36.6’’E, 19.viii.2015, *ex* Live tree, Vidyashree, A.S.; Mausi 17$^{0}$44’32.2’’N 73$^{0}$45’97.8’’E, 19.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Mandrewadi, 16$^{0}$22’37.5’’N 73$^{0}$55’25.4’’E, 16.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Chipnur, 17$^{0}$14’31’’N 73$^{0}$33’13.7’’E, 16.viii.2015, *ex* Dead wood**,** Vidyashree, A.S.; Goa: Bhagwan mahaveer wildlife sanctuary and mollem national park, 15$^{0}$22’42.6’’N 74$^{0}$13’50.7’’E, 11.02.2016, *ex* Dead wood, Vidyashree, A.S.; Bandoli, 15$^{0}$17’59.1’’N 74$^{0}$08’7.1’’E, 12.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Gujarath: Shravaniya, 21$^{0}$01’57.91’’N 73$^{0}$41’18.74’’E, *ex* Dead wood, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 4.

**Distribution:** Karnataka, Kerala, Tamil Nadu, Maharashtra, Goa and Gujarath.

***Microtermes incertoides*** Holmgren

*Microtermes incertoides* Holmgren: 1913, 113-114.

**General appearance:** Head-capsule straw yellow; labrum yellowish; antennae and body Whitish; mandiles reddish brown, paler basally.

**Head:** Head-capsule oval; a little longer than wide (length to base of mandiles 0.80 mm, max. width 0.76 mm); sides converging in front. Antennae with 14 segments; segment 2 subequal to 3+4. Labrum lancet-shaped, extending upto 2/3 of mandibles; tip narrow and pointed (length 0.30, width 0.20 mm, Table 4). Mandibles thin, delicate, weakly incurved anteriorly (length 0.50 mm), index mandible-length/head-length 0.63). Postmentum a little longer than wide; sides weakly convex (length 0.45, width 0.34 mm).

**Thorax:** Pronotum saddle-shaped; notched anteriorly and broadly incurved medially at posterior margin (length 0.34, width 0.50 mm).

**Material examined:** INDIA: Maharashtra: Pratapgarh Fort, 17$^0$56’9.5’’N 73$^0$37’22.1’’E, 18.viii.2015, *ex* Dead wood, Pavithra.; Pratapgarh,17$^0$56’9.3’’N 73$^0$37’30.4’’E, 18.viii.2015, *ex* Closed mound,Pavithra.; *Poladhpur, 18$^0$00’24.9’’N 73$^0$28’4.90’’E, 17.viii.2015, *ex* Closed mound, Pavithra.; Poladhpur, 18$^0$00’26.5’’N 73$^0$28’3.7’’E, 17.viii.2015, *ex* Deadwood, Pavithra.; Poladhpur, 18$^0$00’26.6’’N 73$^0$28’3.8’’E, 17.viii.2015, *ex* Dead wood, Kavitha.; Amba ghat forest, 16$^0$53’42’’N 73$^0$58’4.2’’E, 14.viii.2015, *ex* Soil gallery,Kavitha.; Amba ghat forest, 16$^0$53’34.3’’N 73$^0$58’43.1’’E, 14.viii.2015, *ex* Soil gallery, Adarsha.; Amba ghat forest, 16$^0$53’34.2’’N 73$^0$58’43.1’’E, 14.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Ponda Ghat, 16$^0$21’46’’N 73$^0$49’24.4’’E, 15.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Ponda Ghat, 16$^0$21’43.2’’N 73$^0$49’23.8’’E, 15.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Kankavoli, 16$^0$17’41’’N 74$^0$24’21’’E, 15.viii.2015, *ex* Cowdung, Vidyashree, A.S.; Raigad, 18$^0$07’33’’N 73$^0$24’6.0’’E, 17.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Raigad, 18$^0$07’33.7’’N 73024’6.8’’E, 17.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Karanjari, 16$^0$57’53’’N 73$^0$34’38’’E, 16.viii.2015, *ex* Leaf litter, Vidyashree, A.S.; Mousi, 17$^0$47’68’’N 73$^0$43’36.6’’E, 19.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Madrewadi, 16$^0$22’37.5’’N

$73^0$55’25.4’’E, 16.viii.2015, *ex* Leaf litter, Pavithra.; Raigad, $18^0$07’33.8’’N $73^0$24’6.90’’E, 17.viii.2015, *ex* Dead wood, Kavitha.

* Measurement of different morphological characters is given in table 4.

**Distribution:** Maharashtra.

**Family: Termitidae**

**Subfamily: Amitermitinae**

***Eurytermes assmuthi assmuthi*** Wasmann

*Eurytermes assmuthi* Wasmann, 1902: 124-125.
*Eurytermes assmuthi assmuthi*Wasmann**:** Roonwal and Chhotani: 1966, 81, 84, 88-89, 105, 106, 110, 112.

**Description:**

**General appearance:** Head yellow; body and legs creamy white; mandibles dark brown, yellowish brown basally. Head-capsule with a few hairs; body densely hairy. Head subrectangular, weakly widening in front, sides subparallel; longer than broad (length without mandibles 2.03, max. width 1.28 mm. Frontanelle indistinct. Eyes and ocelli absent. Antennae with 14 segments; segment 3 shorter than 2. Labrum subtriangular, tip broadly pointed; length 0.28 and width 0.30 mm (Table 4). Mandibles thick, stout Weakly incurved near tip; length 0.88 mm. Left mandible with a large, sharp, acute-angle tooth at about distal fourth and a weak indentation near base; left mandibular tooth index 0.43. Right mandible with a small tooth at distal third. Postmentum long, club-shaped; waist lying below middle; max. width 0.32, at waist 0.20 mm.

**Thorax:** Pronotum strongly saddle-shaped; length 0.32, width 0.55 mm.

**Materials examined:** INDIA: Maharashtra: Mausi, $17^0$47’68’’N $73^0$43’36.6’’E, 19.viii.2015, *ex* Dead wood, Pavithra.

Measurement of different morphological characters is given in table 4.

**Distribution:** Maharashtra.

***Eurytermes buddha*** Bose and Maiti

*Eurytermes buddha* Bose and Maiti, 1966: 115-119.

**Description:**

**General appearance:** Head pale yellow to brown; thorax, legs and abdomen whitish to pale brown; mandibles basally yellowish, distally dark brown.

**Head**: Head-capsule subrectangular, longer than broad, length to base of mandibles 1.75, width 1.20 mm (Table 4); with substraight sides narrowing posteriorly to weakly convex posterior margin. Antennae with 14 segments; segment 2 smaller than 1, longer than 3;4 shortest. Labrum subtriangular (length 0.20, width 0.24 mm); with a few long and short hairs. Mandibles thick, stout, short (0.66 mm); basally broad, distally narrowed, apices pointed and weakly incurved. Left mandible with a prominent tooth at about 1/3 rd its length from tip (distance of tooth from tip 0.20 mm, tooth index *i.e* tooth distance from tip/mandible-length 0.30); with a small basal indentation. Right also with one prominent tooth a little below 1/3rd of mandible-length from tip) with a smaller basal indentation. Postmentum long, club shaped (length 1.22, width 0.34, width at waist 0.22 mm); broadest at distal one-third; waist fairly long; anterior margin substraight, posterior concave.

**Thorax:** Pronotum strongly saddle-shaped, small (length 0.44, width 0.65 mm); anterior margin strongly convex. Mesonotum very much narrow and metanotum slightly narrow than pronotum.

**Material examined:** INDIA: Karnataka: *Aayanur, Shivamogga, $13^{0}59^{'}05''$N, $75^{0}22^{'}24''$E, 16.ix.2013, *ex* Soil nest, Vidyashree, A.S.

*Measurement of different morphological charactersis given in table 4.

**Distribution:** Karnataka.

**Table 4. Measurements of different morphological characters in species belonging to Amitermitinae and Macrotermitinae**

| Sl. No. | Measurement parameters#* | *Eurytermes* | | *Synhamitermes* | *Microcerotermes* | | | *Microtermes* | |
|---|---|---|---|---|---|---|---|---|---|
| | | ***assmuthi assmuthi*** | ***buddha*** | ***quadriceps*** | ***minor*** | ***fletcheri*** | ***pakistanicus*** | ***obesi*** | ***incertoides*** |
| 1 | Number of antennal segments | 14 | 14 | 13 | 13 | 13 | 13 | 14 | 14 |
| 2 | Head length with mandibles | 2.58 | 2.40 | 1.37 | 2.48 | 2.44 | 2.54 | 1.53 | 1.27 |
| 3 | Head length without mandibles | 2.03 | 1.75 | 0.84 | 1.22 | 1.56 | 1.64 | 0.90 | 0.80 |
| 4 | Head width | 1.28 | 1.20 | 0.76 | 0.79 | 0.96 | 0.95 | 0.90 | 0.76 |
| 5 | Head width at base of mandibles | 0.90 | 1.24 | 0.70 | 0.66 | 0.72 | 0.88 | 0.54 | 0.45 |
| 6 | Mandible length | 0.88 | 0.66 | 0.65 | 0.71 | 0.90 | 0.87 | 0.54 | 0.50 |
| 7 | Labrum length | 0.28 | 0.20 | 0.22 | 0.19 | 0.28 | 0.25 | 0.33 | 0.30 |
| 8 | Labrum width | 0.30 | 0.24 | 0.16 | 0.22 | 0.26 | 0.29 | 0.23 | 0.20 |
| 9 | Pronotum length | 0.32 | 0.44 | 0.28 | 0.23 | 0.32 | 0.35 | 0.33 | 0.34 |
| 10 | Pronotum width | 0.55 | 0.65 | 0.47 | 0.49 | 0.60 | 0.59 | 0.53 | 0.50 |
| 11 | Postmentum length | 1.30 | 1.22 | 0.54 | 0.67 | 0.90 | 1.00 | 0.41 | 0.45 |
| 12 | Postmentum width | 0.32 | 0.34 | 0.25 | 0.28 | 0.32 | 0.32 | 0.40 | 0.34 |
| 13 | Mandible index | 0.43 | 0.38 | 0.77 | 0.62 | 0.58 | 0.53 | 0.60 | 0.63 |
| 14 | Head index | 0.63 | 0.69 | 0.91 | 0.65 | 0.62 | 0.58 | 1.00 | 0.95 |
| 15 | Labrum index | 1.09 | 1.20 | 0.79 | 1.15 | 0.93 | 1.16 | 0.69 | 0.66 |
| 16 | Tooth index | 0.00 | 0.30 | 0.36 | ----- | ----- | ----- | ----- | ----- |
| 17 | Postmentum index | 0.25 | 0.28 | 0.46 | ------ | ------ | ----- | 0.96 | 0.75 |
| 18 | Postmentum width at waist | 0.20 | 0.22 | 0.16 | 0.16 | 0.20 | 0.20 | ---- | ----- |

# Average of 5 specimens; * Length and width in mm.

***Synhamitermes quadriceps*** Wasmann

*Amitermes quadriceps* Wasmann, 1902: 123.
*Termes (Eutermes) quadriceps* (Wasmann), 1904: 41.
*Hamitermes (Synhamitermes) quadriceps* (Wasmann), 1953: 16.
*Synhamitermes quadriceps* (Wasmann): Roonwal and Chhotani, 1989: 18.

**Description:**

**General appearance:** Head pale yellow to brownish yellow; antennae slightly paler than head; mandibles reddish brown to dark brown, paler basally; pronotum creamish yellow; legs and abdomen whitish to pale yellow.

**Head:** Head –capsule subsquarish, a little longer than wide (length to base of mandibles 0.84, max. width 0.76 mm, Table 4); Y-suture absent. Antennae with 13 segments; segment 3 shortest.Labrum broadly tongue-shaped. Mandibles short, stout, 0.65 mm long; outer margin incurved medially; each mandibles with a triangular tooth on inner margin at about middle. Postmentum short, club-shaped, strongly incurved at waist (length 0.54, max. width 0.25, width at waist 0.16 mm).

**Thorax:** Pronotum saddle-shaped; anterior margin without notch, posterior margin substraight or indistinctly incurved medially (length 0.28, max. width 0.47 mm). Mesonotum as wide as and metanotum a little wider than pronotum; both not emarginated at posterior margin.

**Materials examined:** INDIA: Maharashtra: *Ambha ghat, 16$^{0}$53’42’’N 73$^{0}$58’4.2’’E, 14.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Bombavade, Kholapur (Dist), 16$^{0}$53’31.4’’N 73$^{0}$58’58.5’’E, 16.viii.2015, *ex* Soil nest, Vidyashree, A.S.; Amboli ghat, 16$^{0}$00’5.9’’N 74$^{0}$03’1.8’’E, 14.viii.2015, *ex* Dead wood, Vidyashree, A.S.; Karanjari, 16$^{0}$57’53’’N 73$^{0}$74’38’’E, 16.viii.2015, *ex* Soil nest, Chipnur, 17$^{0}$14’31’’N 73$^{0}$33’13.7’’E, 16.viii.2015, *ex* Soil nest, Pavithra.

**Distribution:** Maharashtra.

***Microcerotermes fletcheri*** Holmgren and Holmgren

*Microcerotermes fletcheri* Holmgren and Holmgren: 1917, 170-171.

**Description:**

**General appearance:** Head yellowish brown to dark brown; antennae and labrum pale brown; mandibles dark brown with a reddish tinge; body pale yellow. Head sparsely and body densely hairy.

**Head:** Head capsule sub-rectangular (length to base of mandibles was 1.56 mm, max. width 0.96 mm) (Table 4); sides subparallel, straight or slightly narrowed posteriorly (index 0.62). Fontanelle minute; situated at anterior 1/3$^{rd}$ of head. Antennae 13 segmented; segment 3 smallest. Labrum pentagonal; anterior margin convex and roundly projected medially. Mandibles stout and coarsely serrated with one slightly larger serration behind middle; length generally less than 2/3rd of head length (length 0.90 mm index left mandible-length/head length 0.58). Postmentum club shaped (length 0.90 mm, width 0.32 mm, width at waist 0.20 mm); waist lying posteriorly.

**Thorax:** Pronotum saddle shaped (length 0.32, width 0.60 mm); anterior margin with a distinct median notch, posterior margin slightly emarginate medially.

**Material examined:** INDIA: Karnataka: Edalli Siddapura forest, 14$^{0}$15’14.5’’N 74$^{0}$47’25.6’’E, 08.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Varoballi, 13$^{0}$52’30.2’’N 75$^{0}$07’7.30’’E, 29.ix.2013, *ex* Arboreal nest, Vidyashree, A.S.; Pilikola Nisargadhama, Mangalore, 12$^{0}$55’32.4’’N 74$^{0}$54’2.0’’E, 22.vi.2014, *ex* Closed mound, Vidyashree, A.S.; Pilikola Nisargadhama Mangalore,12$^{0}$55’31.2’’N 74$^{0}$54’8.5’’ E, 22.vi.2014, *ex* Dead wood, Vidyashree, A.S.; Pilikola Nisargadhama, Mangalore, 12$^{0}$55’30.8’’N 74$^{0}$54’12.6’’E, 22.vi.2014, *ex* Soil gallery, Vidyashree,A.S.; Near Agumbe, 13$^{0}$31’46.8’’N 75$^{0}$06’13.5’’E, 15.xi.2013, *ex* Closed mound, Vidyashree, A.S.; Pura, Sagara, 14$^{0}$10’49.2’’N 74$^{0}$56’46.1’’E, 23.viii.2014, *ex* Closed mound, Vidyashree, A.S.; *KVK, Brahmavara, 13$^{0}$25’46.2’’N 74$^{0}$45’47’’E, 14.xii.2013, *ex* Soil nest near tree, Vidyashree, A.S.; KVK, Brahmavara, 13$^{0}$25’46.2’’N 74$^{0}$45’32.6’’E, 14.xii.2013, *ex* Soil galleries on Acacia, Vidyashree, A.S.; Humchadakatte, 13$^{0}$51’22’’N 75$^{0}$13’30’’E, 27.iv.2014, *ex* Unidentified forest tree, Vidyashree, A.S.; Kukunjaru road, Shringeri, 13$^{0}$23’67’’N 74$^{0}$54’92.8’’E, 14.xii.2013, *ex* Dead wood, Vidyashree, A.S.; Kukunjaru road, Shringeri, 13$^{0}$25’43.2’’N 74$^{0}$45’40.4’’E, 14.xii.2013, *ex* Closed mound, Vidyashree, A.S.; Siddinakai, Sagara, 14$^0$09’13.2’’N 74$^0$56’37.9’’E, 06.xii.2013, *ex* Dead wood, Vidyashree, A.S.; Bheemanakone, Sagara, 14$^0$07’35.5’’N 75$^0$03’28’’E, 06.xii.2013, *ex* Closed mound, Vidyashree, A.S.; Muttinakoppa, 13045’18.3’’N 75028’19.4’’E, 23.viii.2014, *ex* Dried bamboo, Vidyashree, A.S.; KVK, Brahmavara, 13$^0$25’46.2’’N 74$^0$45’47’’E, 14.xii.2013, *ex* Nest at the base of starfruit tree, Vidyashree, A.S.; Keladi, 14$^0$12’19.6’’N 75$^0$01’14.5’’E, 27.iv.2014, *ex* Nest in soil, Vidyashree, A.S.; Goa: Mandovi guest house, 15$^0$22’41.2’’N 74$^0$13’49.6’’E, 11.ii.2016, *ex* Dried coconut waste, Vidyashree, A.S.; Mhadei wildlife sanctuary, 15$^0$36’17.1’’N 74$^0$06’10.3’’E, 10.ii.2016, *ex* Arboreal nest, Vidyashree, A.S.; Curtorim,15$^0$16’2.0’’N 74$^0$01’12.9’’E, 12.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Curtorim, 15$^0$16’2.0’’N 74$^0$01’12.9’’E, 12.ii.2016, *ex* Arboreal nest, Vidyashree, A.S.; Curtorim, 15$^0$16’2.0’’N 74$^0$01’12.9’’E, 12.ii.2016, *ex* Soil gallery on live tree, Vidyashree, A.S.; Bhagwan mahaveer balavihar camphal, Panaji, 15$^0$29’48.5’’N 73$^0$49’6.3’’E, 11.ii.2016, *ex* Arboreal nest, Vidyashree, A.S.; Karnataka: Chorla, Belgaum, 15$^0$39’16.3’’N 74$^0$08’52.6’’E, 10.ii.2016, *ex* Arboreal nest, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 4.

**Distribution:** Karnataka and Goa.

***Microcerotermes pakistanicus*** Akhtar

*Microcerotermes pakisthanicus* Akhtar: 1974: 54-56.

**General appearance:** Head brownish yellow; antennae yellow with brownish tinge; mandibles dark reddish brown; pronotum yellow; legs and abdomen yellowish white. Head sparsely hairy with few scattered bristles and short hairs; pronotum with a few hairs and bristles on margins and body.

**Head:** Head elongate, sub rectangular (length to base of mandibles range 1.64, max. width 0.95); Width about half the length and Mandible index 0.53, sides of mandible almost parallel. Fontanelle indistinct. Antennae 13 segmented; segment 2 equal to 3+4, 3 shortest. Labrum pentagonal; tip broadly rounded; with a few long and several short hairs. Mandibles short, strong and apically strongly incurved (length 0.87 mm); coarsely serrated with one little larger serration slightly below middle (Table 4). Postmentum club shaped, with a long waist length 1.00, width 0.32, width at waist 0.20 mm.

**Thorax:** Pronotum saddle shaped, anterior margin weakly notched posterior margin substraight (0.35 mm of length, width of about 0.59 mm).

**Materials examined**: INDIA: Karnataka: *Someshwara, $13^0$29'18.6''N $75^0$03'45.5''E, 02.ix.2014, *ex* Closed mound, Vidyashree, A.S.; Amberagodlu, Sagara, $14^0$04'40.9''N $74^0$55'33.1''E, 06.xii.2013, *ex* Closed mound, Vidyashree, A.S.; Panaji road, $15^0$47'4.5''N $74^0$27'47.1''E, 13.viii.2015, *ex* Dead wood, Pavithra.; Kerala: Thalekadu, $10^0$02'59.1''N $76^0$43'41.4''E, 27.xii.2015, *ex* Dead wood, Pavithra.; Thalekadu, $10^0$03'10.3''N $77^0$03'10.3''E, 27.xii.2015, *ex* Arboreal nest, Vidyashree, A.S.; Charukara, $10^0$55'52.9''N $76^0$13'35.7''E, 27.xii.2015, *ex* Arboreal nest, Kavitha.; KFRI, Peechi, $10^0$02'59.1''N $76^0$43'41.4'' E, 27.xii.2015, *ex* Arboreal nest, Vidyashree, A.S.; Goa: Mhadei wildlife sanctuary, $15^0$36'17.1''N $74^0$06'10.3'' E, 10.ii.2015, *ex* Arboreal nest, Vidyashree, A.S.; Mhadei wildlife sanctuary, $15^0$36'16.4''N$74^0$06'9.9''E, 10.ii.2016, *ex* Arboreal nest, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 4

**Distribution**: Karnataka, Kerala and Goa.

***Microcerotermes minor* Holmgren**

*Microcerotermes heimi* f. *minor* Holmgren: 1914: 285.

*Microcerotermes minor* Holmgren: 1967: 48-50.

**General appearance:** Head-capsule pale brown to dark brown; antennae and labrum pale brown; mandibles dark reddish brown; body pale yellow.

**Head:** Head sparsely and body fairly hairy. Head-capsule subrectangular, sides subparallel (length to base of mandibles 1.22, max. width 0.79 mm, Table 4); Fontanelle minute; circular, whitish spot; situated at anterior third of head. Antennae with 13 segments; segment 3 smallest.Labrum with sub parallel sides, converging anteriorly into somewhat pointed tip (length 0.19, width 0.22 mm).Mandibles coarsely serrated, length

(0.71 mm); about 2/3 of head-length (index left mandible-length/head-length 0.62). Postmentum club-shaped; waist lying posteriorly (length 0.67, max. width 0.28, width at waist 0.16 mm).

**Thorax:** Pronotum saddle-shaped; anterior margin with a distinct notch; posterior margin emarginated; length 0.23, width 0.49 mm.

**Material examined:** INDIA: Karnataka, *Edalli Siddapura forest, $14^{0}$15’14.5’’N $74^{0}$47’25.6’’E, 08.ii.2016, *ex* Arboreal nest, Vidyashree, A.S.; Bandipur national park, $11^{0}$39’57.6’’N $76^{0}$37’41.4’’E, 04.x.2014, *ex* Closed mound, Vidyashree, A.S.; Bandipur national park, $11^{0}$39’58.5’’N $76^{0}$37’39.6’’E, 04.x.2014, *ex* Dead wood, Vidyashree, A.S.; KVK, Chamarajnagar, $10^{0}$17’41’’N $77^{0}$12’44’’E, 30.xii.2015, *ex* Gallery on live tree, Pavithra.

* Measurement of different morphological characters is given in table 4.

**Distribution:** Karnataka.

**Family:** Termitidae

**Subfamily:** Termitinae

***Dicuspiditermes obtusus*** (Silvestri)

*Dicuspiditermes obtusus* Silvestri: 1923, 229-231.
*Capritermes obtusus* var. *abbreviatus* Silvestri: 1923. 231-232. Person synonymised.

**Description:**

**General appearance:** Head pale brownish yellow, brownish yellow, brownish yellow near base of mandibles; labrum yellowish translucent; left mandible blackish, right reddish brown; body and legs creamish yellow.

**Head:** Head-capsule subrectangular; sides substraight, very slightly narrowed in front (length with mandibles 3.82, length to base of mandibles 1.89, max. width 1.34 mm, Table 5); Fontannelle transverse; situated at base of frontal inclination. Antennae with 14 segments; segments 2, 3 and 4 subequal; Labrum assymmetrial, deeply incurved at anterior margin; anterior margin; antero-lateral margins with a few serrations (length 0.45-0.50, width 0.27-0.35 mm). Mandibles assymmetrical, almost as long as head-length to base of mandibles (left mandible-length 1.80 mm, right slightly smaller; index left mandible- length/ head- length 0.97). Left mandible weakly twisted and with a beak-like tip. Right mandibles blade- Like; weakly incurved on outer and inner margins in distal half; apical blade elongate and incurved appreciably on inner margin. Postmentum club-shaped, with a long and narrow waist; minimum width of waist lying near posterior end (length 1.05, max. width 0.30. width at waist 0.14mm).

**Thorax:** Pronotum strongly saddle-shaped; anterior lobe semi-circular, with a weak notch; posterior margin rounded; length 0.26, width 0.76 mm.

**Material examined:** INDIA: Maharashtra:*Amba Ghat, Kholapur, $16^0$53’42’’N $73^0$58’4.20’’E, 14.viii.2015, *ex* Soil nest, Pavithra.; Pondaghat, $16^0$21’46’’N $73^0$49’24.4’’E, 15.viii.2015, *ex* Soil nest, Pavithra.; Raigad, $18^0$07’33’’N $73^0$24’6.0’’E, 17.viii.2015, *ex* soil nest, Pavithra.; Raigad, $18^0$07’34.7’’N $73^0$24’6.80’’E, 17.viii.2015, *ex* soil nest, Pavithra.; Radhanagari, Kholapur, $16^0$25’58.5’’N $74^0$02’36.2’’E, 16.viii.2015, *ex* Soil nest, Kavitha; Radhanagari, $16^0$25’58.3’’N $74^0$02’32.5’’E, 16.viii.2015, *ex* Soil nest, Kavitha.; Karanjari, $16^0$57’53’’N $73^0$34’38’’E, 16.viii.2016, *ex* Soil nest, Vidyashree, A.S.; Amba Ghat, Kholapur, $16^0$59’55.4’’N $73^0$46’9.1’’E, 14.viii.2015, *ex* Soil nest, Vidyashree, A.S.

*Measurement of different morphological characters is given in table 5.

**Distribution:** Maharashtra.

***Dicuspiditermes gravelyi*** (Silvestri)

*Capritermes gravelyi* Silvestri: 1922, 535-537.
*Dicuspiditermesgravelyi* (Silvestri): Krishna, 1965: 18.

**Description:**

**General appearance:** Head-capsule browish yellow; antennae pale brown; left mandible blackish, right reddish brown; legs pale yellow; body creamish.

**Head:** Head-capsule subrectangular, length 1.57-1.65 times that of width (length with mandibles 3.68, length to base of mandibles 1.91, max. width 1.28 mm, Table 5); sides substraight, slightly narrowed in front; frons weekly to somewhat sharply inclined in front, angle of inclination 50°-60°; antero-lateral corners weakly to fairly well projected in front as tubercles; median suture extending upto a little below middle. Fontanelle transverse; Fontanelle gland fairly large, extending to a little beyond middle of head. Antennae with 14 segments; segments 2, 3 and 4 subequal. Labrum assymmetrical, elongate, deeply incurved at anterior margin; lateral margins with small serrations. Mandibles a little shorter than to as long as head without mandibles (left mandible length 1.81 mm, index 0.95 mm). Left mandible twisted at middle and with a weak beak at tip. Right mandible slightly shorter than left; outer and inner margins weakly incurved in distal half; apical portion strongly incurved on inner margin and tip elongately projected. Postmentum club-shaped; waist below middle (length 0.79, max. width 0.36 and width at waist 0.20 mm).

**Thorax:** Pronotum strongly saddle-shaped (length 0.29, width 0.58 mm); anterior lobe semicircular, with a faint notch; posterior margin without notch.

**Material examined:** INDIA: Maharashtra:* Mahabaleshwar, $17^{0}$55'25.9''N $73^{0}$37'55.1''E, 18.viii.2015, *ex* Soil Nest, Vidyashree, A.S.; Ponda Ghat, $16^{0}$21'46''N $73^{0}$49'24.4''E, 15.viii.2015, *ex* Soil Nest, Vidyashree, A.S.

*Measurement of different morphological characters is given in table 5.

**Distribution:** Maharashtra.

***Discuspiditermes incola*** (Wasmann)

*Eutermes incola* Wasmann: 1893, 242.
*Discuspiditermes incola* (Wasmann): Chhotani, 1993, 302-309.

**Description:**

**General appearance:** Head-capsule browish yellow; antennae pale brown; left mandible blackish, right Head yellowish to yellowish brown; antennae yellowish brown to pale

**Table 5. Measurements of different morphological characters in species belonging to Termitinae**

| Sl. No. | Measurement parameters[#*] | *Dicuspiditermes* | | | *Pseudocapritermes* | *Angulitermes* | *Labriocapritermes* |
|---|---|---|---|---|---|---|---|
| | | *obtusus* | *gravelyi* | *incola* | *fletcheri* | *fletcheri* | *distortus* |
| 1 | Number of antennal segments | 14 | 14 | 13 | 14 | 14 | 14 |
| 2 | Head length with mandibles | 3.82 | 3.68 | 4.28 | 2.59 | 2.52 | 2.65 |
| 3 | Head length without mandibles | 1.89 | 1.91 | 2.19 | 1.57 | 1.20 | 1.65 |
| 4 | Head width | 1.34 | 1.28 | 1.45 | 1.00 | 0.94 | 0.90 |
| 5 | Head width at base of mandibles | 1.18 | 1.05 | 1.11 | 0.88 | 0.76 | 0.82 |
| 6 | Mandible length | 1.80 | 1.81 | 2.01 | 1.20 | 1.44 | 1.10 |
| 7 | Labrum length | 0.50 | 0.61 | 0.59 | 0.33 | 0.33 | 0.26 |
| 8 | Labrum width | 0.28 | 0.25 | 0.31 | 0.20 | 0.30 | 0.38 |
| 9 | Pronotum length | 0.26 | 0.29 | 0.31 | 0.25 | 0.20 | 0.28 |
| 10 | Pronotum width | 0.76 | 0.58 | 0.78 | 0.60 | 0.53 | 0.58 |
| 11 | Postmentum length | 1.05 | 0.79 | 0.89 | 0.70 | 0.45 | 0.56 |
| 12 | Postmentum width | 0.30 | 0.36 | 0.35 | 0.28 | 0.31 | 0.32 |
| 13 | Mandible index | 0.97 | 0.95 | 0.92 | 0.76 | 1.20 | 0.67 |
| 14 | Head index | 0.71 | 0.67 | 0.66 | 0.64 | 0.78 | 0.54 |
| 15 | Labrum index | 0.56 | 0.40 | 0.52 | 0.64 | 0.90 | 1.09 |
| 16 | Postmentum index | 0.41 | 0.46 | 0.22 | 0.60 | 0.69 | 0.58 |
| 17 | Postmentum width at waist | 0.14 | 0.20 | 0.20 | 0.12 | 0.25 | 0.14 |

# Average of 5 specimens; * Length and width in mm.

brown; labrum translucent, weakly chitinized medially; left mandible blackish, right reddish brown; legs and body creamy white to pale yellow.

**Head:** Head capsule sub-reactangular, sides substraight or slightly converging in front; antero-lateral corners projected into medium sized lateral tubercles (length with mandibles 4.28 to base of mandibles 2.19, maximum width 1.45 mm, index width/length 0.66). Fontanelle transverse, situated anteriorly at about 4/5 of head-length from posterior margin on the frontal inclination. Antennae with 14 segments (Table 5), segments 2, 3 and 4 subequal, 3 some times longer than 2 or 4. Labrum asymmetrical, deeply Incurved at anterior margin; antero-lateral corners produced into long, needle –like process and antero-lateral margins with 1 or 2 tooth–like projections or serrations; length 0.59, width 0.31 mm. Mandibles asymmetrical, only a little shorter than head (length of left mandible 2.01 mm, index left mandible-length/ head –length to base of mandibles 0.92). Left mandible twisted at middle and with a prominent beak at tip. Right mandible blade-like, weakly incurved on inner and outer margins; apical parts strongly incurved and with a long, pointed apex. Postmentum club-like; waist 0.35, minimum width at waist 0.20 mm.

**Thorax:** Pronotum saddle-shaped and weakly notched at anterior margin (length 0.31, width 0.78 mm).

**Material examined:** INDIA: Maharashtra: Karanjari, $16^{0}57^{'}53''$N, $73^{0}34^{'}38''$E, 16.viii.2015, *ex* Soil nest, Vidyashree, A.S.

**Distribution:** Maharashtra.

***Pseudocapritermes fletcheri*** (Holmgren and Holmgren)

*Pseudocapritermes fletcheri* (Holmgren and Holmgren): Chhotani: 1993, 297-302.

**Description:**

**General appearance:** Head yellowish, fontanelle gland area creamy white; antennae, legs and body creamish; left mandible blackish, right reddish black. Head fairly and body densely hairy. Legs thin, long, hairy; apical tibial spurs 3: 2: 2, dorsal spur on fore-legs weak; tarsi 4 jointed. Abdomen elongate, hairy; cerci 2-jointed; styli absent.

**Head:** Head capsule subrectangular, sides substraight; width a little more than ¾ of length to base of mandibles (length to base of mandibles 1.57, max. width 1 mm, index width/length 0.76 mm given in table 5); with a weak frontal projection and sharply inclined in front at frons and in profile slightly inclining posteriorly; median suture present, extending from posterior margin to about 1/3 to 1/2 of head-length. Fontanelle small, situated below frontal projection; fontanelle gland variable in size.Antennae with 14 segments; segment 3 generally shorter than 2, club-like; 4 generally shortest; sometimes segments 2, 3 subequal and 4 slightly shorter. Labrum asymmentrical, sides convex (length 0.33, width 0.20 mm); anterior margin deeply incurved with antero-lateral corners sharp and projecting in front. Mandibles asymmetrical subequal; shorter than head, about ¾ of head-length (length: left 1.20, right 1.25 mm; index left mandible-length/head-length ratio 0.76) left mandible strongly twisted and with an incurved, beak like tip; portion below tip strongly and roundly swollen on inner margin; and very broad at middle of the twist. Right mandible blade-like with long incurved apical part; weakly incurved in anterior half at outer margin and near middle on inner margin. Postmentum club-like; waist lying below midpoint (length 0.70, max. width 0.28, width at waist 0.12 mm).

**Thorax:** Pronotum strongly saddle-shaped, anterior and posterior margins faintly emerginate (length 0.25, max. width 0.60mm).

**Materials examined:** INDIA: Tamil Nadu:*Upasi Tea Research Institute, Valporai, $10^0$15’53.6’’N $76^0$58’7.0’’E, 06.x.2014, *ex* Nest in soil, Vidyashree, A.S.; Kerala: Munnar, $10^0$03’0.56’’N $76^0$57’13.8’’E, 27.xii.2015, *ex* Nest in soil, Pavithra.; Palanadu, $10^0$13’49.7’’N $77^0$68’19.4’’E, 27.xii.2015, *ex* Nest in soil, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 5.

**Distribution:** Tamil Nadu and Kerala.

***Angulitermes fletcheri*** (Holmgren and Holmgren)

*Angulitermes fletcheri* (Holmgren and Holmgren): Krishna: 1965: 13.

**Description:**

**General appearance:** Head pale yellow; antennae legs and body creamish; mandibles brown.

**Head:** Head-capsule subrectangular, sides substraight (length to tip of frontal projection 1.35, to base of mandibles 1.20, width 0.94 mm, Table 5); Frontal projection Sharp, conical extending much beyond base of mandibles (length of frontal projection 0.22mm). Antennae with 14 segments; segments 3 longer than 2; 4 slightly shorter than 2; segments long and narrow. Labrum with anterior margin deeply incurved (length 0.33, width 0.30 mm). Mandibles long, rod –like, hooked at tips; much longer than head –length to base of mandibles (1.44 mm, index left mandible-length/head-length 1.20). Postmentum club-shaped (length 0.45, max. width 0.31, which at waist 0.25mm).

**Thorax:** Pronotum strongly saddle-shaped (length 0.20, width 0.53mm).

**Material examined:** INDIA: Tamil Nadu: Valporai, 10$^{0}$15'53.6’’N, 76.58'7.0’’E, 07.x.2014, *ex* Soil nest, Vidyashree, A.S.

The measurement of different morphological characters is given in table 5.

**Distribution:** Tamil Nadu.

***Labriocapritermes distortus*** (Silvestri)

*Capritermesdistortus* Silvestri: 1922, 451-543.
*Labriocapritermes distortus* (Silvestri): Krishna: 1968, 304, 305.
*Pericapritermes vythirii* Verma: 1983, 296-298, 299. Person Synonymised.

**Description:**

**General appearance:** Head reddish yellow; antennae pale brownish; labrum translucent to yellowish; left mandible blackish , right reddish black; body creamish.

**Head**: Head-capsule subrectangular, sides sub-parallel (length to base of mandibles 1.65, max. width 0.90 mm, index width/length 0.54) (Table 5); only median suture present, extending upto about ½ of head–length from posterior margin. Fontanelle minute, situated just at base of frontal inclination. Antennae with 14 segments; segments 4 shortest; 3 almost as long as 2nd. Clypeus not clearly demarcated into anteclypeus and postclypeus. Labrum strongly swollen and asymmetrical; with a few short bristle on body; anterior margin slightly incurved (length 0.26, width 0.38 mm). Mandibles asymmetrical; left mandible greatly twisted and widened at middle, tip blunt, without beak; right mandible shorter and blade-like, at inner margin incurved at distal one-third (length: left mandible 1.10). Postmentum long, club-shaped; strongly narrowed at waist, minimum width lying near 0.14 mm).

**Thorax:** Pronotum saddle-shaped, without any notch at anterior or posterior margins (length 0.28, width 0.58 mm).

**Material examined:** INDIA: Karnataka: Balehonnur, $13^{0}20^{'}71.5''$N, $75^{0}26^{'}14.7''$E, 08.xi.2014, *ex* soil nest, Vidyashree, A.S.; CCRI, Balehonnur, $13^{0}22^{'}4.8''$N, $75^{0}25^{'}24.2''$E, 08.xi.2014, *ex* soil nest, Vidyashree, A.S.

**Distribution:** Karnataka.

**Family:** Termitidae

**Subfamily:** Nasutitermitinae

***Trinervitermes biformis*** (Wasmann)

*Eutermes biformis* Wasmann: 1902, 133-135.
*Trinervitermes biformis* (Wasmann): 1963, 110.
*Eutermes heimi* Wasmann: 1902, 135-137.
*Trinervitermes heimi* (Wasmann): Roonwal and Bose, 1964, 45, 46-48.
*Nasutitermes (Trinervitermes) longinotus* Snyder: 1934, 14-15.

**Description:**

**General appearance:** Soldier head dark golden yellow to brown, fontanelle gland area paler, rostrum reddish to dark brown, apically reddish brown; antennae brown, apical segments slightly paler, straw colored. Head with minute hairs all over longer hairs generally absent; pronotum with minute hairs along margins; abdominal tergites with short hairs, a few longer hairs present on distal tergites and sternite with short and long hairs.

**Head:** Head capsule without rostrum broadly pyriform to almost round, anteriorly sharply convergent (length with rostrum 2.15-2.52, mean of 2.20 mm; Length without rostrum 1.54; max width 1.25 mm) (Table 6). Rostrum short, conical width at base variable (length 0.82 mm); about ½ to 2/3 of head length without rostrum (index rostrum length/ head length 0.53). Antennae with 12-14 segmented; segment 3, two-and-a half times as long as 2 and subequal to 4 in 12 segmented one, almost 2.5 times as long as 2. Mandibles vestigial without spines.

**Thorax:** Pronotum strongly saddle shaped, anterior margin weakly emarginate at middle.

**Material examined:** INDIA: Karnataka: Near Gopalaswamy betta, Gundlupet, $11^{0}$43’37.7’’N $76^{0}$37’3.7’’E, 04.x.2014, *ex* Open mound. Vidyashree, A.S.; Panaji road, $15^{0}$47’4.5’’N $74^{0}$27’47.1’’E, 13.viii.2015, *ex* Closed mound, Pavithra.; *Agumbe, $13^{0}$29’26.3’’N $75^{0}$04’26’’E, 15.xi.2013, *ex* Soil galley on forest tree, Vidyashree, A.S.; Thorehadlu, Near Shringeri, $13^{0}$27’30.1’’N $75^{0}$16’29.7’’E, 20.xi.2013, *ex* Deadwood, Vidyashree, A.S.; Kerala: KFRI, Peechi, $10^{0}$02’59.1’’N $76^{0}$43’41.4’’E, 27.xii.2015, *ex* Dead wood. Vidyashree, A.S.; Maharashtra: Elephant head point, Mahabaleshwar, $17^{0}$56’21.6’’N $73^{0}$57’58.1’’E, 18.viii.2015, *ex* Dead wood. Adarsha.; Radhanagari, Kholapur, $16^{0}$25’58.5’’N $74^{0}$02’36.2’’E, 15.viii.2015, *ex* Dead wood, Pavithra.; Radhanagiri, $16^{0}$25’58.7’’N $74^{0}$02’32.2’’E, 15.viii.2015, *ex* Soil nest, Kavitha.; Mausi, $17^{0}$47’68’’N $73^{0}$43’36.6’’E, 19.viii.2015, *ex* Soil nest, Pavithra.; COA, Kholapur (D), $16^{0}$41’10.8’’N $74^{0}$56’2.9’’E, 16.viii.2015, *ex* Dead wood, Pavithra.; Gujarath: Vansad national park, $20^{0}$41’30.56’’N $73^{0}$32’25.33’’E, 25.v.2016, *ex* Soil nest. Vidyashree, A.S.; Amthava, $21^{0}$01’38.31’’N $73^{0}$39’26.71’’E, 23.v.2016, *ex* Soil nest, Vidyashree, A.S.; Goa: Poinguinim, $14^{0}$58’43.2’’N$74^{0}$06’12.6’’E, 10.ii.2016, *ex* Dead wood, Vidyashree, A.S.; Pollem, $14^{0}$54’55.1’’N $74^{0}$04’48.7’’E, 09.ii.2016, *ex* Dead wood, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 6.

**Distribution:** Karnataka, Kerala, Maharashtra, Gujarath and Goa.

***Trinervitermes nigrirostris*** Mathur and Sen-Sarma

*Trinervitermes nigrirostris* Mathur and Sen-Sarma: 1959, 71-77.

**Description:**

**General appearance:** Head-capsule brown, blackish brown anteriorly; rostrum blackish brown, tip slightly paler; antennae pale brown; abdominal tergites smoky brown. Head with a fewminute hairs, longer hairs wanting; pronotum with small hairs on margins and some on body; abdominal tergites without any long hairs, sternites with long and short hairs.

**Head:** Head capsule without rostrum subcircular (length with rostrum 2.23, length without rostrum 1.50, max. Width 1.35 mm, Table 6); in profile incurved appreciably behind rostrum; rostral hump absent. Rostrum subcylindrical (length 0.83 mm, index rostrum-length/head-length 0.55). Antennae with 14 segments; segment 3 long, about one-and-a-half times of 2; 4 slightly longer than 3 and 5. Mandibles vestigial, without any spines.

**Thorax:** Pronotum saddle-shaped (length 0.24, width 0.63 mm); anteriorly strongly raised; anterior margin rounded with a broad, shallow, median depression; posterior margin convex.

**Material examined:** INDIA: Kerala: CPCRI, Kasaragodu, 13$^{0}$58$^{'}$26.2’’N, 75.34$^{'}$43.7’’E, 24.xii.2015, *ex* Soil nest, Pavitha.

The measurement of different morphological characters is given in table 6.

**Distribution:** Kerala.

***Trinervitermes sensarmai*** Bose

*Trinervitermes sensarmai* Bose: 1984, 248-253.

**Description:**

**General appearance:** Soldier head-capsule golden brown; rostrum reddish brown, apically a little paler; antennae golden yellow; thorax, legs and abdomen brownish

**Table 6. Measurements of different morphological characters in species belonging to Nasutitermitinae**

| Sl. No. | Measurement parameters[#*] | *Trinervitermes* | | | *Nasutitermes* | | | |
|---|---|---|---|---|---|---|---|---|
| | | ***biformis*** | ***sensarmai*** | ***nigrirostris*** | ***anamalaiensis*** | ***indicola*** | ***dunensis*** | ***gardneri*** |
| 1 | Antennal segments | 12 | 13 | 14 | 12 | 12 | 12 | 13 |
| 2 | Head length with rostrum | 2.20 | 1.96 | 2.23 | 1.75 | 1.52 | 1.58 | 1.64 |
| 3 | Head length without rostrum | 1.54 | 1.23 | 1.50 | 1.18 | 1.00 | 1.02 | 1.01 |
| 4 | Rostrum length | 0.82 | 0.69 | 0.83 | 0.63 | 0.58 | 0.52 | 0.61 |
| 5 | Head width | 1.25 | 1.11 | 1.35 | 1.26 | 0.90 | 0.97 | 1.13 |
| 6 | Width of rostrum at base | 0.20 | 0.29 | 0.28 | 0.29 | 0.20 | 0.19 | 0.25 |
| 7 | Pronotum length | 0.17 | 0.22 | 0.24 | 0.23 | 0.17 | 0.18 | 0.23 |
| 8 | Pronotum width | 0.46 | 0.52 | 0.63 | 0.55 | 0.45 | 0.48 | 0.52 |
| 9 | Rostrum head index | 0.53 | 0.62 | 0.55 | 0.53 | 0.58 | 0.51 | 0.60 |

# Average of 5 specimens; * Length and width in mm

yellow; abdominal tergites dark brownish. Head covered with minute hairs; body sparsely hairy.

**Head:** Head-capsule roundly pear-shaped; length without rostrum only slightly more than max. width (length with rostrum 1.96, length to base of mandibles 1.23, max. Width 1.11 mm, Table 6); in profile head incurved behind rostrum and with a slight hump. Rostrum narrow, long; about 2/3 of head –length without rostrum; length 0.69 mm, index rostrum-length/head-length 0.62.Antennae with 13 segments; segment 2 and 4 subequal; 3 about twice the length of 2.Mandibles vestigial, without spine-like process. Postmentum short and broad, length 0.22, max. width 0.32 mm.

**Thorax:** Pronotum small, saddle shaped, upper lobe short; anterior margin with a weak median notch; length 0.22, width 0.52 mm. Legs long and robust.

**Material examined**: INDIA:Tamil Nadu: TNAU campus, $11^0$00’37.3’’N $76^0$56’0.4’’E, 05.x.2014, *ex*Nest in soil, Vidyashree, A.S.; *Palanighat area, $10^0$22’38.43’’N $77^0$31’7.6’’E, 05.x.2014, *ex* Nest in soil, Vidyashree, A.S.; Nelliyampathy, $10^0$32’2.98’’N $76^0$41’46.5’’E, 06.x.2014, *ex* Nest in soil, Vidyashree, A.S.; Nelliyampathy, $10^0$32’2.98’’N $76^0$41’46.5’’E, 06.x.2014, *ex* Nest in soil, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 6.

**Distribution:** Tamil Nadu.

***Nasutitermes anamalaiensis*** Snyder

*Nasutitermes (Rotunditermes) anamalaiensis* Snyder: 1933. 11, 12.
*Nasutitermes anamalaiensis* Snyder: Ahmad, 1958: 155.
*Alstonitermes flavescens* Thakur: 1975. 61. Person Synonymised.

**Description:**

**General appearance:** Head capsule straw coloured; rostrum pale brown basally darker distally; antennae slightly pale brown, darker than head pronotum yellowish, darker anteriorly; abdomen yellowish white. Head with numerous minute hairs all over and a pair of longer bristles each on vertex and at base of rostrum; abdominal tergite each with a long bristle on either side, few tergites with more long hairs and sternites densely hairy with long and short hairs.

**Head:** Head capsule sub circular, broader than long. Length with rostrum with a mean of 1.75 mm and ranges from 1.75-1.98, length without rostrum 1.18, width 1.26 mm (Table 6); in profile incurved appreciably behind rostrum. Rostrum conical, very thick at base (rostrum length 0.63), Rostrum head index 0.52-0.65 with a mean of 0.53 mm. Antenna with 12 segments, segment 3 one-and-half times of 2. Mandibles vestigial without or with a very minute spine like process.

**Thorax:** The pronotum saddle shaped, with several minute hairs and a few long ones (length 0.23 and width 0.55); anterior margin not emarginated.

**Material examined**: INDIA: Karnataka: *Agumbe, $13^{0}$29’2.98’’N $75^{0}$04’26’’E, 15.xi.2013, *ex* Soil galleries on forest tree, Vidyashree, A.S.; Near Agumbe, $13^{0}$31’46.8’’N $75^{0}$06’13.5’’E, 15.xi.2013, *ex* Soil galleries on forest tree, Vidyashree, A.S.; Kerala: Munnar, $10^{0}$03’0.56’’N $76^{0}$57’13.8’’E, 27.xii.2015, *ex* Nest in soil, Pavithra.; Marayoor forest Division, $10^{0}$14’36.6’’N $77^{0}$08’19.4’’E, 29.xii.2015, *ex* Gallery on live tree, Kavitha.

* Measurement of different morphological characters is given in table 6.

**Distribution:** Karnataka and Kerala.

***Nasutitermes indicola*** (Holmgren and Holmgren)

*Eutermes indicola* Holmgren and Holmgren: 1917, 161
*Nasutitermes indicola* (Holmgren and Holmgren): Ahmad, 1958: 157
*Nasutitermes beckeri* Prashad and Sen-Sarma: 1959: 4, 5, 8-13. Person synonymised.
*Eutermes (Eutermes) processionarius* Schmitz: 1924. 302-304. Person synonymised.
*Nasutitermes processionarius* (Schmitz): Prashad and Sen-Sarma: 1959: 4, 57-58, 60.

**Description:**

**General appearance:** Head capsule brown, fontanelle gland area slightly paler; rostrum dark brown with reddish tinge antennae, legs and body pale brown. Head with a few long hairs, microscopic hairs rather sparse; pronotum with several minute hairs; abdominal tergites with a long hair on both side and a pair of hairs at middle.

**Head**: Head capsule pear shaped, (length with rostrum with a mean of 1.52 and ranges from 1.45-1.70, length without rostrum 1.00, width 0.90) (Table 6); Rostrum long, slendar, cylindrical and narrow (length 0.58) index 0.58-0.74); with a tuft of hairs at tip. Antennae with 12 segments, segment 3 slightly longer than 2. Mandibles vestigial; each with a short spine like process.

**Thorax:** Pronotum saddle shaped (length 0.17 and width 0.45).

**Material examined**: INDIA: Karnataka: *Amberagodlu, Sigandoor, $14^{0}$04’40.9’’N $74^{0}$55’33.1’’E, 11.i.2014, *ex* Nest in soil,$10^{0}$14’36.6’’N, Vidyashree, A.S.; Varoballi, Hosanagara, $13^{0}$52’30.2’’N $75^{0}$07’7.30’’E, 02.ix.2014, *ex* Dead wood, Vidyashree, A.S.; Kerala: Attukad, $10^{0}$03’10.3’’N$77^{0}$03’33.3’’E, 27.xii.2015, *ex* Nest in soil, Adarsha.; Kerala: Attukad, $10^{0}$03’10.3’’N$77^{0}$03’33.3’’E, 27.xii.2015, *ex* Arboreal nest, Kavitha.; Munnar, $10^{0}$03’0.56’’N $76^{0}$57’13.8’’E, 27.xii.2015, *ex* Nest in soil, Pavithra.; Munnar, $10^{0}$03’0.56’’N $76^{0}$57’13.8’’E, 27.xii.2015, *ex* Dead wood, Pavithra.; Tamil Nadu: Palanighat area, $10^{0}$22’38.43’’N $77^{0}$31’7.60’’E, 05.x.2014, *ex* Nest in soil, Vidyashree, A.S.; Anakatti, Valporai road, $10^{0}$39’68.81’’N $76^{0}$77’40.5’’E, 06.x.2014, *ex* Dead wood, Vidyashree, A.S.; Goa: Quepem, $15^{0}$12’14.1’’N 74012’51.5’’E, 11.ii.2016, *ex* Arboreal nest, Pavithra.; Karmane, $15^{0}$19’21.4’’N $74^{0}$10’36.3’’E, 12.ii.2016, *ex* Nest in soil, Vidyashree, A.S.; Collem, $14^{0}$54’45.1’’N $74^{0}$04’48.7’’E, 09.ii.2016, *ex* Dead wood, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 6.

**Distribution:** Karnataka, Kerala Tamil Nadu and Goa.

***Nasutitermes dunensis*** Chatterjee and Thakur

*Nasutitermes dunensis* Chatterjee and Thakur: 1969, 57-65.
*Nasutitermes lambai* Verma and Thakur: 1978, 50-55. Person Synonymised
*Nasutitermes guptai* Sen-Sarma and Thakur: 1980, 25-29. Person Synonymised

**General appearance:** Head-capsule pale reddish brown, fontanelle gland area paler; rostrum deep brown, darker near tip; antennae brown; body pale yellow. Head and abdominal tergites with numerous minute hairs; head with 2 or 3 longer hairs at vertex on either side and a pair at base of rostrum; pronotum with short hairs on margin and body;

anterior abdominal tergites without any longer hairs and posterior ones with a few long hairs; sternites with short and long hairs.

**Head**: Head-capsule broadly pear-shaped (length with rostrum 1.58, length without rostrum 1.02, width 0.97 mm, Table 6); Rostrum short, conical (length 0.52 mm, index rostrum/head-length 0.51); tip with a tuft of hairs. Antennae with 12 segment 3 slighlty longer than 2; 4 almost as long as 3. Mandibles vestigial; each with a spine-like process.**Thorax:** Pronotum saddle-shaped, anterior lobe darker (length 0.18, width 0.48 mm); anterior margin convex, with a faint emargination at middle; posterior margin convex.

**Material examined**: INDIA: Kerala: *Marayoor Forest Division, 10$^{0}$14’36.6’’N, 77$^{0}$08’19.4’’E, 29.xii.2015, *ex* Gallery on live tree, Pavithra.;KFRI, Peechi,10$^{0}$02’59.1’’N 76$^{0}$43’41.4’’E, 27.xii.2015, *ex* Dead wood, Kavitha.; KFRI, Peechi,10$^{0}$02’59.1’’N 76$^{0}$43’41.4’’E, 27.xii.2015, *ex* Gallery on rubber tree, Pavithra.;Cherukara, 10$^{0}$55’52.9’’N 76$^{0}$13’35.7’’E, 27.xii.2015, *ex* Gallery on live tree, Adarsha.; CPCRI, Kasargod,13$^{0}$58’26.2’’N 75$^{0}$34’43.7’’E, 24.xii.2015, *ex* Dead wood, Pavithra.

* Measurement of different morphological characters is given in table 6.

**Distribution:** Kerala.

***Nasutitermes gardneri*** Snyder

*Nasutitermes gardneri* Snyder: 1933, 12.

**Description:**

**General appearance:** Head pale brown, fontanelle gland area paler; rostrum reddish brown, brownish at base; antennae straw coloured; pronotum darker than antennae; abdomen creamy white. Head with a pair of long hairs at vertex and a pair at base of rostrum and some minute hairs all over; pronotum with several short and a few long hairs; abdominal tergites each with a long hair laterally and a pair at middle, sternites densely hairy with short and long hairs.

**Head:** Head-capsule pear-shaped, sides sharply converging in front (length with rostrum 1.64, length without rostrum 1.01, max. width 1.13 mm, Table 6); in profile faintly incurved and with very weak rostral hump. Rostrum cylindrical to slightly conical (length 0.61 mm, index rostrum/head-length 0.60); with a tuft of hairs at tip.Antennae with 13 segments; segment 3 much longer than 2, 4 shortest. Mandibles vestigial, without any spine like process.

**Thorax:** Pronotum saddle-shaped (length 0.23, width 0.52 mm); anterior margin round with a faint emargination medially; posterior margin straight.

**Material examined**: INDIA: Karnataka: *Edalli Siddapura forest, $14^{0}15^{'}14.5''$N, $74.47^{'}25.6''$E, 08.ii.2016, *ex* Deadwood, Vidyashree, A.S.

**Distribution:** Karnataka

***Heterotermes balwanti*** Mathur and Chhotani

*Heterotermes balwanti* Mathur and Chhotani: 1969: 4-8, 10.

**Description:**

**General appearance:** Head creamish white to yellowish brown; body whitish; mandibles dark brown.

**Head:** Head-capsule sub rectangular, about one-and-a half times as long as wide (length to base of mandibles-1.07 ranged from 1.00-1.10) (Table 7); width 0.74 mm); sides parallel; posterior margin round; anteriorly swollen and with a median groove. Fontanelle minute; leading to a small, brownish tube; situated at base of median groove.Eyes and ocelli absent.Antennae with 12-14 segments; segment 3 variable generally subequal to or sometimes a little longer than 4.Labrum triangular (length with tip 0.38, width 0.23mm); with a long hyaline tip. Mandible thin, sabre shaped, length 0.78 mm which is ranged from 0.73 to 0.78 mm about $3/4^{th}$ of head capsule, index mandible 0.73. Postmentum long, club shaped length 0.78, width 0.34, width at waist 0.16 waist lying a little behind middle.

**Thorax:** Pronotum flat, length 0.33 width 0.53 mm (Table 7); anterior margin weakly to fairly deep and broadly notched medially; posterior margin with a faint median incurving.

**Material examined**: INDIA: Karnataka: *Kodur, Kakanahasudi, 13$^{0}$45’11.2’’N, 75$^{0}$33’21.1’’E, 27.iv.2014, *ex* Deadwood, Vidyashree, A.S.

**Distribution:** Karnataka.

***Heterotermes malabaricus*** Snyder

*Heterotermes malabaricus* Snyder: 1933, 4-6.

**Description:**

**General appearance:** Head and labrum light yellow brown to brown; mandibles dark brown, basally pale; antennae, pronotum and abdomen paler than head. Abdomen oblong, hairy; cerci 2-segmented.

**Head:** Head-capsule sub rectangular, much longer than broad; length to base of mandibles 1.23, width 0.81 mm (Table 7); sides subparallel; posterior margin rounded. Fontanelle small with a narrow tube, situated near anterior third of head. Antennae with 14 segmented; segment 3 shortest. Labrum subtriangular (length 0.40, width 0.24 mm); sides converging anteriorly to a hyaline, pointed, needle-like tip.Mandibles sabre-shaped, long (0.87 mm); more than half of head-length to base of mandibles; outer margin substraight; apices weakly incurved.Left mandible with 3-4 crenulations in basal half of inner margin.Postmentum club-shaped, length 0.83, maximum width (at club) 0.32, minimum width (at waist) 0.16 mm, waist lying in posterior one-third.

**Thorax:** Pronotum flat, trapezoidal; much broader than long, width 0.56, length 0.33 mm; anterior margin distinctly emarginated, posterior margin substraight or with a very weak median emargination.

**Material examined**: INDIA: Karnataka: *Kodur, Hosanagara, 13$^{0}$56’6.8’’N 75$^{0}$08’19.2’’E, 29.ix.2013, *ex* Deadwood, Vidyashree, A.S.; Goa: Sanguem,

**Table 7. Measurements of different morphological characters in species belonging to subfamilies Heterotermitinae and Coptotermitinae**

| Sl. No. | Measurement parameters#* | *Heterotermes* | | *Coptotermes* | | |
|---|---|---|---|---|---|---|
| | | ***balwanti*** | ***malabaricus*** | ***ceylonicus*** | ***heimi*** | ***kishori*** |
| 1 | Number of antennal segments | 14 | 14 | 14 | 15 | 14 |
| 2 | Head length with mandibles | 1.82 | 2.00 | 2.18 | 2.24 | 1.97 |
| 3 | Head length without mandibles | 1.07 | 1.23 | 1.48 | 1.20 | 1.23 |
| 4 | Head width | 0.74 | 0.81 | 1.18 | 1.26 | 1.09 |
| 5 | Head width at base of mandibles | 1.65 | 0.55 | 1.32 | 0.69 | 0.66 |
| 6 | Mandible length | 0.78 | 0.87 | 0.82 | 0.90 | 0.80 |
| 7 | Labrum length | 0.38 | 0.40 | 0.32 | 0.28 | 0.28 |
| 8 | Labrum width | 0.23 | 0.24 | 0.25 | 0.23 | 0.23 |
| 9 | Pronotum length | 0.33 | 0.33 | 0.69 | 0.44 | 0.39 |
| 10 | Pronotum width | 0.53 | 0.56 | 0.90 | 0.86 | 0.73 |
| 11 | Postmentum length | 0.78 | 0.83 | 0.98 | 0.93 | 0.80 |
| 12 | Postmentum max. width | 0.34 | 0.32 | 0.40 | 0.41 | 0.36 |
| 13 | Postmentum width at waist | 0.16 | 0.16 | 0.22 | 0.25 | 0.23 |
| 14 | Mandible index | 0.73 | 0.71 | 0.69 | 0.64 | 0.65 |
| 15 | Head index | 0.69 | 0.66 | 0.79 | 0.90 | 0.89 |
| 16 | Labrum index | 0.59 | 0.60 | 0.78 | 0.78 | 0.81 |

# Average of 5 specimens; * Length and width in mm.

15022’41.3’’N $74^0$13’49.6’’E, 09.ii.2016, *ex* Deadwood, Vidyashree, A.S.: Gautonm, $15^0$32’49.5’’N $74^0$00’55’’E, 10.ii.2016, *ex* Dead wood, Vidyashree, A.S.

* Measurement of different morphological characters is given in table 7.

**Distribution**: Karnataka and Goa.

***Coptotermes ceylonicus*** Holmgren

*Coptotermes ceylonicus* Holmgren: 1911, 192-193.

**Description:**

**General appearance:** Head-capsule straw-coloured to yellow, fontanelle region paler; mandibles dark brown, rest of body pale. Head with a few erect bristles and with one bristle on either side of fontanelle; pronotum with a small hairs on anterior margin and longer ones on body. Abdomen with a row of hairs on posterior margins of terga and some scattered ones on body. Legs with femora long; tibiae long and slender; apical tibial spurs 3:2:2; tarsi for jointed. Abdomen elongate; styli one-jointed; cerci 2-jointed.

**Head:** Head capsule oval, longer than broad (length to mandible base 1.48, width 1.18 mm, Table 7); sides convexical, converging anteriorly; posterior margin rounded. Fontanelle gland tubular, visible from head-surface; opening at posterior margin of clypeus and with a brown chitinous rim. Eyes and ocelli absent. Antennae with 13 segments, segment 3 usually shortest. Labrum subtriangular; with a pointed hyaline apex; a little longer than broad (length 0.32, width 0.25 mm); broadest near base; with a pair of long bristles just below hyaline tip. Mandibles thin, sabre-shape, with inwardly pointed apices. Left mandible with fairly large basal projection and 4 small well marked crenulations. Right mandible also with 4 but small to minute crenulations basally. Postmentum long, club-shaped; broadest at anterior one-third and from there narrowing down to thick waist at middle and again widening out at base (length 0.90, maximum width 0.40, minimum width 0.22 mm); anterior margin weakly convex, with a pair of hairs on either side; posterior margin concave.

**Thorax:** Pronotum flat; a little broader than long (width 0.90, length 0.43 mm) and narrower than head; anterior margin convex with a well marked, obtuse, median notch; antero-lateral corners broadly rounded; posterior margin substraight with a faint median depression.

**Material examined**: INDIA: Karnataka: Bandipur national park, $11^0$39’57.6’’N $76^0$37’41.4’’E, 04.x.2014, *ex* Deadwood, Vidyashree, A.S.; Near Agumbe, $13^0$31.468’N $75^0$06.135’E, 15.xi.2013, *ex* Deadwood, Vidyashree, A.S.: Tamil Nadu: *Anakatti, Valporai road, $10^0$39’68.81’’N $76^0$77’40.5’’E, 06.x.2014, *ex* Dead wood, Vidyashree, A.S.; Udumalpet Road, $10^0$19’41’’N $77^0$12’43.9’’E, 29.xii.2015, *ex* Gallery on live tree, Pavithra.; Mullimalai, $11^0$15’56.17’’N $76^0$37’57.1’’E, 28.xii.2015, *ex* Gallery on live tree, Kavitha.; Kerala: Munnar, $10^0$03’0.56’’N $76^0$57’13.8’’E, 26.xii.2015, *ex* Dead wood, Adarsha.

*Measurement of different morphological characters is given in table 7.

**Distribution:** Karnataka, Tamil Nadu and Kerala.

***Coptotermes heimi*** (Wasmann)

*Arrhinotermes heimi* Wasmann: 1902: 104
*Coptotermes heimi* (Wasmann): Holmgren, 1911. 73
*Coptotermes parvulus* Holmgren: 1913. 102, 104. Person Synonymised.

**Description:**

**General appearance:** Head capsule straw yellow to yellowis; fontanelle area paler than rest of head; antennae, legs pronotum and labrum also paler than head; mandibles reddish brown to dark brown; abdomen yellowish white. Head with a few erect bristles and one on each side of fontanelle; pronotum with small setae-like hairs on anterior margin and longe-ones all over; each abdominal tergum with a row of hairs at posterior margin and some scattered ones on body. Legs with femora long and tibiae long and slender; tibial spurs 3:2:2; tarsi 4-jointed. Abdomen long with two longitudinal rows of brown pigmented bands in middle. Cerci 2 segmented; styli one segmented.

**Head**: Head capsule-pyriform to sub circular (length to base of mandibles 1.20, width 1.26 mm; index Width/Length 0.77-1.04); sides converging anteriorly; posterior margin rounded. Fontanelle large, circular, prominent; with a highly sclerotized border. Eyes and ocelli absent. Antennae with 15 segments; segment, 3 either smallest or subequal to 2 or 4. Labrum subtriangular, longer than broad (length 0.28, width 0.23 mm); covering the little more than half the length of mandibles. Mandibles long (0.90 mm), sabre-shaped, broad at base and narrowing distally to a sharply pointed, incurved apex. Left mandible with 4 small crenulations and a basal projection in proximal half. Right with 4 small crenulations in proximal one-third. Postmentum generally club shaped; posteriorly curving at waist (0.25 mm); anterior margin round, posterior margin concave.

**Thorax:** Pronotum flat much broader than long (width 0.86, length 0.44 mm).

**Material examined**: INDIA: Goa: Gauttonn, $15^{0}32^{'}49.5''$N, $74^{0}04^{'}55''$E, 10.ii.2016, *ex* Deadwood, Vidyashree, A.S.

*Measurement of different morphological characters is given in table 7.

**Distribution:** Goa.

***Coptotermes kishori*** Roonwal and Chhotani

*Coptotermes kishori* Roonwal and Chhotani, 1960: 127.

**Description:**

**General appearance:** Head yellow; antennae, labrum, pronotum, legs and abdomen paler than head; mandibles dark brown, basally yellow. Head sparsely hairy with one on either side of fontanelle; pronotum fairly pilose with long hairs; abdominal terga each with a posterior row of hairs and a few on body.

**Head**: Head oval, longer than broad (length to base of mandibles 1.23, width 1.09 mm); narrowed anteriorly, posterior margin rounded; head a little elevated in between antennae, depressed in middle and again raised a little posteriorly so that in profile it appears wavy in outline. Fontanelle opening circular, ring like and chitinized. Eyes and ocelli absent. Antennae with 13-14 segments, segment 3 smallest or sub equal to or longer than 2 or 4. Postclypeus and anteclypeus narrow, trapezoidal. Labrum sub triangular little longer than broad (length 0.28, width 0.23 mm); subparallel sided; apex hyaline, pointed with a long bristle on either side of tip. Mandibles long (0.80 mm), sabre shaped; incurved and sharp at tip. Left mandible with four crenulations and a basal projection in proximal one-third of inner margin. Postmentum long (0.80 mm), broadly vase-shaped, broadest in anterior one-third (maximum width 0.36 mm); anteriorly narrowing slightly to a convex anterior margin, posteriorly to a broad waist (waist width 0.23 mm) and curving to a broader concave posterior margin.

**Thorax:** Pronotum broader than long (length 0.39, width 0.73 mm); narrow than head; anterior margin weakly convex and weakly, medially incurved posterior margin.

**Material examined**: INDIA: Goa: Collem, $14^{0}$54'45.1''N $74^{0}$04'48.7''E, 09.ii.2016, *ex* Soil gallery on Cashew, Vidyashree, A.S.

*Measurement of different morphological characters is given in table 7.

**Distribution:** Goa.

### 4.2 Molecular Identification of selected termites

#### 4.2.1 DNA analysis

In the present investigation, mitochondrial 16s rRNA region marker was used in species diagnosis and genetic diversity studies. Termites were identified using molecular markers from 12 species collected from selected locations in Western Ghats of Karnataka (Table 8). Firstly, they are identified by morphological characters of soldier caste which belongs to four subfamilies under two families *viz.*, Rhinotermitidae and Termitidae, and were belonging to six genera and four subfamilies (Table 9). It was possible to extract DNA from all the collected termite samples with the modified method. DNA concentration varied from 20.5 to 112.8 ng/µL (Table 10), in different samples. In most of the cases, the 260:280 absorbance ratios satisfied for pure DNA requirements and varied between 1.74-1.86 (Table 10). The efficacy of the method was indicated by amplifying and sequencing a known amplicon.

**Table 8. Termite specimens collected from selected locations in Western Ghats of Karnataka used for molecular study**

| Sl. No. | Species name | Place of collection | Site of Collection | Coordinates | Date of collection | NCBI Accession number |
|---|---|---|---|---|---|---|
| 1 | *Heterotermes balwanti* Mathur and Chhotani | Kakanahasudi | Dead wood | $13^0 45^{'}$ N, $75^0 33^{'}$ E, 633m | 20.xi.2013 | KU574658 |
| 2 | *Odontotermes obesus* (Rambur) | Rakshidi, Sakleshpur | Closed mound | $12^0 58.7^{'}$ N, $75^0 43.22^{'}$ E | 6.x.2013 | KU574648 |
| 3 | *Odontotermes feae* (Wasmann) | Hiregouja, Chikmaglur | *Ficus religiosa* | $13^0 22.44^{'}$ N, $75^0 52.25^{'}$ E | 4.x.2013 | KU574649 |
| 4 | *Odontotermes bellahunisensis* Holmgren and Holmgren | Aayanur, Shivamogga | Closed mound | $13^0 52.12^{'}$ N, $75^0 12.12^{'}$ E | 29.ix.2013 | KU574650 |
| 5 | *Odontotermes assmuthi* Holmgren | Ganadahole, Sakleshpur | Dead wood | $12^0 57.25^{'}$ N, $75^0 44.33^{'}$ E | 6.x.2013 | KU574651 |
| 6 | *Microcerotermes fletcheri* Holmgren and Holmgren | KVK, Brahmavara | Soil nest near tree | $13^0 25^{'}$ N, $74^0 45^{'}$ E, 27m | 14.xii.2013 | KU574652 |
| 7 | *Microcerotermes pakistanicus* Akhtar | Someshwara | Closed mound | $13^0 29^{'}$ N, $75^0 03^{'}$ E, 108m | 14.xii.2013 | KU574652 |
| 8 | *Microtermes obesi* Holmgren | Bisilamane, Theerthahalli | Closed mound | $13^0 46.10^{'}$ N, $75^0 19.57^{'}$ E | 9.x.2013 | KU574654 |
| 9 | *Odontotermes yadevi* Thakur | Someshwara | Dead wood | $13^0 29^{'}$ N, $75^0 03^{'}$ E, 114m | 14.xii.2013 | KU574656 |
| 10 | *Trinervitermes biformis* (Wasmann) | Near Agumbe | Soil galleries on forest tree | $13^0 30^{'}$ N, $75^0 05^{'}$ E, 665m | 21.iv.2015 | KU574657 |
| 11 | *Nasutitermes anamalaiensis* Snyder | Near Agumbe | Galleries on forest tree | $13^0 40^{'}$ N, $75^0 11^{'}$ E, 653m | 15.xi.2013 | KU574659 |
| 12 | *Nasutitermes indicola* (Holmgren and Holmgren) | Kogara, Sagara | Dead wood | $14^0 03^{'}$ N, $75^0 43^{'}$ E, 662m | 25.xi.2014 | KU574660 |

**Table 9. Termite species used for molecular identification and phylogenetic study**

| Family | Subfamily | Genera | Species |
|---|---|---|---|
| Rhinotermitidae | Heterotermitinae | *Heterotermes* | *balwanti* Mathur and Chhotani |
| Termitidae | Macrotermitinae | *Microtermes* | *obesi* Holmgren |
| | | *Odontotermes* | *obesus* (Rambur) |
| | | | *feae* (Wasmann) |
| | | | *assmuthi* Holmgren |
| | | | *bellahunisensis* Holmgren and Holmgren |
| | | | *yadevi* Thakur |
| | Amitermitinae | *Microcerotermes* | *fletcheri* Holmgren and Holmgren |
| | | | *pakistanicus* Akhtar |
| | Nasutitermitinae | *Nasutitermes* | *anamalaiensis* Snyder |
| | | | *indicola* (Holmgren and Holmgren) |
| | | *Trinervitermes* | *Biformis* (Wasmann) |

**Table 10. DNA yield of termite samples and absorption ratio**

| Sl. No. | Sample | Concentration (ng/ul) | Ratio (260/280 ηm)* |
|---|---|---|---|
| 1 | *Odontotermes obesus* | 46.7 | 1.76 |
| 2 | *Odontotermes feae* | 29.5 | 1.8 |
| 3 | *Odontotermes bellahunisensis* | 58.7 | 1.84 |
| 4 | *Odontotermes assmuthi* | 56.5 | 1.79 |
| 5 | *Microcerotermes fletcheri* | 42.4 | 1.82 |
| 6 | *Microcerotermes pakistanicus* | 85.4 | 1.76 |
| 7 | *Microtermes obesi* | 91.5 | 1.74 |
| 8 | *Odontotermes yadevi* | 51.7 | 1.8 |
| 9 | *Trinervitermes biformis* | 20.9 | 1.79 |
| 10 | *Heterotermes balwanti* | 112.8 | 1.8 |
| 11 | *Nasutitermes anamalaiensis* | 20.5 | 1.82 |
| 12 | *Nasutitermes indicola* | 43.6 | 1.86 |

*****Wavelength rate higher than 1.7 indicates pure samples and lower than 1.7 indicates samples withsignificant levels of buffer/organic components and proteins.

Except for the species/populations of *O. obesus* and *Microtermes obesi*, no prior genomic information is available. The sequence data of other species was submitted to NCBI and got GenBank accession numbers (Table 8). Fragment of mitochondrial gene 16s rRNA was subjected to PCR amplification by using specific primers (Fig. 4). Each individual yielded fragments of specific base pair length of ~420bp (Fig. 4). Chromatograms were edited to discard ambiguous bases, and edited sequences were aligned by using the Basic Local Alignment Search Tool (BLAST), with the sequences of same or related genera retrieved from the nucleotide database (PUBMED) of National Centre for Biotechnology Information (NCBI). The gene sequences of 16s rRNA were edited using Bioedit software V 7.2.5 and aligned using clustalW. The detailed nucleotide sequence analysis of gene revealed the significantly high percentage of A+T base composition content in each of the studied species. The sequence base composition of various species of termites (Table 11) depicted average composition of A-41.83 per cent, T-24.28 per cent, C-21.55 per cent and G-12.34 per cent. The overall transition/transversion bias is R=1.821. The predominance of transitions over transversions was observed in the gene sequence data of 16S rRNA (Fig. 5). Transition and transversion versus distance plots for each data partition indicated the x-axes 'F84 distance' is based on the F84 substitution model and was increased linearly with divergence time.

The percent variations of the species belong to the family Termitidae was found to be highest in species from family Rhinotermitidae. Among Macrotermitinae, the maximum percent sequence variation (Table 12) of 12.93 per cent was observed between *O. obesus* with *O. bellahunisensis*, *O. assmuthi*and *M. obesi* followed by *O. yadevi* and *O. feae* (12.24%). Whereas, between species, minimum percent variation was observed between *O. feae* and *O. yadevi* and Maximum percent sequence variation was observed between *Microtermes obesi* with *O. obesus*. Among the subfamilies, in Amitermitinae (Table 13), minimum percent variation of 0-1.81 per cent was observed between *Microcerotermes fletcheri* with *M. pakistanicus*. However in Nasutitermitinae minimum percent sequence variation of 4.31 per cent was observed between *Nasutitermes indicola*

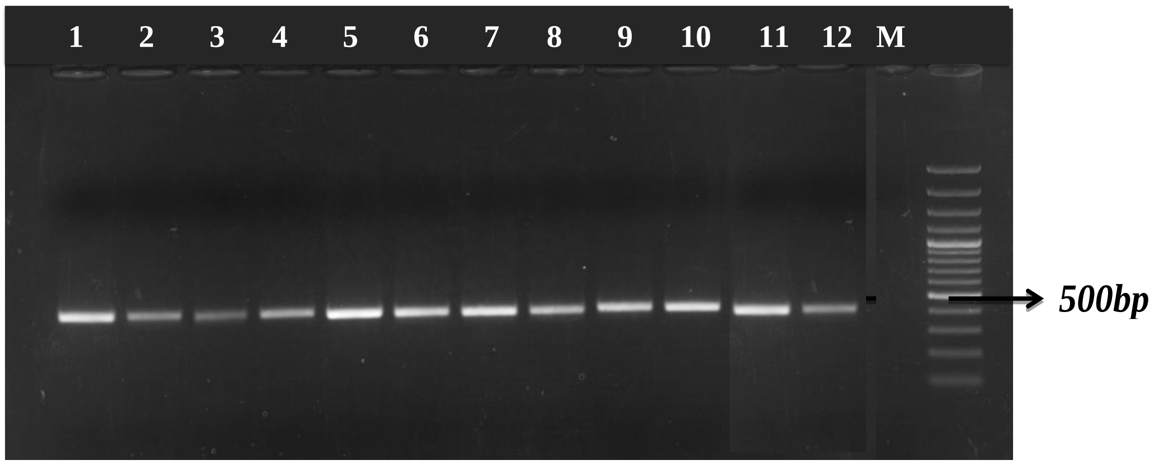


**Fig. 4: Agarose (1.0%) gel electrophoresis of mitochondrial 16S Ribosomal RNA gene PCR amplified products of termites of Western Ghats of Karnataka.**

Legend: M-Molecular weight marker (1.0 kb, Thermo Scientific, USA); 1-*Microcerotermes fletcheri*; 2-*M. pakistanicus*; 3-*Microtermes obesi*; 4-*Odontotermes obesus*; 5-*O. feae*; 6-*O. assmuthi*; 7-*O. bellahunisensis*; 8-*N. indicola*; 9- *N. anamalaiensis*; 10-*O. yadevi*; 11- *H. balwanti*; 12- *T. biformis*.

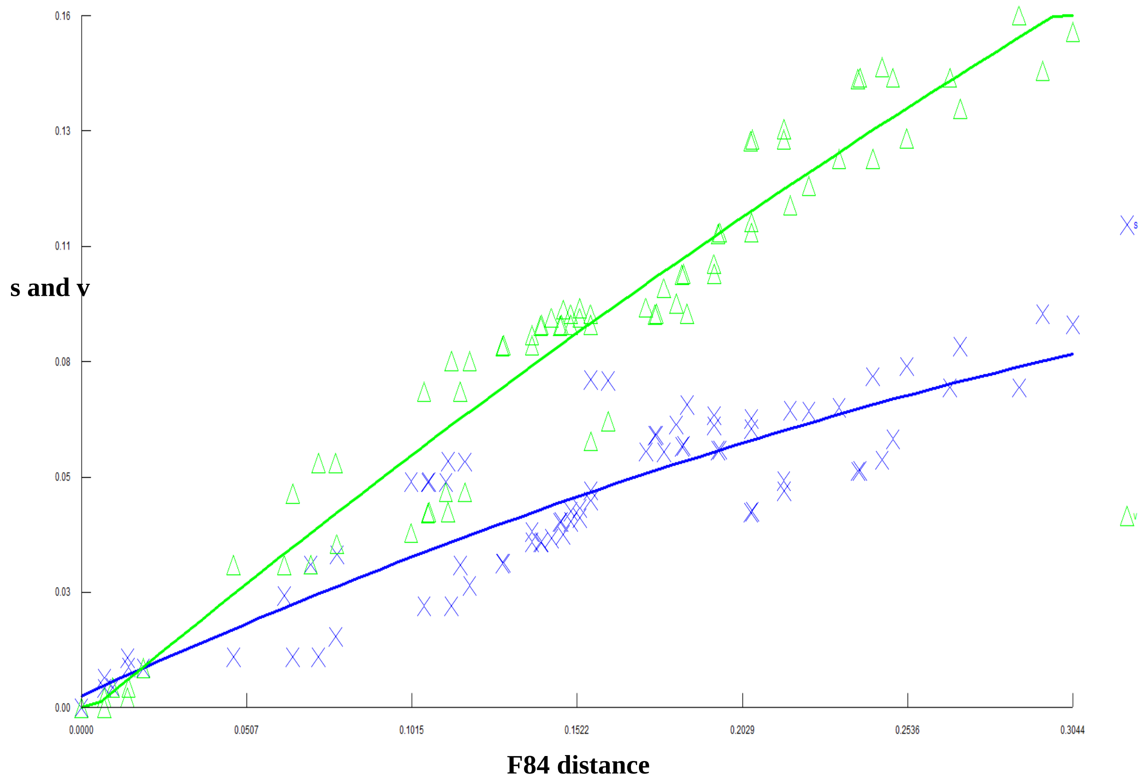


**Fig. 5: Transition and transversion versus F84 distance plots of 16S rRNA sequences of termite species in DAMBE for each data partition**

Note: Transitions are represented by blue crosses and transversion are represented by green triangles. Least squares best fit lines are indicated.

**Table 11. Maximum composite likelihood estimate of the pattern of nucleotide substitution**

| | A | T | C | G |
|---|---|---|---|---|
| A | **-** | **3.74** | **3.32** | **11.23** |
| T | *6.45* | **-** | **9.35** | **1.9** |
| C | *6.45* | *10.53* | **-** | **1.9** |
| G | *38.07* | *3.74* | *3.32* | **-** |

NOTE: Probability of substitution (r) from one base (row) to another base (column). Rates of different transition substitutions are shown in bold and those of transversion substitutions are shown in italics. The nucleotide frequencies are 41.83% (A), 24.28% (T), 21.55% (C), and 12.34% (G). The overall transition/transversion bias is R = 1.821, where R = [A*G*k1 + T*C*k2]/[(A+G)*(T+C)]. The analysis involved 12 nucleotide sequences. All positions with less than 95% site coverage were eliminated. That is, fewer than 5% alignment gaps, missing data, and ambiguous bases were allowed at any position. There were a total of 411 positions in the final dataset. Evolutionary analyses were conducted in MEGA7 [2].

**Table 12. Matrix showing the divergence and per cent identity among the 12 species under study**

| Percentage of Sequence Variation | *Odontotermes obesus* | *Odontotermes feae* | *Odontotermes bellahunisensis* | *Odontotermes assmuthi* | *Odontotermes yadevi* | *Microtermes obesi* | *Microcerotermes fletcheri* | *Microcerotermes pakistanicus* | *Trinervitermes biformis* | *Nasutitermes anamalaiensis* | *Nasutitermes indicola* | *Heterotermes balwanti* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Odontotermes obesus*** | 0 | | | | | | | | | | | |
| ***Odontotermes feae*** | 12.24 | 0 | | | | | | | | | | |
| ***Odontotermes bellahunisensis*** | 12.93 | 0.68 | 0 | | | | | | | | | |
| ***Odontotermes assmuthi*** | 12.93 | 0.68 | 0 | 0 | | | | | | | | |
| ***Odontotermes yadevi*** | 12.24 | 0 | 0.68 | 0.68 | 0 | | | | | | | |
| ***Microtermes obesi*** | 12.93 | 0.68 | 1.36 | 1.36 | 0.68 | 0 | | | | | | |
| ***Microcerotermes fletcheri*** | 22.68 | 14.97 | 15.65 | 15.65 | 15.19 | 15.65 | 0 | | | | | |
| ***Microcerotermes pakistanicus*** | 22.00 | 14.29 | 14.97 | 14.97 | 14.51 | 14.74 | 1.81 | 0 | | | | |
| ***Trinervitermes biformis*** | 20.41 | 15.87 | 16.55 | 16.55 | 15.87 | 16.55 | 14.51 | 14.06 | 0 | | | |
| ***Nasutitermes anamalaiensis*** | 20.86 | 15.42 | 16.10 | 16.10 | 15.42 | 16.10 | 13.38 | 12.93 | 10.20 | 0 | | |
| ***Nasutitermes indicola*** | 21.77 | 18.14 | 18.82 | 18.82 | 18.14 | 18.59 | 17.69 | 17.23 | 4.31 | 12.70 | 0 | |
| ***Heterotermes balwanti*** | 18.37 | 10.43 | 11.11 | 11.11 | 10.43 | 11.11 | 9.07 | 8.62 | 5.90 | 5.67 | 9.30 | 0 |

**Table 13. Matrix showing the per cent sequence variation among the subfamilies**

| Subfamily | Macrotermitinae | Amitermitinae | Nasutitermitinae | Heterotermitinae |
|---|---|---|---|---|
| Macrotermitinae (*Odontotermes*&*Microtermes*) | 0 – 18.82% | 8.84% - 22.68% | 6.58% - 21.77% | 1.13% - 18.37% |
| Amitermitinae (*Microcerotermes*) | | 0 – 1.81% | 12.93% -17.69% | 8.62% - 9.07% |
| Nastitermitinae (*Trinervitermes*&*Nasutitermes*) | | | 4.31% - 12.70% | 5.67% - 9.30% |
| Heterotermitinae (*Heterotermes*) | | | | 0 |

and *Trinervitermes biformis*. Maximum percent variation of 12.7 per cent was observed among species of *N. anamalaiensis* and *N. indicola*.

### 4.2.2 Phylogenetic analysis

A Phylogenetic tree of the species using Bayesian analysis was drawn on the basis of multiple sequence alignment of 16S rRNA gene (Fig. 6) and this is the first study on phylogenetic study of Rhinotermitidae and Termitidae using 16SrRNA gene. The genus belonging to *Microtermes* and *Odontotermes* originating from the major cluster showed a close relatedness to the species belonging to their respective genera.

In the present study the *Odontotermes* species formed the separate clade with *Microtermes* belongs to Macrotemitinae. However, *O. obesus* found to be highly divergent among *Odontotermes* species, which is collected from the same geographic region. Amitermitinae species namely *Microcerotermes fletcheri* and *M. pakistanicus* formed a separate cluster. Two genera and three species of Nasutitermitinae clustered together. Rhinotermitidae clustered separately from Termitidae which is in congruent with morphological identification. The grouping of the different species is in accordance with the geographic locations and their taxonomic positions based on the 16S r RNA gene sequences.

## 4.3 Estimation of termite diversity in different types of ecosystems

### 4.3.1 Comparison of species composition in three habitats

The present study indicated differences in the species composition in the three different habitats. A total of 17 species were recorded which belongs to five sub families (Macrotermitinae, Heterotermitinae, Amitermitinae, Nasutitermitinae, Termitinae) and seven genera (Table 14). Twelve species (*Odontotermes obesus, O. feae, O. anamallensis, O. bellahunisensis, O. assmuthi, O. yadevi, Heterotemes malabaricus, Labriocapritermes distortus*, *Microcerotermes fletcheri*, *Microtermes obesi*, *Nasutitermes anamalaiensis, Dicuspiditermes gravelyi*) were recorded in forest ecosystem (Table 14), while seven species (*Odontotermes obesus*, *O. feae*, *O. bellahunisensis*, *O. assmuthi*, *O.vaishno, O. yadevi, Labriocapritermes distortus*) were recorded in pasture habitat and


**Fig. 6: MrBayes Bayesian phylogenetic analysis based on the analysis of 420bp from the 16S rRNA marker locus in Termitidae and Rhinotermitidae collected from Western Ghats of Karnataka**

**Table 14. Termite fauna collected in three different ecosystem**

| Sl. No. | Species | Subfamily | Forest | Pasture | Plantation |
|---|---|---|---|---|---|
| 1 | *Odontotermes obesus* (Rambur) | Macrotermitinae | + | + | + |
| 2 | *O. feae* (Wasmann) | Macrotermitinae | + | + | + |
| 3 | *O. anamallensis* Holmgren & Holmgren | Macrotermitinae | + | - | - |
| 4 | *O. bellahunisensis* Holmgren & Holmgren | Macrotermitinae | + | + | + |
| 5 | *O. assmuthi* Holmgren | Macrotermitinae | + | + | + |
| 6 | *O. vaishno* Bose | Macrotermitinae | - | + | - |
| 7 | *O. bhagwatii* Chatterjee and Thakur | Macrotermitinae | - | - | + |
| 8 | *O. yadevi* Thakur | Macrotermitinae | + | + | - |
| 9 | *Labriocapritermes distortus* (Silvestri) | Termitinae | + | + | - |
| 10 | *Microtermes obesi* Holmgren | Macrotermitinae | + | - | + |
| 11 | *Microcerotermes fletcheri* Holmgren & Holmgren | Macrotermitinae | + | - | - |
| 12 | *Odontotermes* spp | Macrotermitinae | - | - | + |
| 13 | *Heterotermes malabaricus* Synder | Heterotermitinae | + | - | - |
| 14 | *Nasutitermes anamalaiensis* Synder | Nasutitermitinae | + | - | - |
| 15 | *Dicuspiditermes gravelyi* (Silvestri) | Termitinae | + | - | + |
| 16 | *Dicuspiditermes obtusus* (Silvestri) | Termitinae | - | - | + |
| 17 | *Eurytermes buddha* Bose and Maiti | Amitermitinae | - | - | + |
| 18 | Unidentified workers | | + | + | - |
| | **Alpha diversity** | | **12** | **7** | **10** |
| | **Beta diversity** | | **F/Pa-7** | **Pa/Pl-10** | **F/Pl-11** |
| | **Gamma diversity** | | 17 | | |

Note: +: Present; - : Absent; F-Forest, Pa-Pasture, Pl-Plantation ten species (*O. obesus, O. feae, O. assmuthi, O. vaishno, O. bhagwatii, Microtermes obesi*, *Dicuspiditermes gravelyi, Dicuspiditermes obtusus, Eurytermes buddha, Odontotermes* spp) were recorded in Teak Plantation. Among the habitats, *Odontotermes obesus, O. feae, O. bellahunisensis* and *O. assmuthi* were found common in all the habitats, whereas, *O. yadevi* and *Labriocapritermes distortus* were restricted to forest and pasture habitats only.

**4.3.2 Per cent contribution of different termite species**

Among the five subfamilies, Macrotermitinae was dominant in three different habitats. The per cent of population during study period constituted 82.34 in pasture, 72.41 per cent in plantation and 58.11 per cent in forest out of total population. The dominant species was *Odontotermes obesus* in both forest (20.10%) and plantation habitat (26.13%) and *O. feae* in pasture (36.22%) during the study period of July 2015 to May 2016 (Table 15). Macrotermitinae recorded the highest number of species in forest and plantation (seven) followed by pasture with six species. Total of ten species belonging to Macrotermitinae were found in three habitats *viz., Odontotermes anamallensis, O. bellahunisensis, O. bhagwatii, O. feae, O. obesus, O. assmuthi, O. vaishno, O. yadevi*, *Microtermes obesi* and *Odontotermes* spp.

In forest, species observed were *Odontotermes obesus* (20.10%), *O. feae* (10.01%), *Microtermes obesi* (8.39%), *O. yadevi* (6.50%), *O. bellahunisensis* (6.46%), *O. anamalaiensis* (3.38%), *O. assmuthi* (3.27%). In pasture, species observed were *O. feae* (36.22%) followed by *O. obesus* (13.84%), *O. vaishno* (13.78%), *O. bellahunisensis* (11.22%), *O. yadevi* (4.89%) and *O. assmuthi* (2.39%) (Table 15). In plantation, species found were *O. obesus* (26.13%), *O. assmuthi* (11.29%), *O. feae* (10.84%), *Microtermes obesi* (9.34%), *O. bhagwatii* (5.68%) and *O. bellahunisensis* (5.38%).

**Termitinae**: The subfamily was represented by two species *(Labriocapritermes distortus* and *D. gravelyi*) in the forest habitat which constitutes 16.85 per cent whereas in plantation, the species observed were *D. gravelyi* (5.14%) and *D. obtusus* (8.20%) and only one species *i.e., Labriocapritermes distortus* was found with per cent occurrence of4.24 out of total population (Table 15). The Heterotermitinae subfamily was

**Table 15. Termite species recorded in forest, pasture and plantation habitats using transect method (July 2015 to May 2016)**

| Sl. No. | Species | Species composition (%) | | |
|---|---|---|---|---|
| | | Forest | Pasture | Plantation |
| | **Dominant species** | ***O. obesus*** **(20.10%)** | ***O. feae*** **(36.22%)** | ***O. obesus*** **(26.13%)** |
| | **SF: Macrotermitinae** | **58.11** | **82.34** | **72.41** |
| 1 | *O. anamallensis* | 3.38 | - | - |
| 2 | *O. bellahunisensis* | 6.46 | 11.22 | 5.38 |
| 3 | *O. bhagwatii* | - | - | 5.68 |
| 4 | *O. feae* | 10.01 | 36.22 | 10.84 |
| 5 | *O. obesus* | 20.10 | 13.84 | 26.13 |
| 6 | *O. assmuthi* | 3.27 | 2.39 | 11.29 |
| 7 | *O. vaishno* | - | 13.78 | - |
| 8 | *O. yadevi* | 6.50 | 4.89 | - |
| 9 | *Microtermes obesi* | 8.39 | - | 9.34 |
| 10 | *Odontotermes* spp. | - | - | 3.75 |
| | **SF: Heterotermitinae** | - | - | - |
| 1 | *Heterotermes malabaricus* | 4.37 | - | - |
| | **SF: Amitermitinae** | **-** | | |
| 1 | *M. fletcheri* | 4.19 | - | - |
| 2 | *Eurytermes buddha* | - | - | 4.89 |
| | **SF: Nasutitermitinae** | **-** | | |
| 1 | *Nasutitermes anamalaiensis* | 8.19 | - | - |
| | **SF: Termitinae** | **16.85** | **-** | **13.34** |
| 1 | *Labriocapritermes distortus* | 15.91 | 4.24 | - |
| 2 | *D. gravelyi* | 0.94 | - | 5.14 |
| 3 | *D. obtusus* | - | - | 8.20 |
| | **Unidentified workers** | 8.29 | 13.42 | 9.36 |

represented by only one species *i.e., Heterotemes malabaricus* in forest habitat. Per cent occurrence of the species was 4.37 per cent. No species belonging to this subfamily was found in pasture and plantation (Table 15).

**Nasutitermitinae:** The subfamily was represented by only one species *i.e., Nasutitermes anamallaiensis* in forest habitat. Per cent occurrence of the species was 8.19. No species belonging to this subfamily was found in pasture and plantation (Table 15).

**Amitermitinae:** The subfamily Amititermitinae was represented by two species *viz Microtermes fletcheri* and *Eurytermes buddha. Microcerotermes fletcheri* found in forest habitat, constitutes 4.19. However *Eurytermes buddha* contributed with 4.89 per cent in plantation. In pasture, none of the species belonging to this subfamily were recorded (Table 15). Unidentified workers constituted 13.42 per cent, 9.36 per cent and 8.29 per cent in pasture, plantation and forest, respectively.

**4.3.3 Diversity and density in three different habitats of study area**

Seasonal fluctuations of richness, abundance and density of termites in three different habitats during study period were calculated and compared using Shannon-Wiener index, Simpson's index, Margalef's diversity index, Menhinick's index and evenness**.**

Species diversity and richness varied across three habitats. Shannon-Wiener index shows that the values ranged from 1.66 to 2.26 (Table 16) in the study area. The index shows that forest had more species diversity (2.26) followed by plantation (2.12) and lowest in pasture (1.66) habitats. Simpson's index also revealed a similar trend. The dominance value ranged from 0.77 to 0.88. The highest dominance value was recorded at 0.88 in forest habitat followed by plantation (0.87), while lower species dominance was recorded at pasture (0.77). The evenness value reveals that the species are distributed evenly in the habitat. Evenness value was ranged from 0.85 to 0.92 (Table 16). Evenness was highest (0.92) in Forest followed by plantation (0.91) and least in pasture habitat (0.85). Margalef's diversity index is directly proportional to the diversity of species distributed in the habitat. This value was ranged from 0.82 to 1.28 in study area (Table

**Table 16. Diversity indices of termite fauna in different habitats**

| Diversity index | Forest | Pasture | Plantation |
|---|---|---|---|
| Total number of individuals (N) | 5476 | 1451 | 3670 |
| Number of species (S) | 12 | 7 | 10 |
| Shannon-Weiner index (‘H) | 2.26 | 1.66 | 2.12 |
| Simpson dominance index | 0.88 | 0.77 | 0.87 |
| Evenness (J) | 0.92 | 0.85 | 0.91 |
| Margalef’s index | 1.28 | 0.82 | 1.10 |
| Menhinick’s index | 0.16 | 0.18 | 0.17 |

16). Highest value of Margalef's diversity index was observed in forest (1.28) followed by plantation (1.10) and lowest in pasture (0.82) and Menhinick's index also highest in pasture (0.18) followed by plantation (0.17) and lowest in forest (0.16). This indicated that forest habitat was more species rich than plantation and pasture land.

#### 4.3.3.1 Forest ecosystem at Balehonnur

**Species richness**

Twelve species were recorded in forest habitat (Table 17). Highest number of species were recorded in the month of November and May (eight) followed by March (seven), September (six), July (six) and lowest was recorded in the month of January (five).

**Shannon-Wiener index (H)**

The Shannon-Weiner diversity index was ranged from 0.88 to 1.87 (Table 17). Highest Shannon-Weiner index was recorded in the month of May (1.87) followed by July (1.67), January (1.32), Septermber (1.29), March (1.28) and lowest was recorded in November (0.88).

**Simpson's index (D)**

The dominance value ranged from was ranged from 0.68 to 0.88. Highest index was recorded in the month of July (0.88) followed by March and May (0.83), November (0.80) and September (0.75) and lowest in January (0.68).

**Margalef's diversity index (Dmg)**

The index was ranged from 0.61 to 1.01 (Table 17). The index was highest in the month of November (1.01) followed by May (0.97), March (0.86), September (0.79), July (0.74). Lowest was recorded in January (0.61).

**Table 17. Diversity indices and density of termite fauna in Forest ecosystem at Balehonnur, Narasimharajapura Taluk (Long. $13^0$ 24' N, Lat. $74^0$50'E) during July 2015 to May-16**

| Month | July-15 | Sep-15 | Nov-15 | Jan-16 | Mar-16 | May-16 | Total |
|---|---|---|---|---|---|---|---|
| No. of species | 6 | 6 | 8 | 5 | 7 | 8 | 12 |
| Shannon's index | 1.67 | 1.29 | 0.88 | 1.32 | 1.28 | 1.87 | 2.26 |
| Simpson's index | 0.88 | 0.75 | 0.80 | 0.68 | 0.83 | 0.83 | 0.88 |
| Margalef's diversity index | 0.74 | 0.79 | 1.01 | 0.61 | 0.86 | 0.97 | 1.28 |
| Menhinick's index | 0.20 | 0.25 | 0.25 | 0.19 | 0.22 | 0.22 | 0.16 |
| Eveness | 0.93 | 0.72 | 0.11 | 0.26 | 0.18 | 0.23 | 0.91 |
| Density (Indi.*/$m^2$) | 4.39 | 3.33 | 5.17 | 4.92 | 5.23 | 6.83 | 29.86 |
| Density (Indi./200$m^2$) | 877 | 565 | 1034 | 669 | 1046 | 1319 | 5971 |
| No. of samples collected | 15 | 17 | 20 | 12 | 19 | 11 | 94 |
| Dominant species | *L. distortus* | *L. distortus* | *M. obesi* | *O. obesus* | *O. obesus* | *O. obesus* | *O. obesus* |

Note: Indi.* – Individuals; Long. – Longitude; Lat. –Latitude

**Menhinick's index (Dmn)**

The index was ranged from 0.19 to 0.25. The highest index was recorded in month of Septermber and November (0.25), 0.22 in March, May. The lowest was in the month of July (0.20).

**Evenness (E)**

The evenness was ranged from 0.11 to 0.93. The more even distribution of species was in the month of July (0.93) followed by September (0.72), January (0.26), May (0.23), March (0.18). 0.11 least was observed in November 2015.

**Density (individuals per square meter)**

The density of individuals per square meter recorded was 3.33 to 6.83. The highest density was recorded in the month of May (6.83) followed by the March (5.23), November (5.17), January (4.92), July (4.39) and lowest density was in month of September (3.33).

**Density per 200 m2**

The individuals present in 100 m long and width of 2m belt transect were ranging 565 to 1319. The highest number of individuals recorded in the month of May (1319) followed by March (1046), November (1034), July (877), January (669) and lowest in the month of the September (565). Total individuals were collected was 5971 out of six sampling done at bi-monthly interval.

**4.3.3.2 Pasture habitat**

**Species richness (S)**

Seven species were recorded in pasture habitat of Shivamogga (Table 18). The highest number of species were recorded in the months of May (five), followed by November (four) and three species were reported in July, January and March. Least was recorded in September with two species.

**Table 18. Diversity indices and density of termite fauna in pasture ecosystem at Agumbe, Thirthahalli Taluk (Long. 13$^0$ 34' N, Lat. 75$^0$ 07' E) during July 2015 to May-2016**

| Month | July-15 | Sep-15 | Nov-15 | Jan-16 | Mar-16 | May-16 | Total |
|---|---|---|---|---|---|---|---|
| No. of species | 3 | 2 | 4 | 3 | 3 | 5 | 7 |
| Shannon's index | 0.68 | 0.67 | 0.27 | 1.02 | 0.97 | 1.47 | 1.66 |
| Simpson's Index | 0.53 | 0.49 | 0.70 | 0.61 | 0.58 | 0.75 | 0.77 |
| Margalef's diversity index | 0.35 | 0.23 | 0.56 | 0.39 | 0.42 | 0.63 | 0.82 |
| Menhinick's index | 0.17 | 0.22 | 0.27 | 0.23 | 0.28 | 0.21 | 0.18 |
| Eveness | 0.62 | 0.97 | 0.92 | 0.93 | 0.88 | 0.91 | 0.85 |
| Density (Indi.*/m$^2$) | 1.55 | 1.17 | 1.26 | 1.03 | 0.56 | 2.82 | 8.38 |
| Density (Indi./200m$^2$) | 310 | 85 | 214 | 166 | 112 | 564 | 1676 |
| No. of samples collected | 3 | 7 | 9 | 7 | 3 | 8 | 37 |
| Dominant species | *O. feae* | *O. vaishno* | *O. obesus* | *O. feae* | *O. feae* | *O. feae* | *O. feae* |

Indi.* – Individuals, O – *Odontotermes*, Long. – Longitude, Lat. –Latitude

**Shannon-Wiener diversity index (H)**

Shannon-Wiener index ranged from 0.27 to 1.47. Highest index was recorded in the month of May (1.47) followed by January (1.02), March (0.97), July (0.68), September (0.67) and lowest was recorded in the month of November (0.27).

**Simpson's diversity index (D)**

The dominance value ranged from 0.49 to 0.75.Highest index was recorded in the month of May (0.75) followed by November (0.70), January (0.61), March (0.58), July (0.53) and lowest index was recorded in the month of September (0.49).

**Margalef's diversity index (Dmg)**

Margalef's diversity index was directly proportional to species richness in the habitat. The index was ranged from 0.23 to 0.63. The index was highest in the month of May (0.63), November (0.56), March (0.42), January (0.39), July (0.35). 0.23 was recorded in September (0.23).

**Menhinick's index (Dmn)**

Menhinick's index was ranged from the 0.17 to 0.28 in the study period (Table 18). The highest index was recorded in month of March (0.28), November (0.27), January (0.23), September (0.22) and lowest index was recorded in the month of July (0.17).

**Evenness (E)**

The evenness was ranged from 0.62 to 0.97 (Table 18). More even distribution of species was in the month of September (0.97) followed by January (0.93), November (0.92), May (0.91), March (0.88) and more uneven distribution was in the month of July (0.62).

**Density (individuals per square meter)**

The range of density of individuals per square meter recorded was 0.56 to 2.82. The highest density was recorded in the month of May (2.82), July (1.55), November (1.26), September (1.17), January (1.03) and lowest density in month of March (0.56).

**Density per 200 $m^2$**

The individuals present in 100 m long and width of 2m belt transect were ranging 85 to 564 (Table 18). The highest number of individuals recorded in the month of May (564) followed by July (310), November (214), January (166), March (112) and lowest in the monthof the September (85). Total individuals were collected was 1676 out of six sampling done at bi-monthly interval.

**4.3.3.3 Plantation habitat**

**Species richness (S)**

Ten species were recorded in Teak plantation habitat of Shivamogga (Table 19). The highest number of species were recorded in the months of January (seven), followed by November (five), September (four) and in July, March, May, three species were recorded.

**Shannon-Wiener diversity index (H)**

Shannon-Wiener index was ranged from 0.37 to 1.75 (Table 19). Highest index was recorded in the month of January (1.75) followed by November (1.20), May (1.00), September (0.85), March (0.83) and lowest was recorded in the month of July (0.37).

**Simpson's diversity index (D)**

The dominance value of Simpson's index was ranged from 0.17 to 0.83 (Table 19). Highest index was recorded in the month of January (0.83) followed by September (0.74), May (0.61), July (0.32), November (0.30) and lowest was recorded in the month of March (0.17).

**Table 19. Diversity indices and density of termite fauna in plantation ecosystem at Aayanur, Shivamogga Taluk (Long. $13^{0}$ 34' N, Lat. $75^{0}$ 07' E) during July 2015 to May 2016**

| Month | July-15 | Sep-15 | Nov-15 | Jan-16 | Mar-16 | May-16 | Total |
|---|---|---|---|---|---|---|---|
| No. of species | 3 | 4 | 5 | 7 | 3 | 3 | 10 |
| Shannon's index | 0.37 | 0.85 | 1.20 | 1.75 | 0.83 | 1.00 | 2.12 |
| Simpson's index | 0.32 | 0.74 | 0.30 | 0.83 | 0.17 | 0.61 | 0.87 |
| Margalef's diversity index | 0.34 | 0.46 | 0.61 | 0.86 | 0.33 | 0.33 | 1.10 |
| Menhinick's index | 0.16 | 0.15 | 0.19 | 0.21 | 0.14 | 0.15 | 0.17 |
| Eveness | 0.33 | 0.61 | 0.75 | 0.90 | 0.76 | 0.91 | 0.92 |
| Density (Indi.*/$m^2$) | 1.83 | 3.95 | 3.97 | 5.59 | 2.40 | 2.52 | 20.25 |
| Density (Indi./200$m^2$) | 331 | 706 | 688 | 1064 | 470 | 411 | 4049 |
| No. of samples collected | 4 | 9 | 8 | 11 | 8 | 9 | 49 |
| Dominant species | *O. bellahunisensis* | *D. obtusus* | *O. obesus* | *O. obesus* | *O. obesus* | *O. obesus* | *O. obesus* |

Note:Indi.* – Individuals; *O – Odontotermes*; *D-Dicuspiditermes*; Long. – Longitude; Lat. – Latitude

**Margalef's diversity index (Dmg)**

The index was ranged from 0.33 to 0.86 (Table 19). The index was highest in the month of January (0.86) followed by November (0.61), September (0.46), July (0.34) and lowest in March and May (0.33).

**Menhinick's index (Dmn)**

Menhinick's index was ranged from the 0.14 to 0.21 in the study period (Table 19). The highest index was recorded in month of January (0.21), November (0.19), July (0.16), September and May (0.15). Lowest index was recorded in the month of March (0.14).

**Evenness (E)**

The evenness was ranged from 0.33 to 0.91. More even distribution of species was in the month of May (0.91) followed by January (0.90), March (0.76), November (0.75), September (0.61) and more uneven distribution was in the month of July (0.33).

**Density (individuals per square meter)**

The range of density of individuals per square meter recorded was 1.83 to 5.59. The highest density was recorded in the month of January (5.59), November (3.97), September (3.95), May (2.52), March (2.40) and lowest density in month of July (1.83).

**Density per 200 $m^2$**

The individuals present in 100 m long and width of 2m belt transect were ranging from 331 to 1064. The highest number of individuals recorded in the month of January (1064), September (706), November (688), March (470), May (411) and least in July (331). Total individuals were collected was 4049 out of six samplings done at bi-monthly interval.

### 4.3.4 Seasonal variation in species diversity across three habitats

#### 4.3.4.1 Forest habitat

**July 2015:** The highest contribution to the total was *Labriocapritermes distortus* (30.33%) followed (Table 20) by the *O. feae* (25.09%), *O. yadevi* (16.08%), *O. obesus* (11.40%), *O. assmuthi* (9.35%) and lowest species was contributed by *O. bellahunisensis* (7.75%).

**September 2015:** The highest contribution to the total was *Labriocapritermes distortus* (37.44%) followed by *O. yadevi* (12.33%), *Microtermes obesi* (12.03%), *O. obesus* (10.98%), *D. gravelyi* (8.42%) and lowest contribution by *O. assmuthi* (3.76%). Remaining (15.04%) were unidentified workers (Table 20).

**November 2015:** The highest contribution to the total was *Microtermes obesi* (27.27%), *Heterotermes malabaricus* (25.24%), *Nasutitermes anamalaiensis* (17.50%), *Labriocapritermes distortus* (8.90%), *O. feae* (7.06), *O. obesus* (4.55%) *O. bellahunesensis* (3.58%) and lowest species contributed by *O. assmuthi* (2.61%). The unidentified workers were 3.29 per cent of total sample (Table 20).

**January 2016:** The highest contribution to the total was *O. obesus* (35.57%) followed by Unidentified workers (32.01%), *Labriocapritermes distortus* (12.09%), *O. yadevi* (8.43%), *O. feae* (7.83%) and *Microtermes obesi* (4.07%).

**March 2016:** The highest contribution to the total was *O. obesus* (53.24 %) followed by *O. feae* (21.80 %), *O. bellahunesensis* (15.58%), *Nasutitermes anamalaiensis* (13.86%), *Microtermes obesi* (9.46%), *Microtermes obesi* (8.41%) and *O. yadevi* (6.21%).

**May 2016:** The highest contribution to the total was *O. obesus* (27.25%) followed by *Microcerotermes fletcheri* (18.32%), *O. anamallensis* (14.80%), *Nasutitermes anamalaiensis* (11.94%), *Labriocapritermes distortus* (9.96%), *O. bellahunesensis* (8.64%), *O. assmuthi* (4.47%) and lowest in *O. yadevi*. Remaining (3.37%) were unidentified workers (Table 20).

**Table 20. Termite species (%) recorded in forest-ecosystem during July 2015 to May 2016 at bimonthly interval**

| Species \ Month | July-15 | Sep-15 | Nov-15 | Jan-16 | Mar-16 | May-16 | Total |
|---|---|---|---|---|---|---|---|
| *Odontotermes anamallensis* | 0 | 0 | 0 | 0 | 0 | 14.80 | 3.38 |
| *O. bellahunisensis* | 7.75 | 0 | 3.58 | 0 | 15.58 | 8.64 | 6.46 |
| *O. feae* | 25.09 | 0 | 7.06 | 7.83 | 21.80 | 0 | 10.02 |
| *O. obesus* | 11.40 | 10.98 | 4.55 | 35.57 | 24.67 | 27.25 | 20.10 |
| *O. assmuthi* | 9.35 | 3.76 | 2.61 | 0 | 0 | 4.47 | 3.27 |
| *O. yadevi* | 16.08 | 12.33 | 0 | 8.43 | 6.21 | 1.25 | 6.50 |
| *Microtermes obesi* | 0 | 12.03 | 27.27 | 4.07 | 9.46 | 0 | 8.39 |
| *Labriocapritermes distortus* | 30.33 | 37.44 | 8.90 | 12.09 | 8.41 | 9.96 | 15.91 |
| *Discuspiditermes gravelyi* | 0 | 8.42 | 0 | 0 | 0 | 0 | 0.94 |
| *Heterotemes malabaricus* | 0 | 0 | 25.24 | 0 | 0 | 0 | 4.37 |
| *Nasutitermes anamalaiensis* | 0 | 0 | 17.50 | 0 | 13.86 | 11.94 | 8.19 |
| *Microcerotermes fletcheri* | 0 | 0 | 0 | 0 | 0 | 18.32 | 4.19 |
| Unidentified workers | 0 | 15.04 | 3.29 | 32.01 | 0 | 3.37 | 8.29 |
| Total number of individuals | 877 | 665 | 1034 | 984 | 1046 | 1365 | 5971 |

#### 4.3.4.2 Pasture habitat

**July 2015:** The highest contribution to the total was *O. feae* (59.35 %) followed by *O. vaishno* (33.55%) and *O. obesus* (7.10%) (Table 21).

**September 2015:** The highest contribution to the total was Unidentified workers (63.68%) followed by *O. vaishno* (21.79%) and *O. feae* (14.53%).

**November 2015:** The highest contribution to the total (Table 21) was *O. obesus (*31.87) followed by *O. vaishno* (30.28%), Unidentified workers (14.74%), *O. feae* (13.15%) and *Labriocapritermes distortus* (9.96%).

**January 2016:** The highest contribution to the total was *O. feae* (42.93%) followed by *O. assmuthi* (19.51%), Unidentified workers (19.02%), *O. obesus* (18.54%).

**March 2016:** The highest contribution to the total was *O. feae* (57.14%) followed by *O. bellahunisensis* (26.79%), *O. yadevi* (16.07%).

**May-16:** The highest contribution to the total was *O. feae* (36.17%) followed by *O. bellahunisensis* (28.01%), *O. obesus* (16.31%), *O. yadevi* (11.35%) and *Labriocapritermes distortus* (8.16%).

#### 4.3.4.3 Plantation habitat

**July 2015:** The highest contribution to the total was by *O. bellahunisensis* (45.08%) which is followed by *O. bhagwatii* (10.93%) and *Microtermes obesi* (34.43%). The unidentified workers constituted 9.56 per cent of total sample (Table 22).

**Sep-15:** The highest contribution to the total was *Dicuspiditermes obtusus* (42.08%) followed by *O. bhagwati* (24.08%) and *Microtermes obesi* (17.87%). The unidentified worker constituted 10.52 per cent of total sample (Table 22).

**November 2015:** The highest contribution to the total was *O. obesus* (38.08%) followed by *O. feae* (34.05%), Unidentified workers (13.24%), *Eurytermes buddha* (7.06%), *O. bellahunisensis* (4.92%) and *Microtermes obesi* (2.65%).

**Table 21. Termite species (%) recorded in pasture ecosystem during July 2015 to May 2016 at bimonthly interval**

| Species \ Month | July-15 | Sep-15 | Nov-15 | Jan-16 | Mar-16 | May-16 | Total |
|---|---|---|---|---|---|---|---|
| *O. bellahunisensis* | 0 | 0 | 0 | 0 | 26.79 | 28.01 | 11.22 |
| *O. feae* | 59.35 | 14.53 | 13.15 | 42.93 | 57.14 | 36.17 | 36.22 |
| *O. obesus* | 7.10 | 0 | 31.87 | 18.54 | 0 | 16.31 | 13.84 |
| *O. assmuthi* | 0 | 0 | 0 | 19.51 | 0 | 0 | 2.39 |
| *O. vaishno* | 33.55 | 21.79 | 30.28 | 0 | 0 | 0 | 13.78 |
| *O. yadevi* | 0 | 0 | 0 | 0 | 16.07 | 11.35 | 4.89 |
| *Labriocapritermes distortus* | 0 | 0 | 9.96 | 0 | 0 | 8.16 | 4.24 |
| Unidentified workers | 0 | 63.68 | 14.74 | 19.02 | 0 | 0 | 13.42 |
| Total number of individuals | 310 | 234 | 251 | 205 | 112 | 564 | 1676 |

**Table 22. Termite species (%) recorded in plantation ecosystem from July 2015 to May 2016 at bimonthly interval**

| Species \ Month | July-15 | Sep-15 | Nov-15 | Jan-16 | Mar-16 | May-16 | Total |
|---|---|---|---|---|---|---|---|
| *O. bhagwatii* | 10.93 | 24.08 | 0 | 0 | 0 | 0 | 5.68 |
| *O. bellahunisensis* | 45.08 | 0 | 4.92 | 1.25 | 0 | 0 | 5.38 |
| *O. feae* | 0 | 0 | 34.05 | 13.43 | 3.96 | 0 | 10.84 |
| *O. obesus* | 0 | 5.45 | 38.08 | 24.89 | 48.96 | 39.68 | 26.13 |
| *O. assmuthi* | 0 | 0 | 0 | 21.58 | 45.00 | 0 | 11.29 |
| *Odontotermes* sp | 0 | 0 | 0 | 0 | 0 | 30.16 | 3.75 |
| *Microtermes obesi* | 34.43 | 17.87 | 2.65 | 8.06 | 0 | 0 | 9.34 |
| *Dicuspiditermes obtusus* | 0 | 42.08 | 0 | 0 | 0 | 0 | 8.20 |
| *D. gravelyi* | 0 | 0 | 0 | 18.62 | 0 | 0 | 5.14 |
| *Eurytermes buddha* | 0 | 0 | 7.06 | 7.43 | 0 | 11.71 | 4.89 |
| Unidentified workers | 9.56 | 10.52 | 13.24 | 4.74 | 2.08 | 18.45 | 9.36 |
| Total number of individuals | 366 | 789 | 793 | 1117 | 480 | 504 | 4049 |

**January 2016:** The highest contribution to the total was *O. obesus* (24.89%) followed by *O. assmuthi* (21.58%), *D. gravelyi* (18.62%), *Microtermes obesi* (8.06%), *Eurytermes Buddha* (7.43%). The unidentified worker constituted 4.74 per cent of total sample whereas *O. bellahunisensis* constituted 1.25 per cent.

**March 2016:** The highest contribution to the total was by *Odontotermes obesus* (48.96%) followed by *O. assmuthi* (45%) and *O. feae* (3.96%). Remaining (2.08%) were recorded as unidentified workers (Table 22).

**May 2016:** The highest contribution to the total was by *Odontotermes obesus* (39.68%), *Odontotermes* sp. (30.16%). Remaining (18.45%) were recorded as unidentified workers and *Eurytermes buddha* (11.71%).

**4.3.5 Characteristics properties of soils in three different habitats**

In all different habitats, sandy loam soil was noticed, all were acidic soils and had an electrical conductivity normal, where as, organic carbon and nitrogen were also high in all collected soil samples (Table 23).

**4.4 Developing distribution maps for termites of Western Ghats**

In Rhinotermitidae family, the species recorded were belonging to two subfamilies Coptotermitinae and Heterotermitinae, *Coptotermes kishori*, *C. heimi* found only in Collem and Gautonm, of Goawhere as, *Heterotermes balwanti* was also found only in Western ghat of Karnataka (Kakanahasudi). *C. ceylonicus* was recorded in six samples, noticed along western ghat of Karnataka, Tamil Nadu and Kerala. However the *Heterotermes malabaricus* was recorded in three different places of Goa and Karnataka (Fig. 7).

Among the subfamily Amitermitinae, *Eurytermes assmuthi assmuthi* and *E. buddha* was reported in one place of Maharashtra (Mausi) and Karnataka (Aayanur, Shivamogga) respectively. *Microcerotermes fletcheri* (24 samples collected) was recorded along Karnataka and Goa. *Microcerotermes pakistanicus* was observed at along western ghat comprised all six states (9 samples). Four samples of *M. minor* found in

**Table 23. Characteristic properties of soils in three different habitats**

| Type of analysis | Forest | Teak plantation | Pasture land |
|---|---|---|---|
| **Particle size analysis** | | | |
| Sand (%) | 62.50 | 65 | 75 |
| Fine sand (%) | 28.65 | 31.75 | 12.25 |
| Silt (%) | 22.50 | 17.50 | 12.50 |
| Clay (%) | 15 | 17.50 | 12.50 |
| Soil textural class | Sandy loam | Sandy loam | Sandy loam |
| **Chemical analysis** | | | |
| pH | 5.52 | 6.39 | 5.55 |
| EC ($dSm^{-1}$ at $25^0C$) | 0.30 | 0.16 | 0.06 |
| Organic carbon (%) | 5.97 | 3.54 | 1.95 |
| Organic matter (%) | 10.29 | 6.10 | 3.36 |
| Available N (kg/ha) | 1059.97 | 658.56 | 570.75 |

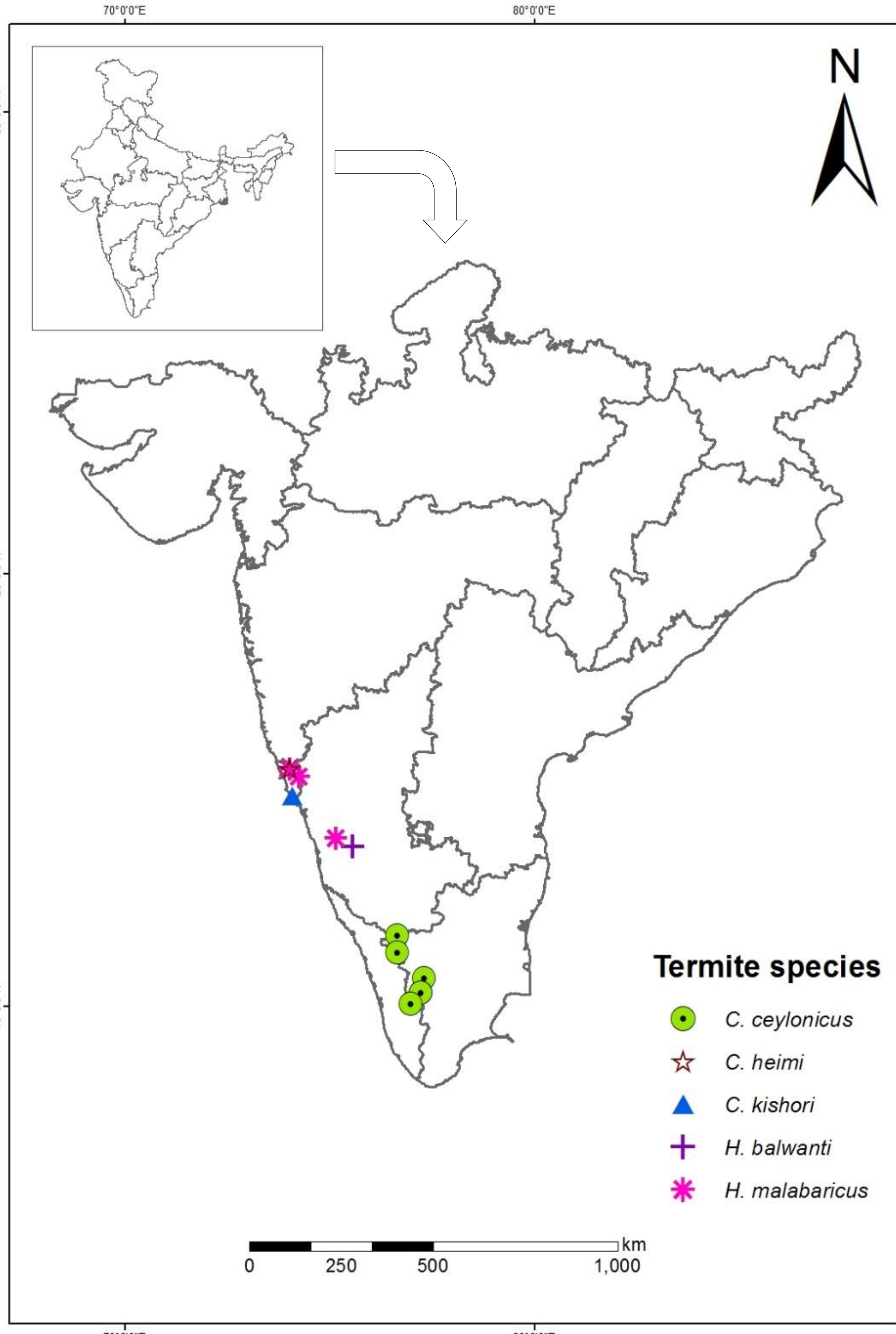


**Fig. 7: Distribution map of termite species belonging to family Rhinotermitidae**

Karnataka, Kerala and Tamil Nadu whereas, *Synhamitermes quadriceps* (5 samples) recorded at Maharashtra (Fig. 8).

In Termitidae, subfamily Macrotermitinae was contributed by highest number of samples from the genera *Odontotermes* and *Microtermes.* The *Microtermes obesi* was reported along Western Ghats. However the *Microtermes incertoides* was recorded only in different places of Maharashtra (17 samples) (Fig. 9). The genera *Odontotermes* was represented by 16 species. In that, *O. assmuthi* was noticed in all the six states, whereas *O. anamallensis* was represented in three samples namely Agumbe (Karnataka) and Maharashtra. *O. bhagwatii* was collected from Krishi vignan kendra, Chamarajnar and *Odontotermes boveni* (3 samples) was recorded at Karnataka (Halladi, Shankarapura; Bandipur national park) and Kerala (Cherukara) (Fig. 10).

Figure 11 showed the distribution and diversity of *O. bellahunisensis* along the Western Ghats and represented in 46 samples. Whereas *O. brunneus* (6 samples)was distributed in five states except Goa, the *O. ceylonicus* found in Tamil Nadu and Kerala.

The species collected from only one locality included *O. globicola* (Chinnar wildlife sanctuary, Kerala), *O. horni* (CCRI, Balehonnur) and *O. peshawarensis* (Quepem, Goa) (Fig. 12). Only few samples of *O. redemanni* were recorded in Western Ghats parts of Karnataka and Goa.

Figure 13 showed the distribution of *O.feae* along the Western Ghats and Figure 14showed the *O. obesus* distribution and diversity (210 samples were collected). It was widely distributed along the Western Ghats and also found in various habitat/sites.

*O. vaishno* was collected from 15 different places (Fig. 15) along the Western Ghats. *O. wallonensis* (6 samples) found in Karnataka, Tamil Nadu and Gujarath. *O. yadevi* found in Karnataka, Maharashtra and Goa.

Nasutitermitinae was represented by two genera *Nasutitermes* and *Trinervitermes.* In Figure 16, *Trinervitermes biformis* was distributed along the Western Ghats where as *Nasutitermes indicola* recorded in Karnataka, Goa, Tamil Nadu and Kerala. *Nasutitermes*

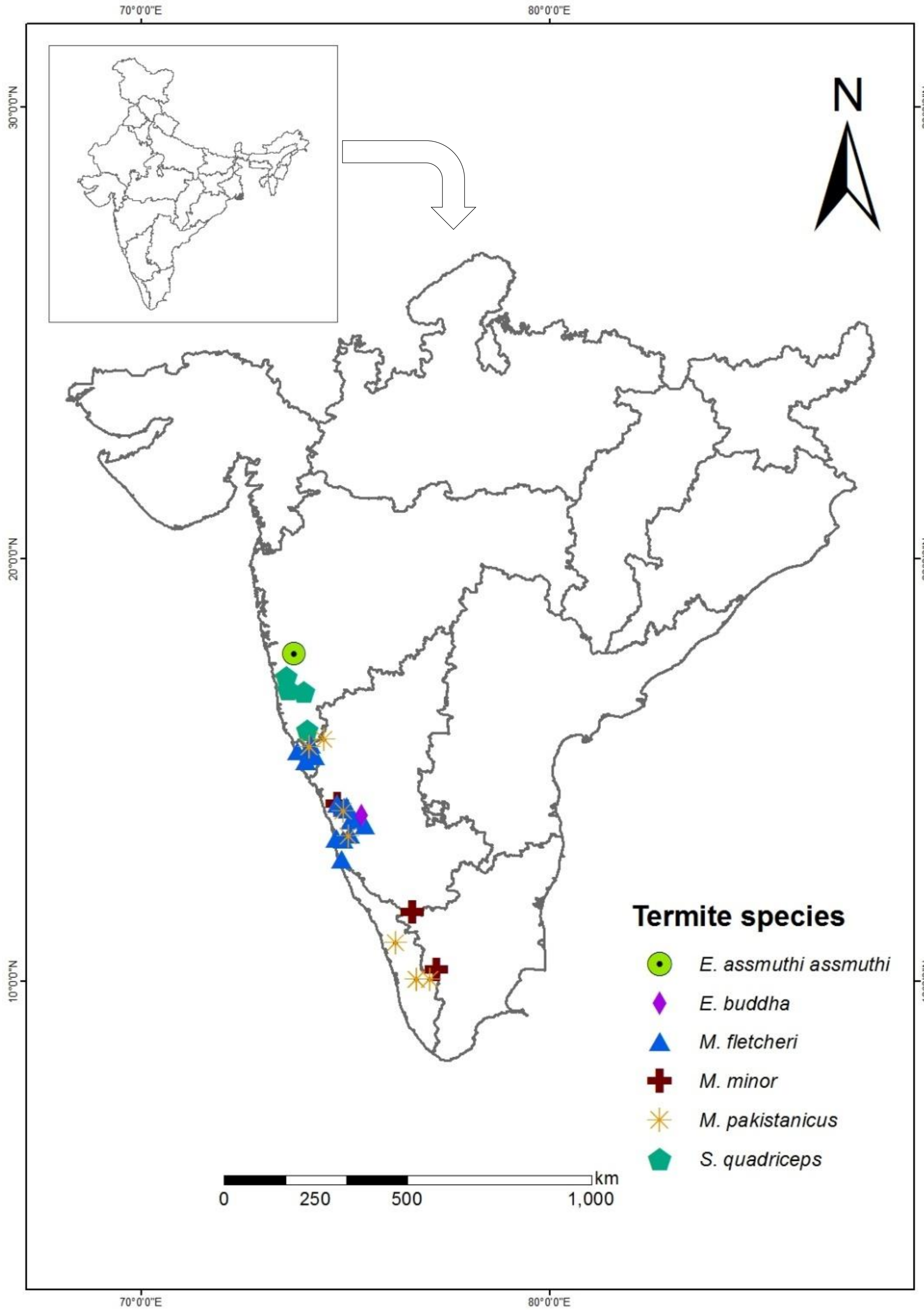


**Fig. 8: Distribution map of termite species belonging to subfamily Amitermitinae**

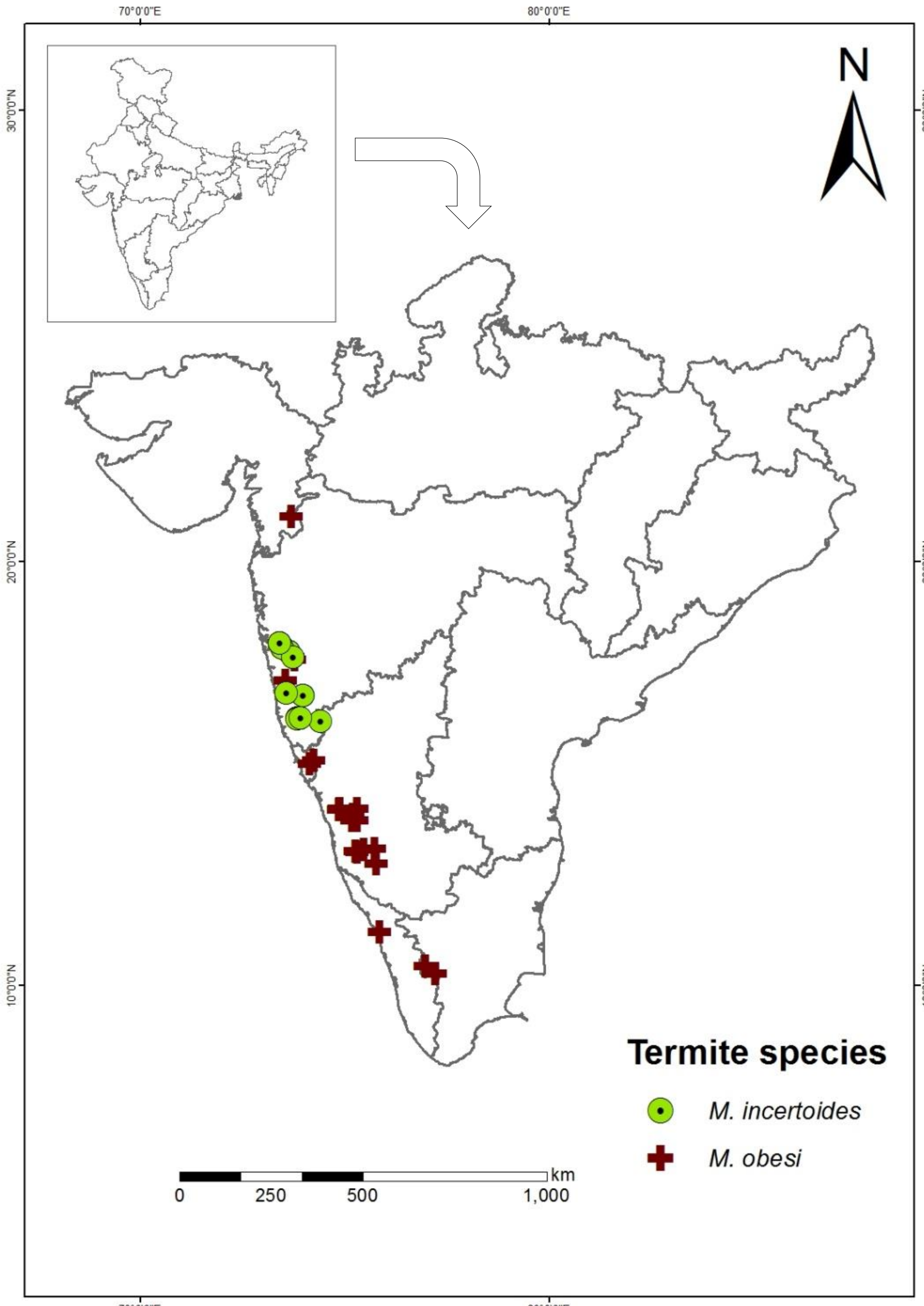


**Fig. 9: Distribution map of termite species belonging to genera *Microtermes***

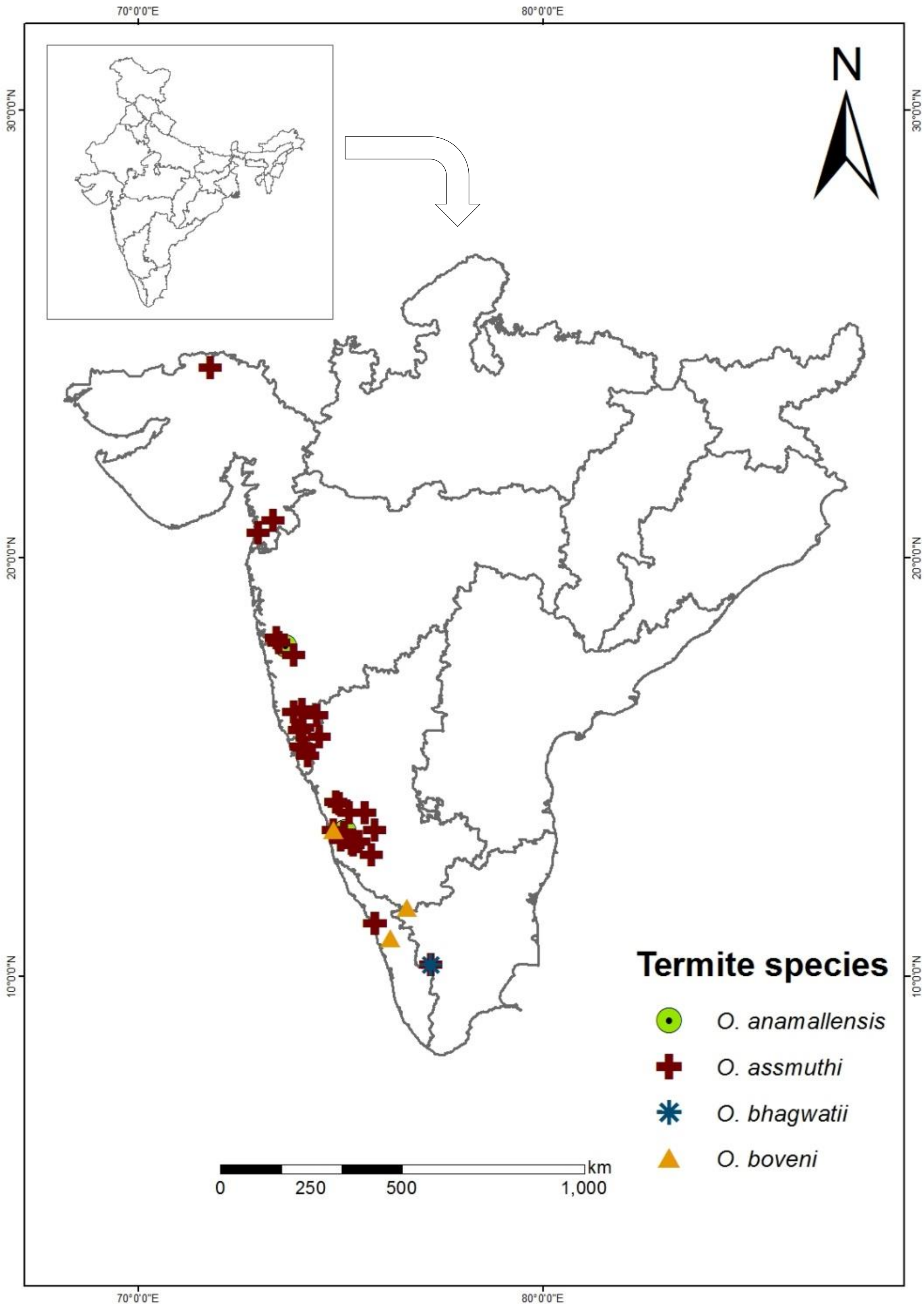


**Fig. 10: Distribution map of termite species belonging to genera *Odontotermes***

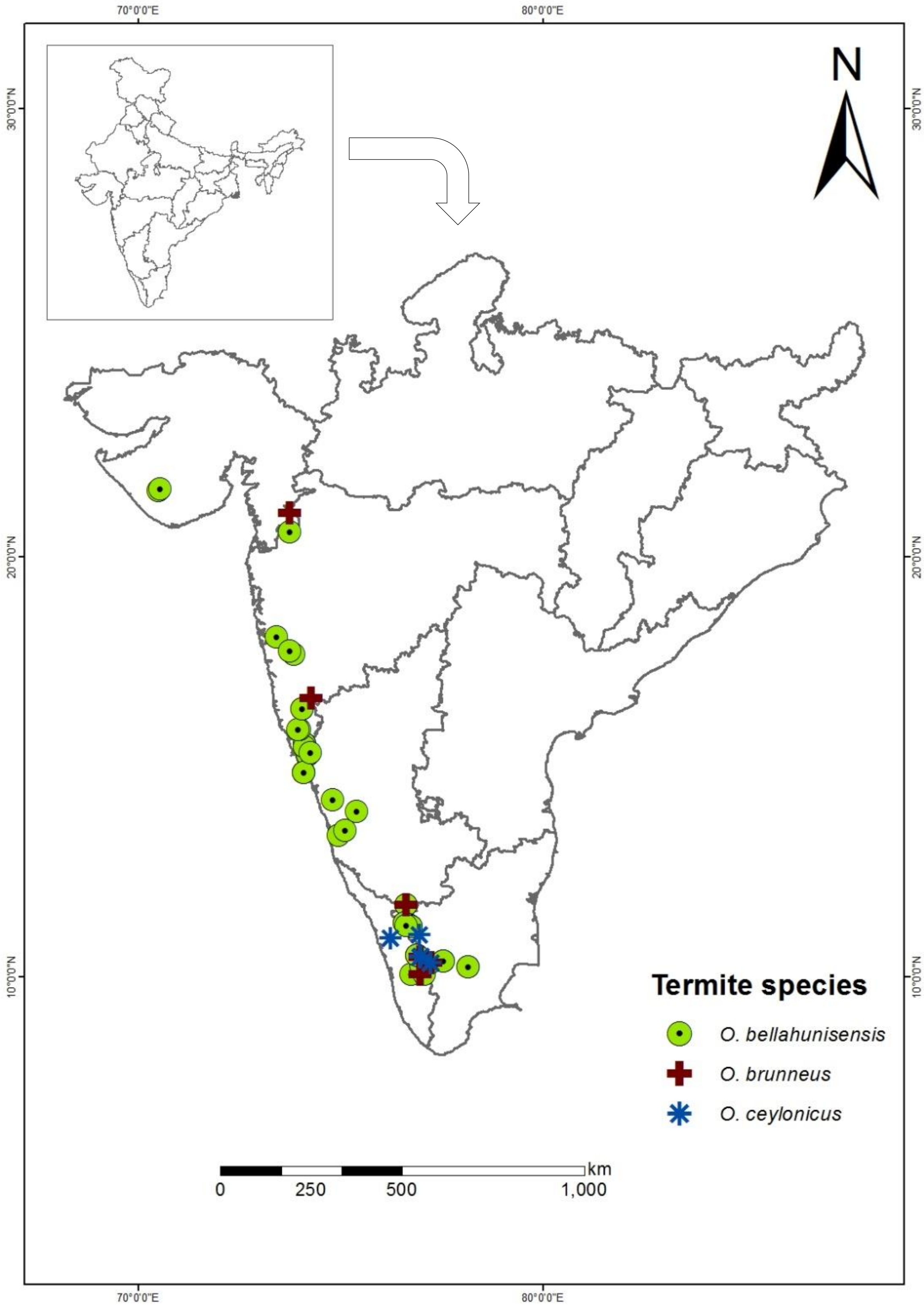


**Fig. 11: Distribution map of termite species belonging to genera *Odontotermes***

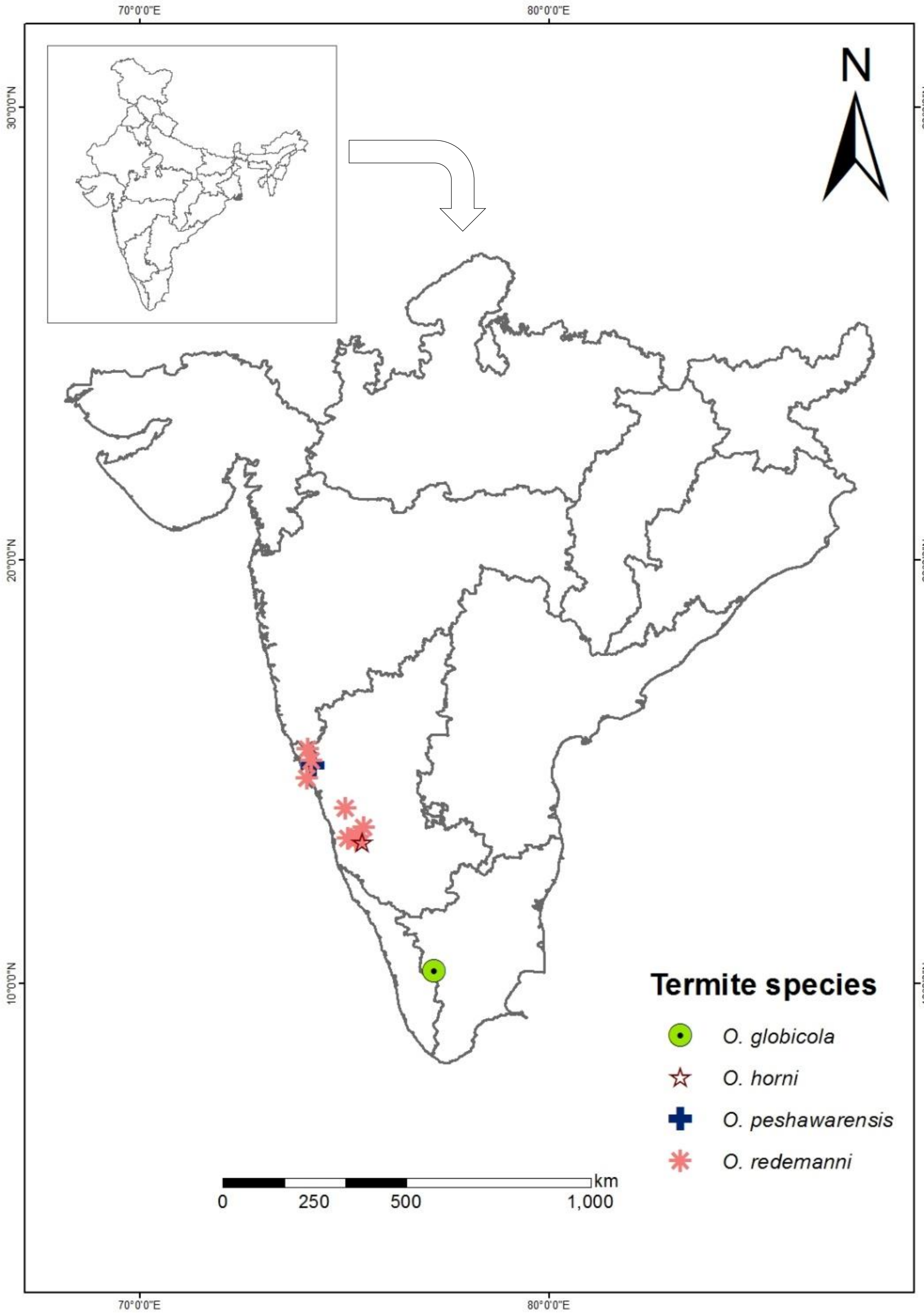


**Fig. 12: Distribution map of termite species belonging to genera *Odontotermes***

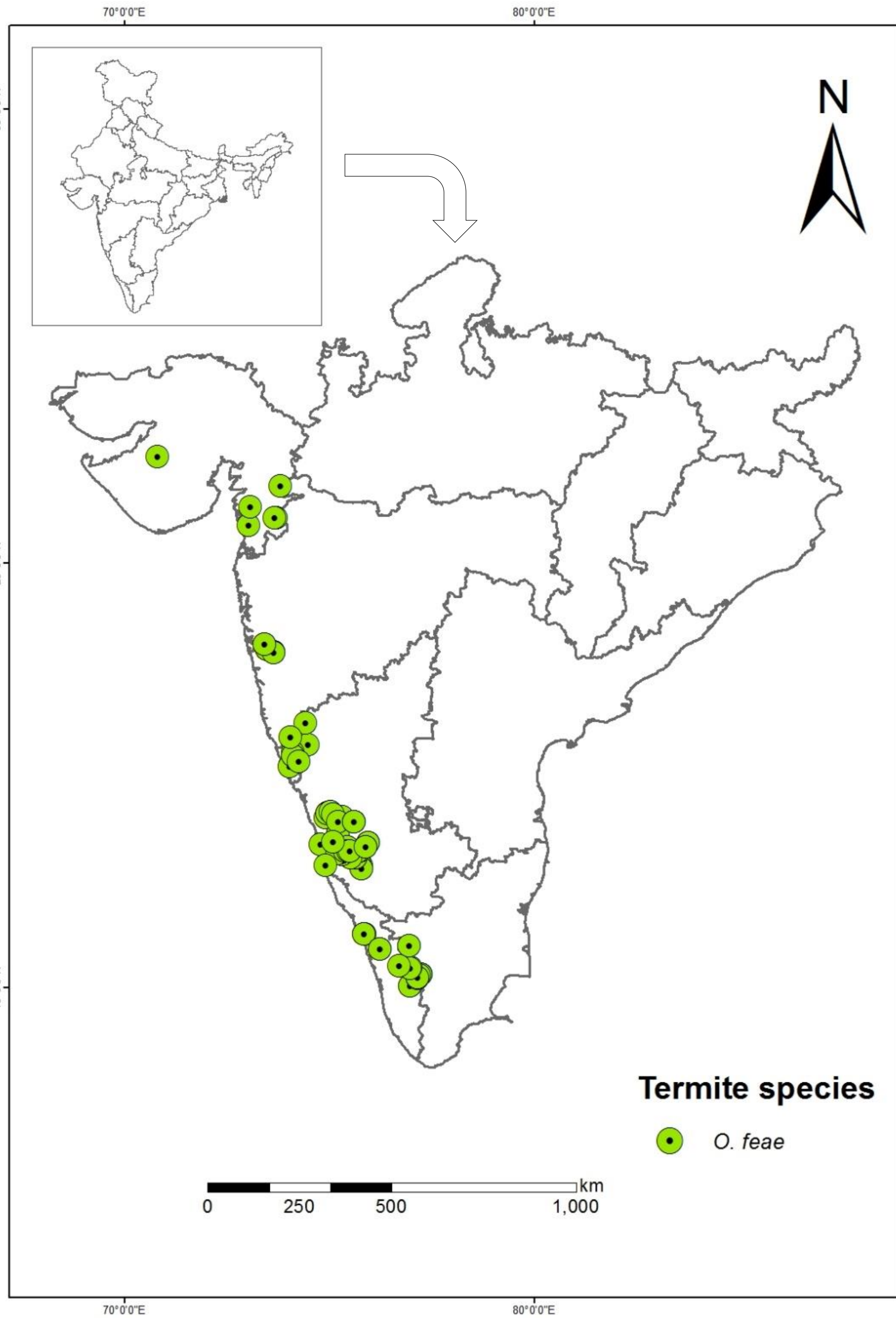


**Fig. 13: Distribution map of *Odontotermes feae***

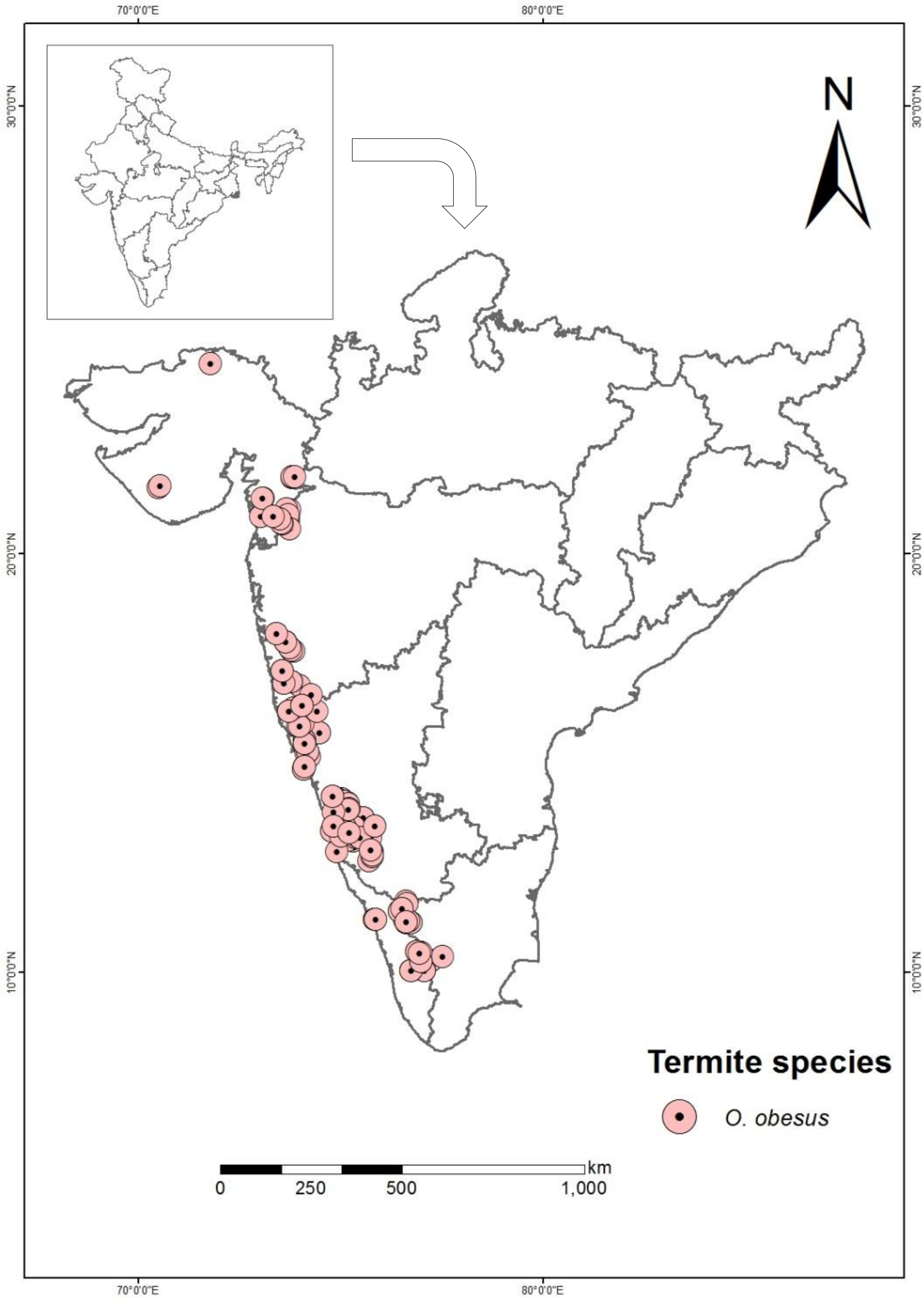


**Fig. 14: Distribution map of *Odontotermes obesus***

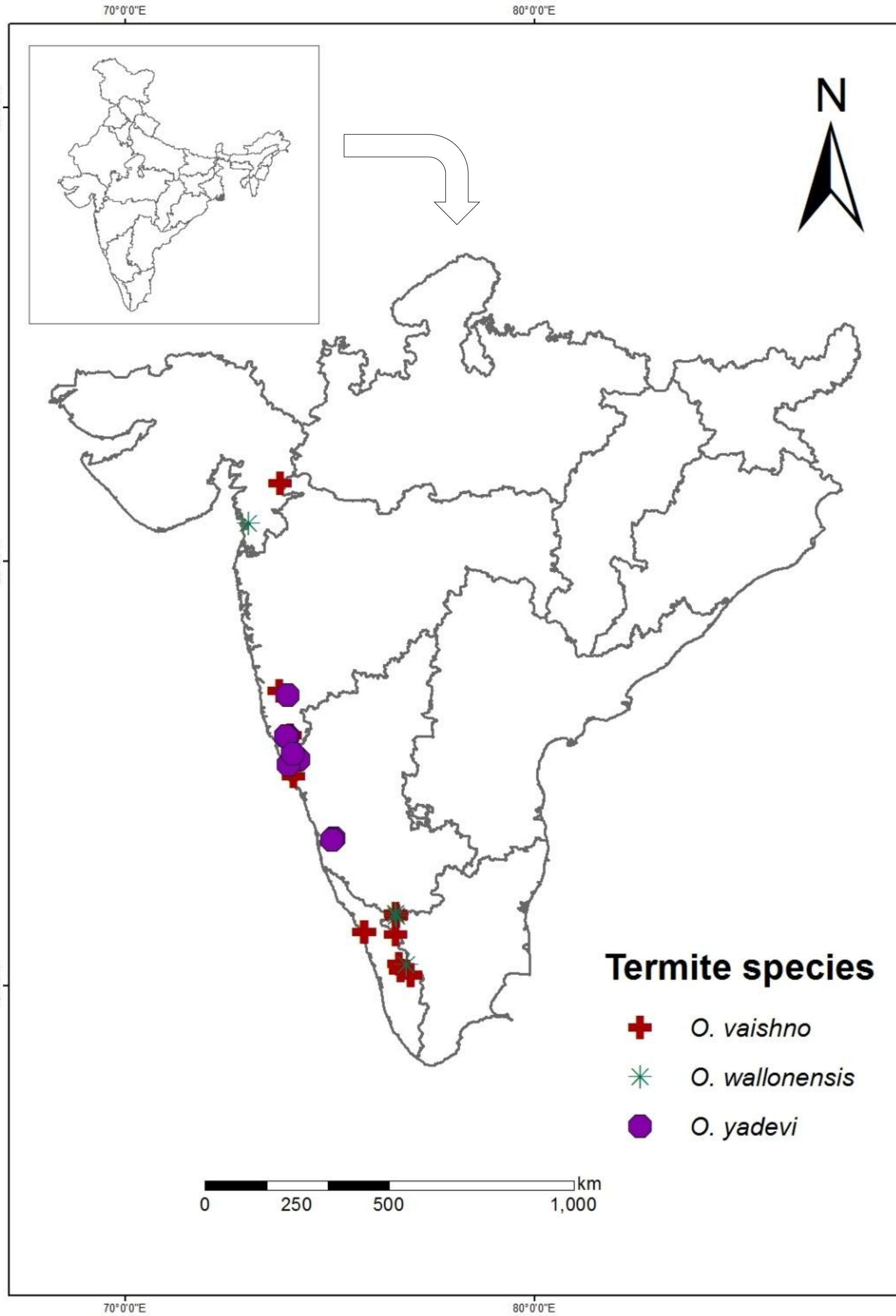


**Fig. 15: Distribution map of termite species belonging to genera *Odontotermes***

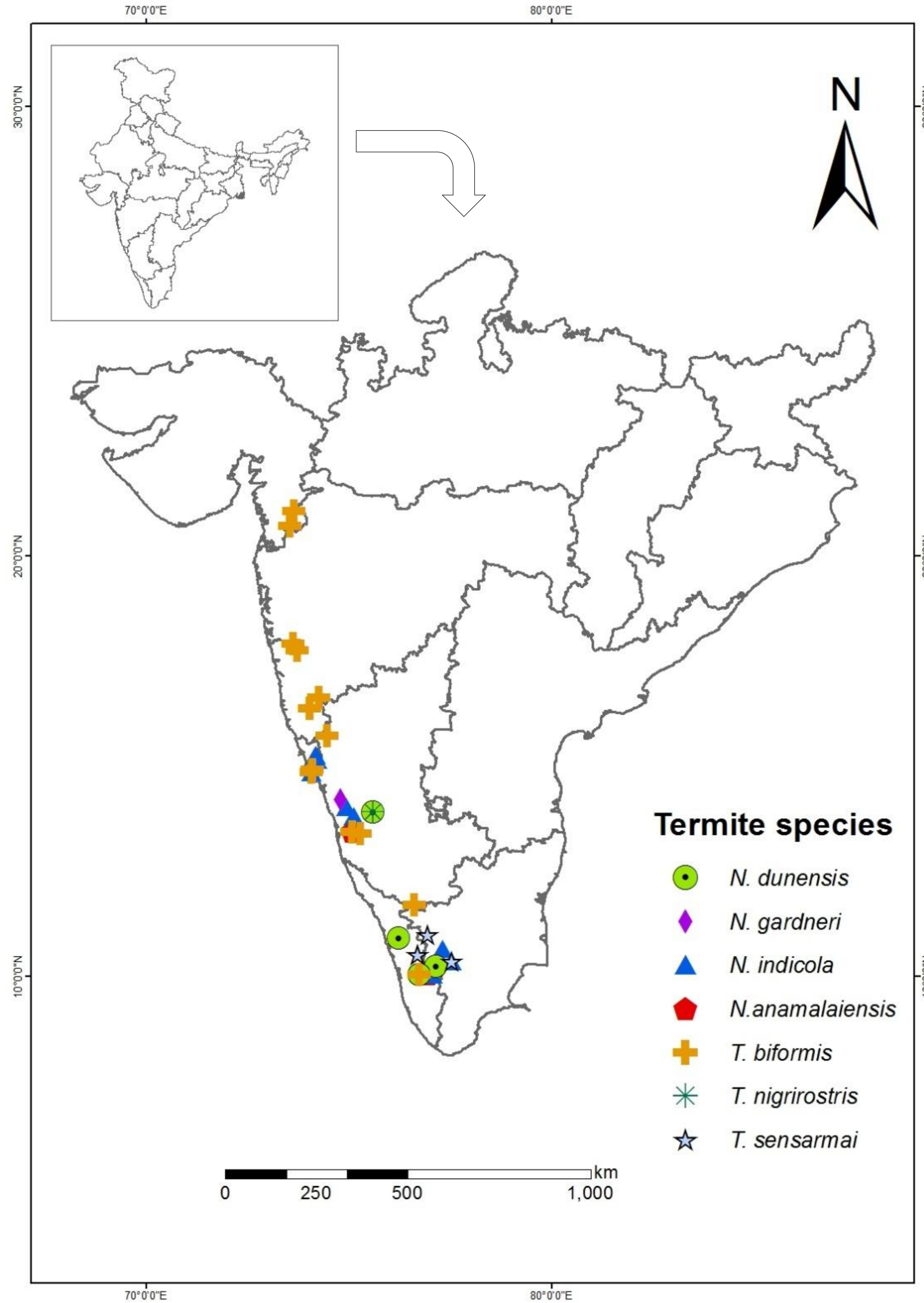


**Fig. 16: Distribution map of termite species belonging to subfamily Nasutitermitinae**

*dunensis* (5 samples) recorded only in Kerala. *Nasutitermes anamallaiensis* and *Trinervitermes sensarmai* (each 4 samples) where the*Nasutitermes anamallaiensis* was collected from Kerala and Karnataka but *Trinervitermes sensarmai* collected at different places of Tamil Nadu. *Nasutitermes gardneri* and *Trinervitermes nigrirostris* were collected from in Edalli, siddapura forest (Karnataka) and CPCRI, Kasargod (Kerala).

In termitinae, *Dicuspiditermes obtusus* (8 samples), *D. gravelyi* (2 samples) and *D. incola* (1 sample) were found to be distributed only in Maharashtra. However *Pseudocapritermes fletcheri* (3 samples) collected at Tamil Nadu and Kerala. *L. distortus* (2 samples) were collected from Karnataka and *Angulitermes fletcheri* was recorded from Tamil Nadu (Fig. 17).

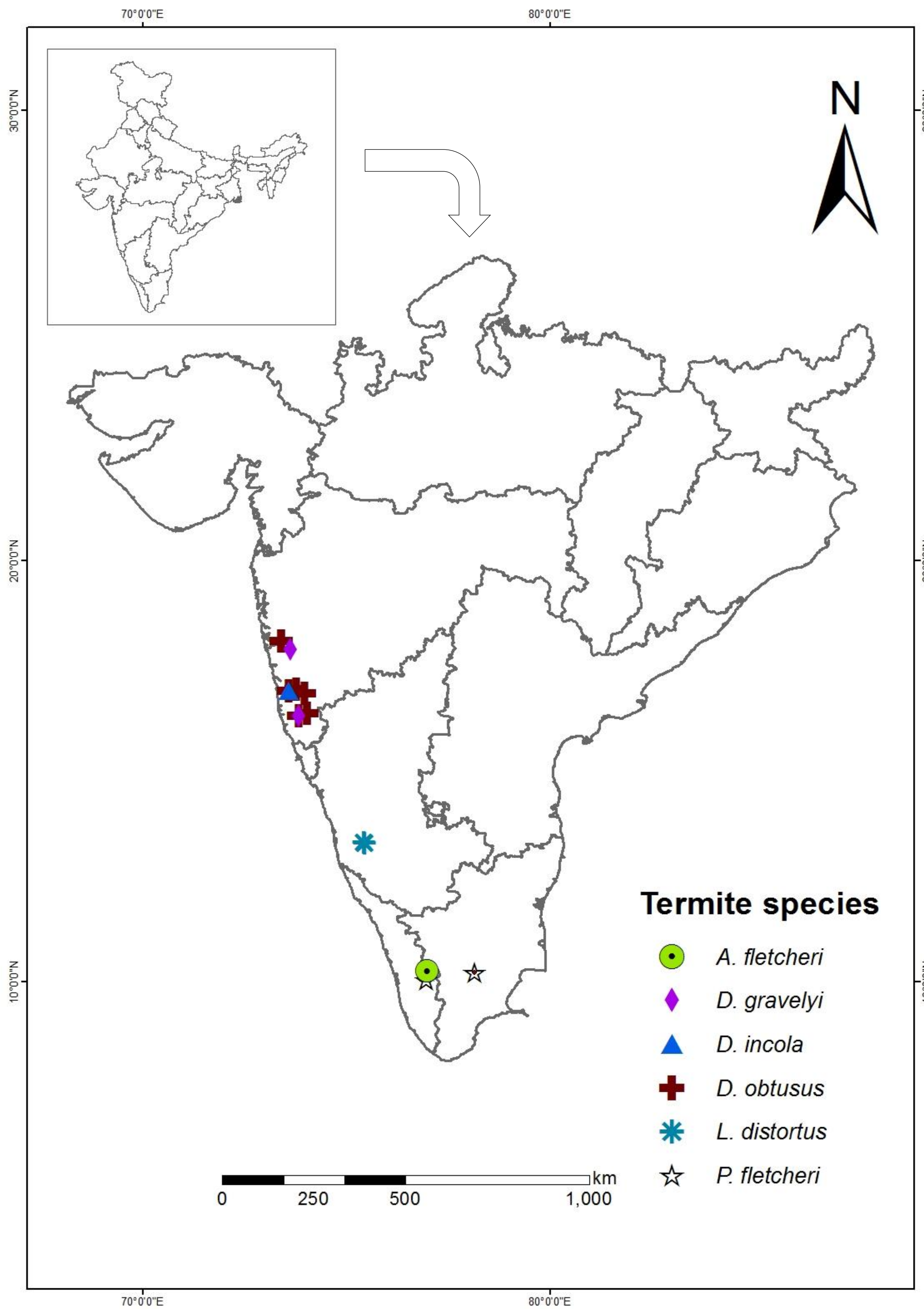


**Fig. 17: Distribution map of termite species belonging to subfamily Termitinae**

# Discussion

# V. DISCUSSION

Discussion on the results of the investigations on "Taxonomy, distribution and diversity of termite (Isoptera) fauna of Western Ghats" which included (i) survey across the Western Ghats and identification to the species level using soldier caste (ii) molecular identification of selected termites (iii) estimation of termite diversity in different ecosystems and (iv) development of species distribution maps of termites of Western Ghats are elaborated in this chapter.

## 5.1 Collection of termites in Western Ghats and species identification using soldier caste

A total of 42 termite species were recorded during the study period from a collection of 598 samples across the Western Ghats covering different states viz., Kerala, Karnataka, Tamil Nadu, Maharashtra and Gujarath. Among the family, Termitidae was most dominant with highest number of species (37), where as Rhinotermitidae recorded only five species. This variability in occurrence is attributed to various factors. Foremost among these are climate suitability, food availability and interactions with other organisms. The present findings are in confirmation with the results of Kambhampati and Eggleton (2000) reported among seven termite families, Termitidae is the largest family covering almost 85 per cent of the known species. It represents approximately 70 per cent of the species in the order Isoptera and it is distributed throughout the world (Kambhapathi *et al.*, 1996).

Termitidae, is considered as the most evolved group of termites, is mainly due to lack of symbiotic cellulolytic protists in their gut region (Ohkuma, 2003). Some of them are mound builders and adapted to various climatic conditions and food habits, which acts as key factors for their success.

In the present study 96 samples collected from mound structures of termites which belongs to family Termitidae and constitutes as major family. The study was supported by Traun and Perry (1998) reported that about 129 species belongs to Termitidae build mounds compared to Rhinotermitidae (17) of overall 153 mound building species present in Australia. Apart from these, Constantino and Acioli (2006) reported Termitidae family has the maximum number of species (2021) compared to Rhinotermitidae (349) in the world; which is the cause for maximum number of species diversity in this region also. The present findings were in conformity with studies of various workers. Sathish (2015) reported that Termitidae with highest number of species (22) as the dominant family whereas Rhinotermitidae with less number of species (3) at Shivamogga segment of the Western Ghats. Similarly, Varma and Swaran (2007), also found 13 species of Termitidae compared with only one species of Rhinotermitidae in Kerala.

### 5.1.1. Subfamilies of Isoptera in Western Ghats

**Macrotermitinae**

Major subfamily found in the study area was Macrotermitinae (81.09 %) with 18 species (Fig. 18). They showed wide range of feeding habits, including wood, litter, soil and cow dung. These characters make the Macrotermitinae dominant group. It also contains fungus growing termite species that feed on wide range of dead and living plant materials by their fungal symbionts with that of Basidiomycete, Termitomyces on fungus combs in the nest (Darlington, 1994).This is in agreement with the studies of Sathish (2015), who observed major subfamily found in Shivamogga segment of the Western Ghats was Macrotermitinae (63%). Other subfamilies were Amitermitinae, Nasutitermitinae and Termitinae. However, the family Rhinotermitidae was represented by two subfamilies, Heterotermitinae and Coptotermitinae. Coptotermitinae represented small portion of samples to the total collections due to narrow feeding habit mainly on wood structures (Jones and Prasetyo, 2002).

**Coptotermetinae and Heterotermitinae**

The subfamily Coptotermetinae was represented by three species, *Coptotermes ceylonicus, C. kishori and C. heimi* in the study area. Varma and Swaran (2007); Shanbhag and Sundararaj (2013) reported only one species in this subfamily from Kerala *i.e.*, *Coptotermes heimi*. These species also had narrow food habit *i.e.*, they require wet wood as the food (Jones and Prasetyo, 2002).

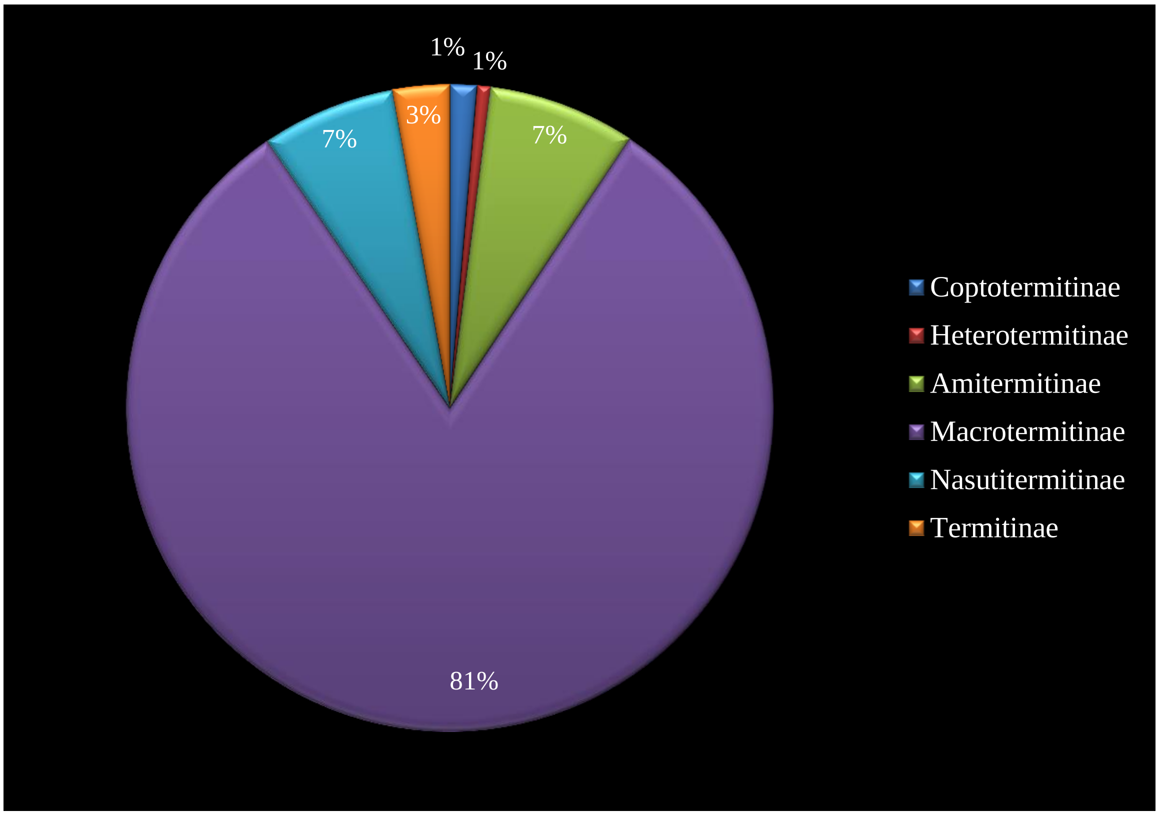


**Fig. 18: Per cent contribution by subfamilies of termites in the study area**

The Heterotermitinae was represented by two species in the present study and it is relatively poor representative to overall samples. The similar results were reported by Kumar and Pardeshi (2011), Rao *et al.* (2012), Mahapatro and Kumar (2013) in different parts of India.

**Amitermitinae**

This subfamily was commonly encountered in forest habitats (Fig. 18) of the study area and was represented by six species. *Microcerotermes fletcheri* was the most dominant species followed by *M. pakistanicus*. This subfamily was reported by various workers in different parts of India (Varma and Swaran, 2007; Kumar and Pardeshi, 2011; Shanbhag and Sundararaj, 2013 and Basu *et al.*, 1996).

**Nasutitermitinae**

The subfamily was represented with seven species, namely*Nasutitermes anamalaiensis, N. dunensis, N. indicola, N. gardneri, Trinervitermes biformis. T. nigrirostris* and *T. sensarmai.* Among these, *Trinervitermes biformis* represents higher number of samples in Western Ghats. This was highly specialised form of higher termites (Homathevi, 1999; Eggleton *et al*., 1999) inhabits in soil galleries on trees and dead wood (Fig. 18).

**Termitinae**

This subfamily had least representation of termite species (6). Species belong to this subfamily are soil feeders and posses peculiar, unnoticeable soil nests. Sathish (2015) reported the presence of *Labriocapritermes distortus* and *Pericapritermes* sp. in Shivamogga segment of Western Ghats.

**5.1.2 Termite species contribution in the study area**

In the present study, the highest contribution was by *O. obesus* (Fig. 19) which inhabits a wide variety of habitats across Western Ghats. The species has adaption to various climatic condition and construct large close mounds. Mound construction could be one of the key success for this species compared to other. The mounds are highly

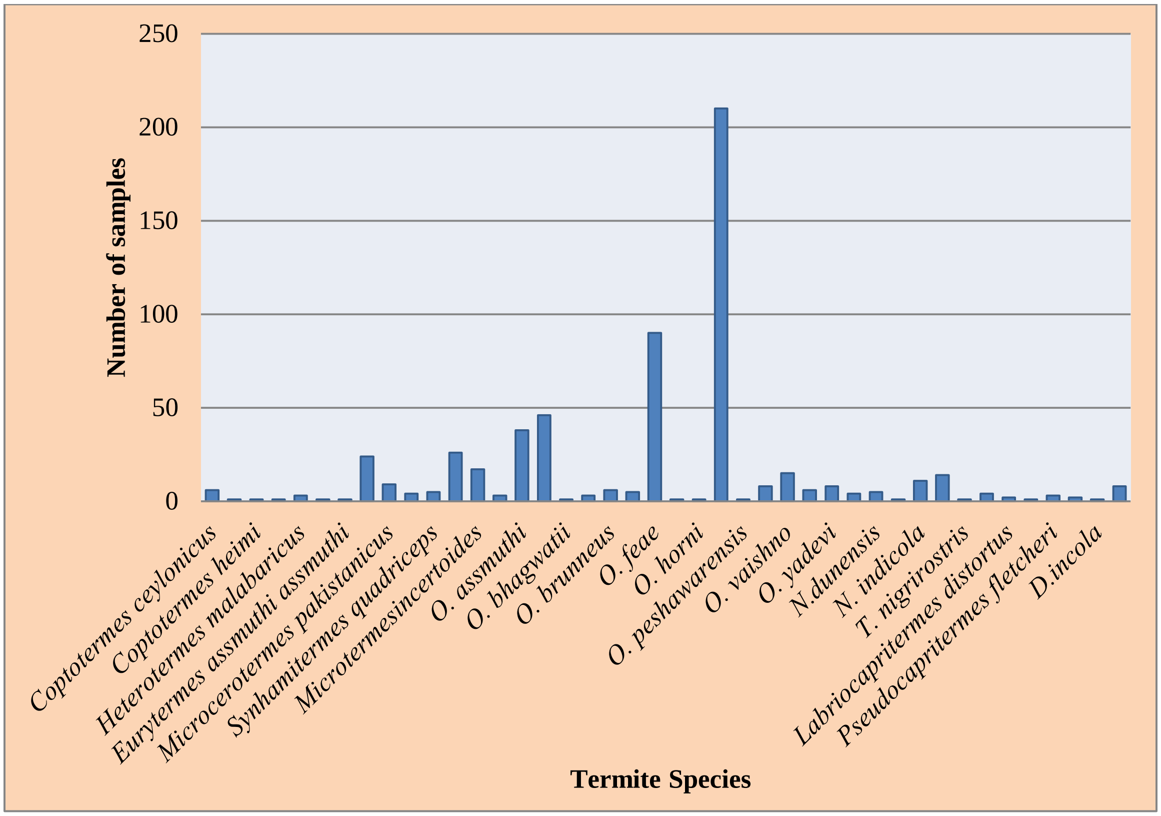


**Fig. 19: Number of samples represented by each species of termites in study area**

variable in shapes, symmetrical and dome shaped. The species reported in all parts of the country (Chhotani, 1997). This was followed by *O. feae*which was also predominantly found in different habitats in all the states. This is due to wide range of food habits (wood and live trees) and resistance to anthropogenic disturbance (Basu *et al.,* 1996). They reported presence of this species on a wide host range in the different ecosystems. The species was also reported in almost all parts of India, Nepal, Bhutan, Bangladesh, Sri Lanka and Thailand (Chhotani, 1997). *O. globicola* was recorded only from Kerala. Chhotani (1997) reported the distribution of thisspecies in Karnataka, Tamil Nadu, Kerala, Uttar Pradesh, Rajasthan, Jammu Kashmir, Sri Lanka and Pakisthan. Thenext predominant species was *O. bellahunisensis,* which inhabits in wide variety of habitats along Western Ghats. The species was reported in Karnataka, Tamil Nadu, Kerala and Orissa (Chhotani, 1997).

### 5.1.4 Developing taxonomical key of termites based on morphological characteristics of soldier caste

In the present study, illustrated keys were prepared, based on the morphology of head and thorax of soldier caste for easy and accurate identification of all the collected samples. These keys could be useful for quick identification and provide the source for any confusion arising on the taxonomical status of termite fauna of this region. To date, two publications (i) Fauna of India and the adjacent countries.Isoptera (Termites) Volume I by Roonwal and Chhotani (1989) and (ii) Fauna of India and the adjacent countries. Isoptera (Termites) Volume II (Family-Termitidae) by Chhotani (1997) are the source for identification of termites of India and adjacent countries. The present study contributes for further addition of species if any, for future publications covering entire India.

## 5.2 Molecular identification of selected termites

About 2650 species of termites in 280 genera and seven families have been so far described worldwide with perhaps 500-1000 species still left to be described (Kambhampati & Eggleton, 2000). The present work was aimed at molecular identification of selected termites, the sequences of the species under investigation were characterized on the basis of frequencies of nucleotide bases and in most of the species, a significantly high percentage of A+T base composition was observed. Phylogenetic position of Indian termites (Isoptera: Termitidae) with their respective genera inferred from DNA sequence analysis of the mitochondrial 16S rRNA gene was assessed.

In Phylogenetic tree, the *Odontotermes* and *Microtermes* species clustered together with same species data collected from NCBI database from the different geographic regions of China, Japan, Malaysia and Kenya. Our observations broadly corroborate with the reports of Singla *et al.*, (2015), who reported genetic relationship of Indian termites based on 12S rRNA and those by Ohkuma *et al*. (2004) and Thompson *et al.* (2000b). They investigated the phylogeny of Asian termites based on COII gene of 31 genera from families Termitidae and Rhinotermitidae. Phylogenetic analysis of termites illuminates key aspects of evolutionary biology *i.e*., mapping of biological traits, nesting type, feeding groups and family relationships (Inward *et al.* 2007a, Donovan *et al.*, 2000, Eggleton, 2000). Phylogenetic analysis of evolutionary relationships may further lead to greater accuracy of pest management with insecticides on the basis that species closely related, are likely to share similar physiology (Gentz *et al*., 2008). The present study results demonstrated that DNA sequences of genes that are not likely to vary in function are useful for inferring termite phylogeny. However, the present studies do not lead to exclusive inference, since a large number of termite groups were not analyzed. Use of multiple samples with morphological and molecular techniques will provide the best species determination. The information generated on the basis of this data can be used for the molecular identification of Indian termite species, their prevalence and classification, which are difficult to differentiate on the basis of morphological parameters.

The technique is used for identification of various closely related insect species which are difficult to be identified by traditional systematics. There are confusion for species status of various species like for example*O. redemanni* and *O. obesus*, *Odontotermes guptai* and *Odontotermes bellahunisensis* as only measurement delineate the species. For molecular identification, any caste can be used and for many species, soldiers are not reported, so this will provide significant contribution in identification.

## 5.3 Estimation of termite diversity in different types of ecosystems

### 5.3.1 Comparison of species composition in three habitats by belt transect method

The termite diversity was more in forest habitat (12 species) compared to Teak plantation (ten species) and pasture (seven species) habitat. The variation could be due to anthropogenic activities and less decomposed matter or leaf litter in pasture habitat. Normally increased disturbance had negative effect on species diversity (Sathish, 2015).

Forest and plantation habitats had more diversity of termite species. Here most termite assemblages have the diverse range of feeding (wood, soil, leaf litter, *etc.*) and nesting strategies like mound, arborial nest, nest of wood (Dawes, 2010). These two habitats had diverse group of flora which provide niche for one or more termite species (Mugerwa *et al.*, 2011) and also high leaf litter, organic matter content and wood accumulation which causes higher termite diversity (Ali *et al.*, 2013). The present results are in conformity with Basu *et al*. (1996) who reported 10 species in undisturbed forest, six in acacia plantation and four in slightly disturbed forest. Soil parameters, vegetation and microclimate strongly modify the termite communities (Basu *et al.*, 1996). It is well known fact that forests are rich in organic matter compared to disturbed lands. In this study, soil characteristics of three different habitats was analysed, where forest ecosystem has high organic matter content (10.29%) compared to plantation (6.10%) and least was in pasture (3.36%). This must be the reason for presence of higher number of species compared to disturbed regions. *Odontotermes obesus* was widely distributed in all the three regions due to its adaption to diverse ecological conditions and habits (wood, live crops, cow dung, tree species, pest to several crops, *etc.*). Next most widely adapted species was *O. feae* which had wide host range (wood, pest of number of crops, orchard and forest species).

#### 5.3.1.1 Dominant species

The diversity of termites recorded during the study could be explained by the degradation of fragile ecosystem, soil texture, moisture content, human interference and hydrogen ion concentration which plays a key role in determining the availability of termite population. Consequently, while *Odontotermes* appeared to play a major role in clay dynamics and soil fertility in the tropical ecosystem. The biological attributes of each species (nest pattern, lifespan and distribution of fungus comb chambers) appear to be the main determinants to account for the relative importance of termite species in soil functioning.

*Odontotermes obesus* dominated in forest (20.10%), plantation (26.13%) and highest in pasture habitats in overall termite assemblage sampled. This may be due to adoption of this species to diverse habits (wood, litter, stump, base of tree, cow dung, mound *etc.*). This result is in accordance with the findings of Ali *et al.* (2013) and Varma and Swaran (2007). The dominant species varies from one habitat to another (Dawes, 2010).

#### 5.3.1.2 Diversity indices

##### 5.3.1.2.1 Shannon-Wiener index

Shannon-Wiener index represented the diversity of species and commonest species found in a habitat. The maximum diversity was observed in forest (2.26) followed by plantation (2.12) was due to the availability of more food sources and climatic conditions. In pasture habitat, non-availability of food and low in organic matter compared to forest and plantation might be the reason for lower termite diversity (Fig. 20). The present findings were in close agreement with the Shanbhag and Sudararaj (2013). They recorded Shannon-Weiner index of 2.20 in forest and 1.56 in plantation.

##### 5.3.1.2.2 Simpson’s index

Simpson’s index indicates the dominance of termite species and species richness. The diversity was maximum in forest (0.88) and plantation (0.87) habitat. This might be due to the greater structural complexity (larger tree, greater plant diversity and more dead wood). Thus, this habitat provides a greater array of nesting and feeding sites for termite fauna compared to the maidan. These results are closely in confirmation with findings of Shanbhag and Sundararaj (2013) who reported higher Simpson index in forest compared to plantation. A closed and very dense canopy in forest provides favourable environmental condition for termite fauna (Fig. 20).

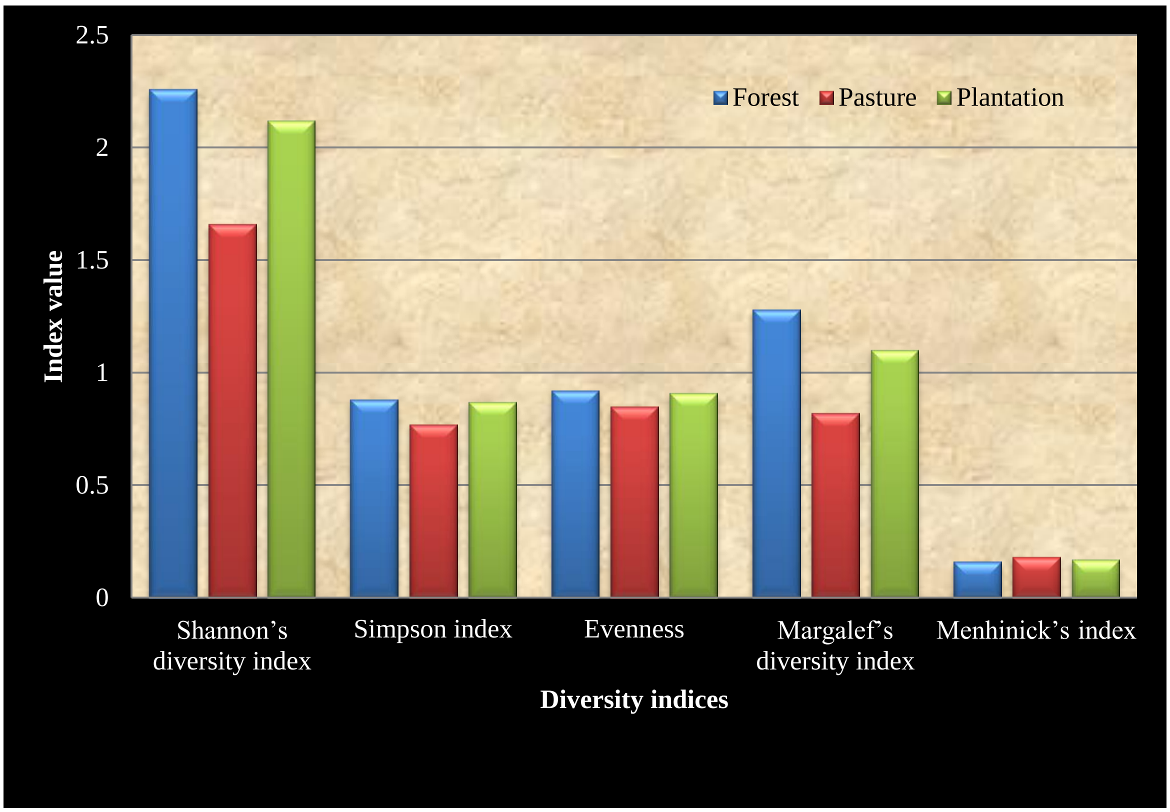


**Fig. 20: Termite diversity indices in forest, pasture and plantation**

#### 5.3.1.2.3 Evenness

More even distribution of species (evenness) was found in forest (0.92) compared to plantation (0.91). Termite species were more unevenly distributed in pasture (0.85). The present investigation is in agreement with Shanbhag and Sundararaj (2013) who reported evenness of 0.85 in forest and 0.76 for planation (Fig. 20).

#### 5.3.1.2.4 Margalef's diversity index

Margalef's diversity index was higher in forest habitat than plantation. Varma and Swaran (2007) reported that rainfall found to have a negative influence on the diversity of the active/foraging species of termites. These results are in agreement with the findings of Shanbhag and Sundararaj (2013).

#### 5.3.1.2.5 Menhinick's index

Menhinick's index was higher in pasture (0.18) compared to plantation (0.17) than forest (0.16) is also indicates the species diversity. The present finding is in close agreement with the findings of Shanbhag and Sundararaj (2013).

### 5.3.2 Species richness and per cent contribution of termite fauna

Among the termite fauna encountered during the study (Fig. 21), Macrotermitinae was found highest in all three different habitats, this could be due to its feeding habit *i.e.*, it prefers wood than the leaf litter and also diverse types of host may be available for their occurrence (Fig. 21). Amitermitinae was present only in forest and plantation habitats and absent in pasture as they are highly sensitive to human disturbance and climate conditions. The present finding is in agreement with the finding of Basu *et al.* (1996). Similarly, Shanbhag and Sundararaj (2013) reported 10 species out of 14 species, belongs to Macrotermitinae. Most of the species were epigeal mound builders and were adapted to different climatic condition. These factors make the species dominant in the study area with two genera, *Microtermes* and *Odontotermes.* Of these, *O. obesus* provided higher contribution of samples in forest and also in plantation habitat, as it feeds significantly on the dead wood, grass and litter (Wood, 1991).

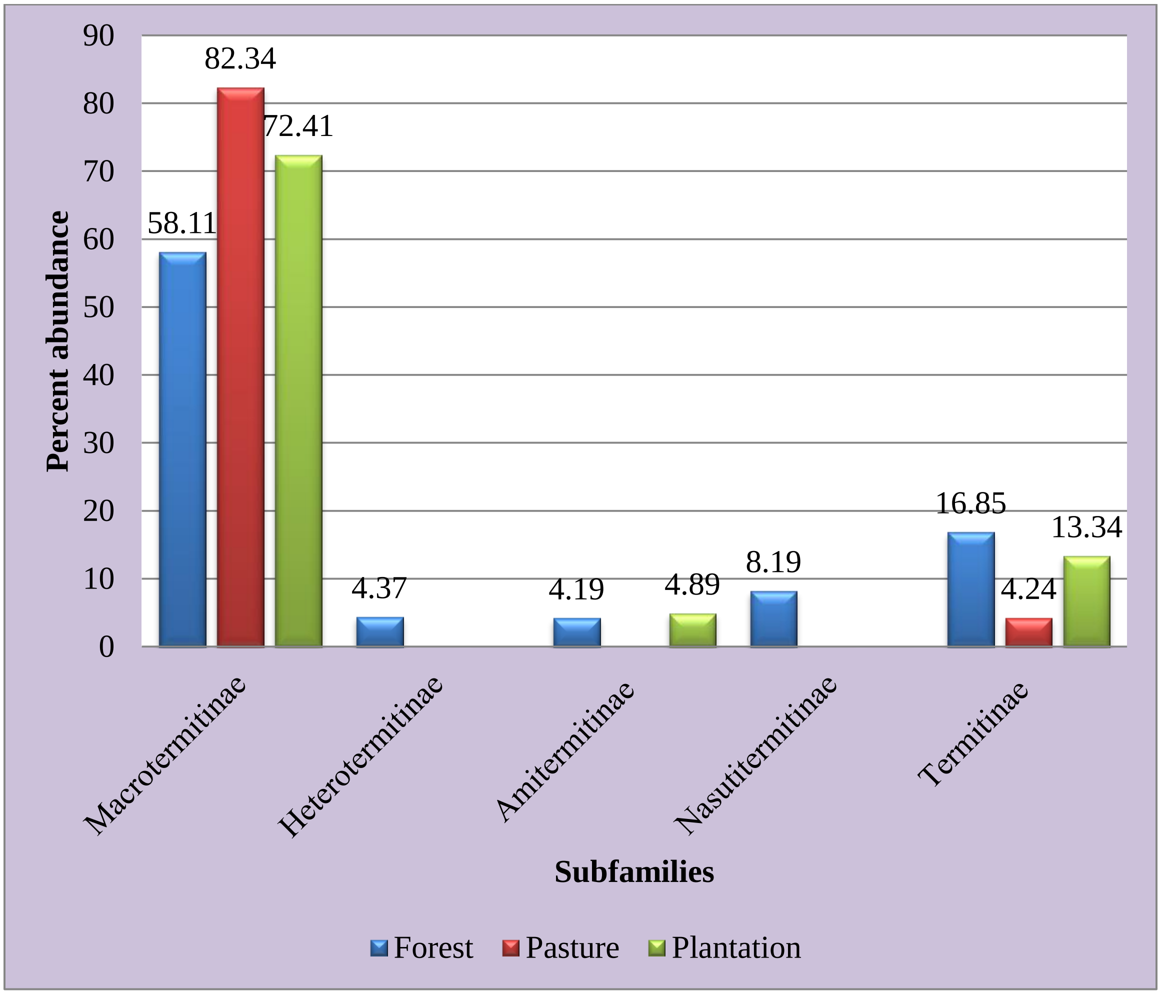


**Fig. 21: Per cent contribution by subfamilies of termites found in different ecosystems in transect method of sampling**

### 5.3.3 Density and diversity of termites in three different habitats of the study area

The density and diversity of species varies across the habitats during the study period in the study area. This was due to movement towards food source or protection from variations in the weather conditions prevailing in different months at different places. The diversity index clearly shows the variation in species richness, abundance and diversity across the study area. This variation could be due to occurrence of biotic (competition between two individuals of different species, predator activity, availability of host, food habitat, *etc.*) and abiotic factors (rainfall, temperature, and soil moisture condition) and also to some extent anthropogenic factors. The extensive search of literature did not yield any findings on these aspects pertaining to termites.

In plantation habitat, Shannon's index and evenness were high in the month of January, indicates higher species richness and even distribution of species. The Simpson's index was high in the month of January which indicates that the commonest species were more as compared to other months. Margalef's diversity and Menhinick's indices were high in the month of January due to the more number of species encountered with less number of individuals (abundance). In pasture habitat, the number of species found was less as compared to forest and plantation habitats. The various indices and density were fluctuated throughout the study period due the anthropogenic causes like irrigation, fertilizer application, herbicide, insecticides *etc*. The agrochemicals affects directly or indirectly on termite population (Sathish, 2015). The earthing up direct exposes the population which causes the negative effect on both richness and abundance. The biotic and abiotic factors also have negative effects to the some extent on the abundance and richness (Basu *et al.*, 1996). The distributions of termite in three habitats clearly shows species diversity was affected by human interference. In order to conserve the termite biodiversity we need to minimise the anthropogenic activities which severely affects the life of termites.

### 5.3.4 Seasonal variation in species diversity in three habitats in transect sampling from July 2015 to May 2016

*Odontotermes obesus* was dominant in forest and plantation habitat as it adapt to variation in climatic conditions very quickly. Where as, *Odontotermes feae* was found to be dominant in pasture habitat. Similar observation was reported by Hemachandra *et al.* (2014).

This seasonal variation in diversity and distribution of termite species in the three different habitats of the study area might be due to anthropogenic disturbances which affects both abundance and species richness (Sathish, 2015). Moderate disturbance can increase/decrease insect diversity, especially when it causes greater habitat heterogeneity; with smaller fragments or heavier disturbance, species loss becomes increasingly evident. The present study seems to be new in this direction. However, this is well documented in other social insects like ants (Anantharaju *et al.*, 2014).

## 5.4 Developing distribution maps for termites of Western Ghats

In the present study, four species were recorded for the first time in this study area, namely *Nasutitermes dunensis*, *Nasutitermes gardneri*, *Trinervitermes nigrirostris* and *T. sensarmai*. That means they might have extended their distribution or they were not collected by earlier workers in this region.

*Coptotermes ceylonicus* has narrow food habit. Roonwal and Chhotani (1989) reported that the species in Western Ghats and Malabar regions in Southern India, Tamil Nadu, Kerala and Andhra Pradesh.

*Coptotermes kishori* was recorded in Collem (Goa) in the study area. It was the first report of its extended distribution. Roonwal and Chhotani (1989) reported that, distribution of this species in Kerala, West Bengal, Kalyani, Tripur, Rajasthan and Madhya Pradesh.

*Coptotermes heimi* was represented by single sample at Gautonm (Goa). Roonwal and Chhotani (1989) reported that its presence in India, Including Pakisthan, Bangladesh, Bhutan and Nepal.

*Heterotermes balwanti* was also found to destroy the wood with poor representation of species (1) to overall samples. The species was distributed in Karnataka, Goa, Orissa, Barkuda island, Puri and Rambha (Roonwal and Chhotani, 1989).

*Heterotermes malabaricus* was represented by three samples collected at Karnataka and Goa. This result was in confirmation with the findings of Roonwal and Chhotani, 1989. He reported the distribution of this species in entire peninsular region of India.

*Eurytermes Buddha* was fairly distributed in the Western Ghats and the species was also recorded in Tamil Nadu, West Bengal and Karnataka (Dharwad) by Roonwal and Chhotani (1997).

*Eurytermesassmuthi assmuthi* was represented by single sample in the study area. Chhotani (1997) reported the distribution of this species in Karnataka, Tamil Nadu, Maharashtra and Orissa.

*Microcerotermes fletcheri* occurred as the most dominant with high number of samples (24). This was due to the specialized, hard, carton nesting nature. These nests protect the species from adverse environmental conditions and predation. These species restricted to forest ecosystem in Shivamogga district. These results are in agreement with the finding of Varma and Swaran (2007) and Basu *et al.* (1996).

*Microcerotermes pakistanicus* represented in moderately high number of samples (9). Chhotani (1997) reported the presence of this species in Kerala, Pakistan and Malaysia.

*Microcerotermes minor* was reported in Karnataka. This was in agreement with Chhotani (1997) who reported the presence of this species in Karnataka, Andhra Pradesh and Tamil Nadu.

*Synhamitermes quadriceps* was represented by five samples in Maharashtra. Chhotani (1997) reported the presence of this species in Maharashtra, Goa, Daman, Rajasthan, Madhya Pradesh, West Bengal, Assam, Tripura, Kerala and as well as in Bangladesh.

*Microtermes obesi* was widely distributed along Western Ghats. The results were in conformity with the findings of Basu *et al.* (1996) who reported occurrence of species in different habitats in Kogar region of Shivamogga.

*Microtermes incertoides* was represented by 17 samples in the Maharashtra. This was in agreement with Chhotani (1997) who reported the presence of this species India and also in Pakisthan.

*O. anamallensis* was represented by three samples in Karnataka and Maharashtra. The species adapted to wide range of climatic conditions and habitats. Chhotani (1997) reported the distribution of this species in parts of Karnataka, Tamil Nadu and Kerala.

*O. assmuthi* found in most parts of study area. Roonwal and Chhotani (1989) reported the presence of this species in India, Pakistan and Bangladesh.

*O. bellahunisensis* inhabits in wide variety of habitats along Western Ghats. The species is widely distributed in Karnataka, Tamil Nadu, Kerala and Orissa by Chhotani (1997).

*O. bhagwatii* was sparsely distributed in Karnataka and it has narrow host range represented by single sample. The species has been reported in Karnataka, Madhya Pradesh, Uttar Pradesh, Punjab and Jammu and Kashmir (Chhotani, 1997).

*O. boveni* was sparsely distributed in the Karnataka and Kerala. The species also reported in Madhya Pradesh, Uttar Pradesh and Nepal by Chhotani (1997).

*O. brunneus* was the represented by six samples in five states except Goa. The species has been reported in Maharashtra, Gujarath, Orissa and Uttar Pradesh.

*O. ceylonicus* was the represented by five samples in Tamil Nadu and Kerala. The species has been reported in Karnataka, Kerala, Tamil Nadu and Srilanka (Chhotani, 1997).

*O. feae* was found predominantly in different habitats in all states, due to wide range of food habits (wood and live trees) and resistance to anthropogenic disturbance (Basu *et al.*, 1996). They reported presence of this species on a wide host range in the different ecosystems. The species was also reported in almost all parts of India, Nepal, Bhutan, Bangladesh, Sri Lanka and Thailand by Chhotani (1997).

*O. globicola* was reported in Kerala. Chhotani (1997) reported the distribution of this species in Karnataka, Tamil Nadu, Kerala, Uttar Pradesh, Rajasthan, Jammu Kashmir, Sri lanka and Pakisthan.

*O. horni* was reported in Karnataka. The species was also reported in Madhya Pradesh, Orissa, West Bengal, Manipur, Butan, Sri Lanka, Vietnam and Cambodia.

*O. obesus* was a common species and inhabits a wide variety of habitats across Western Ghats. The species has adaption to various nesting in microhabitats (mound, wood) and food resources. Mound construction may be the one of the key successes for this species compared to other. The mounds are highly variable in shapes, symmetrical and dome shaped. The species reported in all parts of the country (Chhotani, 1997).

*O. peshawarensis* was represented by single sample in the study area. The species was also reported in Pakisthan (Peshawar). This was the first record in the study area, reported from Quepem, Goa.

*O. redemanni* was fairly distributed in the study area due to its narrow host range. The species is distributed in the Southern India, Sri Lanka, Eastern Bihar, West Bengal (Chhotani, 1997).

*O. vaishno was* fairly distributed in the study area and reported in Karnataka and Kerala. *O. wallonensis* was represented by six samples in the study area. Chhotani (1997) reported the distribution of this species in Karnataka, Tamil Nadu, Maharashtra, Gujarath, Andhra Pradesh, Madhya Pradesh, Bihar and Orissa.

*O. yadevi* was represented by eight samples in Karnataka, Maharashtra and Goa. The similar findings was by Chhotani (1997).

*Nasutitermes anamalaiensis* constructs the arborial nest. This may give greater protection against environmental fluctuation (temperature and moisture extremes) afforded by mound walls possibly reduced predation of ants. Chhotani (1997) reported the presence of the species in various parts of Karnataka, Tamil Nadu and Andhra Pradesh.

*Nasutitermes dunensis* was represented by five samples in the study area. Chhotani (1997) reported that species was distributed only in Uttar pardesh. This is also first record of this species in the study area, reported from Kerala segment of Western Ghats.

*Nasutitermes gardneri* was reported in Karnataka. Chhotani (1997) reported that species was distributed in West Bengal, Assam, Arunachal Pradesh, Manipur, Bhutan. This is also first record in the study area, reported from Karnataka.

*Nasutitermes indicola* fairly distributed throughout the Western ghat.  The species was distributed in various parts of the country such as Karnataka, Tamil Nadu and Andhra Pradesh (Chhotani, 1997).

*Trinervitermes biformis* occurs in maidan and it contributes less number of samples to the total, in the study area. It has peculiar type of nest and confuses with the nests of ants. The species was reported by Chhotani (1997) in various parts of Karnataka, Tamil Nadu, Kerala, Andhra Pradesh, West Bengal and Maharashtra.

*Trinervitermes nigrirostris* was reported in Kerala. The species was reported by Chhotani (1997) in Tamil Nadu but in this study, it was recorded from Kerala.

*Trinervitermes sensarmai* was represented by four samples collected at Tamil Nadu. The distribution was contradictory with Chhotani (1997) who reported it from Andhra Pradesh. *Labiocapritermes distortus* was recorded in Balehonnur (Karnataka). Basu *et al.* (1996) reported the distribution of this species in different ecosystems from plantationto undisturbed forest of Western Ghats. The species was dominant in undisturbedforest region, open pasture and acacia plantation.

*Angulitermes fletcheri* was reported from Tamil Nadu. The same result was confirmed by Chhotani (1997). *Pseudocapritermes fletcheri* was represented by three samples which were collected at Tamil Nadu and Kerala. Chhotani (1997) reported this from Karnataka and Goa.

*Dicuspiditermes gravelyi* was represented by two samples in the study area. The species was reported by Chhotani (1997) in Karnataka and Maharashtra.

*Dicuspiditermes incola* was reported from Maharashtra. The species was reported by Chhotani (1997) in India and Srilanka.

*Dicuspiditermes obtusus* was represented by eight samples in the study area. The species was reported by Chhotani (1997) in Karnataka, Madhya Pradesh and Orissa but in the present study it was reported only from Maharashtra.

The study indicated that many species expanded their distribution but some species are recorded only in few localities compared to earlier reports. Two possibilities can be assumed here (i) The expansion may be due to their adjustment to various biotic and abiotic variabilities and became common in all the places. This has negative effect as for as the agriculture is considered but has positive effect, its role in the biodegradation. (ii) The reduction in their distribution may be due to anthropogenic activities. This has negative effect in long run and provide information on the conservation efforts to be initiated which otherwise become still uncommon or extinct.

**Salient findings of research**

1. Total of 42 termite species were identified along Western Ghats and developed the illustrated key for easy and quick identification for the species collected

2. Four species (*Nasutitermes dunensis, Nasutitermes gardneri, Trinervitermes nigrirostris* and *T. sensarmai*) recorded for the first time from the study area

3. Mitochondrial 16sRNA was used in identification of selected termites, which gives an information that dependency on soldier caste can be eliminated in future wherever soldiers were not available

4. Forest habitat had highest species diversity compared to plantation and pasture habitats indicating these two habitats are subjected to anthropogenic disturbances and conservation efforts should be initiated

5. Species distribution maps were developed for all the collected species from Western Ghats

**Future line of work**

1. Intensive survey in other parts of Western Ghats need to be continued for comprehensive documentation of termite fauna

2. Morphological diversity of each collected termite species at different localities needs investigation

3. Search for other molecular markers for identification

4. Role of termites as bio degraders in forest ecosystem is necessary

5. Some species have disjunct distribution. The reason for this type of distribution needs investigation

# *Summary*

# VI. SUMMARY

The outcome of the investigations on Termite (Isoptera) fauna of Western Ghats, identification using soldier caste, molecular identification of selected termites and diversity across the three different habitats and development of distribution maps of termites were summarized below.

Over 598 samples collected and observed to know the Termite (Isoptera) fauna of Western Ghats yielded a total of 42 species belonging to 13 genera and 6 subfamilies (Amitermitinae, Coptotermitinae, Heterotermitinae, Macrotermitinae, Nasutitermitinae and Termitinae) under two families *viz.*, Rhinotermitidae and Termitidae. Termitidae was the most dominant family which represented 97.99 per cent of the total collections with 37 species in eleven genera belongs to four subfamilies *viz.,* Amitermitinae, Macrotermitinae, Nasutitermitinae and Termitinae.

Macrotermitinae contributed highest percentage (81.11%) followed by Amitermitinae (7.36%), Nasutitermitinae (6.68%), Termitinae (2.84%), Coptotermitinae (1.34%) and Heterotermitinae (0.67%). It had the highest number of species (18) belonging to two genera, namely *Microtermes* and *Odontotermes*. The *Microtermes* genus represented only two species *i.e., Microtermes obesi* and *Microtermes incertoides.* The genus *Odontotermes* was represented by the highest number of species (16), *viz., O. anamallensis, O. assmuthi, O. bellahunisensis, O. bhagwatii, O. boveni, O. brunneus, O. ceylonicus, O. feae, O. globicola, O. horni, O. obesus, O. peshawarensis, O. redemanni, O. vaishno, O.wallonensis* and *O. yadevi.* Among these, *O. obesus* was widely distributed and dominant species recorded along Western Ghats.

An illustrated identification key to termites of Western Ghats was developed. This will be useful for quick identification of termite species found in Western Ghats. For molecular study, selected termites of Karnataka were used. The present investigation has two principle outcomes. First, termites were identified using morphological characters of soldier caste, further this reports Termitidae as predominant family with five genera and three subfamilies *viz.,* Macrotermitinae, Amitermitinae and Nasutitermitinae.

Macrotermitinae had the highest number of species belonging to two genera, *viz*., *Microtermes* and *Odontotermes* while Amitermitinae had two species namely, *Microcerotermes fletcheri* and *M. pakistanicus*.The family Rhinotermitidae was represented by the single subfamily Heterotermitinae. In Heterotermitinae, one species namely *Heterotermes balwanti* was recorded. Second, representative taxa were used to conduct a test case of molecular characters in termites. That is, evaluated how well nucleotide sequence information from the 16S rRNA region of the mitochondrial genome can resolve species relationships through phylogenetic analysis. This morphological identification is consistent with molecular finding that Amitermitinae, Macrotermitinae, Nasutitermitinae and Rhinoterminae have statistically distinct 16S rRNA profiles. A Bayesian analysis tree based on aligned nucleotide sequences shows the complete set of sequenced specimens to cluster by species, and by genus. This clustering is perfect in the sense that no species or genus is mis-classified and no taxon is shown to be paraphyletic with respect to current taxonomy. This combined analysis therefore supports the notion that Amitermitinae, Macrotermitinae, Nasutitermitinae and Rhinoterminae are evolutionarily distinct, monophyletic genera. These results revealed that molecular character holds promise for helping to solve termite taxonomic problems, with nearest neighbour distances for exceeding maximum intra specific divergence, at least for the specimen examined here.

Termite species richness was one of the most important measures to know the anthropogenic cause. The belt transect method of sampling was used to know the species diversity in three habitats. The present study revealed that the termite species varies from one habitat to another habitat with 17 species reported from all the three habitats. Forest habitat had maximum number of species with 12 compared to plantation with ten termite species and less number was reported in pasture. *Odontotermes obesus* and *O. feae* were found in all three habitats which indicate its adaptability. Species diversity and richness varied across three habitats. Shannon-Wiener index shows that the values ranged from 1.66 to 2.26 in the study area, which indicates that forest had more species diversity (2.26) followed by plantation (2.12) and lowest in pasture (1.66) habitats. Simpson's index also revealed a similar trend. The evenness value reveals that the species are distributed evenly in the different habitats. Evenness was highest (0.92) in forest followed by plantation (0.91) and least in pasture habitat (0.85).Highest value of Margalef’s diversity index was observed in forest (1.28) followed by plantation (1.10) and lowest in pasture (0.82) and Menhinick’s index was also highest in pasture (0.18) followed by plantation (0.17) and was lowest in forest (0.16).

For all collected termites species along Western Ghats, distribution maps were developed. From these maps, the pattern of distribution, species rich areas and species poor areas were easily identified. Based on that, *Odontotermes obesus* was found to be widely distributed followed by *O. feae.* However, the following species recorded in only one locality along Western Ghats which included *Coptotermes kishori*, *C. heimi*, *Heterotermes balwanti*, *Eurytermes buddha*, *E. assmuthi assmuthi*, *O. bhagwatii, O. globicola, O. horni, O. peshawarensis, Nasutitermes gardneri*, *Trinervitermes nigrirostris, Angulitermes fletcheri* and *Dicuspiditermes incola.*

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*Original not seen