Comparative Termite (Isoptera) Diversity in Three Different Habitats of Shivamogga District, Karnataka, India[1]

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Abstract A comparative study of termite (Isoptera: Termitidae) species diversity and richness in three ecologically different habitats was conducted in the Shivamogga District of Karnataka, India, from September 2014 to August 2015. A standard belt transect method was used to sample the termites in each habitat for the duration of the study. The three habitats studied were rainforest, semimalnad represented by degraded forest area that was previously rainforest, and maidan represented by open field and plantation crops with no tree cover. Twenty-two species were collected, all representing the family Termitidae. Nine species were recorded from the maidan habitat, 14 species from the semimalnad habitat, and 18 species from a rainforest habitat. Of the 18 species recorded from the rainforest, 6 were exclusively recorded there and not in the maidan or the semimalnad habitats. Species richness, as indicated by Shannon's diversity index (H), was highest in the rainforest (1.62), followed by the semimalnad (1.43) and maidan (1.13) habitats. The variation in diversity across these three habitats is attributed to anthropogenic disturbance, cropping patterns, topography, and bioclimatic factors. Implications of habitat disturbance on termite diversity are discussed.

Key Words Isoptera, semimalnad, rain forest, termite diversity

Termites (Isoptera) play important roles in ecological systems. They are decomposers, especially of a variety of cellulose-based resources, and thus insure cycling of organic matter in ecological habitats (Ackerman et al. 2009, Sugimoto et al. 2000), while contributing to gas exchange, nitrogen fixation, and soil stability and quality (Bignell 2000). The magnitude and dimension of the ecological role played by termites in a habitat is a function of their population density and biomass (Lee and Wood 1971, Evans et al. 2011).

Termites are abundant throughout the tropics and subtropics, as well as in many temperate areas of the world, with species diversity and total biomass being greatest in the tropics (Pearce 1999). Termite assemblage composition is impacted by habitat disturbance which may, in turn, alter the beneficial impact of termites in the affected system (Maiti 1983, Jones and Eggleton 2000, Pardeshi and Prusty 2010). Previous studies in the Western Ghats region of India suggest that increased anthropogenic activities in that region are adversely affecting the soil macrofauna and diversity (Blanchart and Julka 1997, Ferry 1992). Large tracts of forest are

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Table 1. Termite species collected in a comparative study of species abundance and richness in three ecological habitats of Shivamogga District, Karnataka, India, 2014–2015.

Species	Subfamily	Rainforest*	Semimalnad*	Maidan*
Odontotermes obesus Rambur	Macrotermitinae	+	+	+
O. feae (Wasmann)	Macrotermitinae	+	+	+
O. anamallensis Holmgren and Holmgren	Macrotermitinae	+	+	-
O. bellahunisensis Holmgren and Holmgren	Macrotermitinae	+	+	-
O. adampurensis Akhtar	Macrotermitinae	+	-	-
O. boveni Thakur	Macrotermitinae	+	-	-
O. horni Wasmann	Macrotermitinae	+	+	+
O. bhagwathi Chatterji and Thakur	Macrotermitinae	-	+	-
O. assmuthi Holmgren	Macrotermitinae	-	-	+
O. yadevi Thakur	Macrotermitinae	+	-	-
Odontotermes sp	Macrotermitinae	+	+	-
Microtermes obesi Holmgren	Macrotermitinae	+	+	+
Microcerotermes fletcheri Holm and Holm	Amitermitinae	+	+	+
M. pakistanicus Akhtar	Amitermitinae	+	+	-
Speculitermes sinhalensis Roonwal and Sen-Sarma	Amitermitinae	-	-	+
Nasutitermes indicola Holmgren	Nasutitermitinae	+	+	-
N. anamallaiensis Snyder	Nasutitermitinae	+	-	-
N. krishna Bose	Nasutitermitinae	+	-	-
Nasutitermes sp	Nasutitermitinae	-	+	-
Grallatotermes grallatoriformis Holmgren and Holmgren	Nasutitermitinae	+	-	-

Table 1. Continued.

Species	Subfamily	Rainforest*	Semimalnad*	Maidan*
Pericapritermes sp.	Termitinae	+	+	+
Dicuspiditermes gravelyi (Silvestri)	Termitinae	+	+	+
Diversity Indices				
Alpha diversity		18	14	9
Beta diversity**		R/S = 6	S/R = 2	M/R = 2
		R/M = 11	S/M = 7	M/S = 2
Gamma diversity			22	

* + = present; - = absent.
** R = rainforest; S = Semimalnad; M - Maidan.

being lost or converted to open or cultivated lands, coffee and areca plantations, or hydroelectric reservoirs (Menon and Bawa 1997). The Shivamogga District of India is characterized by a large and diverse assemblage of endemic plant and animal species. It is home to several wildlife sanctuaries, reserves, and national parks. Continued anthropogenic activities could decrease biodiversity in the region. The study reported herein is a comparison of termite fauna in three different ecological habitats in Shivamogga, with the objective of providing an accurate baseline of information on termite species diversity and richness in the region for eventual use in conservation decision making.

Materials and Methods

Study sites. The study was conducted in the Shivamogga District in the mid-southwestern part of the Karnataka State of India. The district is characterized by three distinct agroecological areas including (a) the maidan zone in the eastern portion of the district, (b) the semimalnad zone in the central part of Shivamogga, and (c) a rainforest forming the western portion of Shivamogga. The maidan zone has an elevation of 600 to 640 m above sea level and an annual rainfall average of 104.8 cm. Land in the zone is primarily made up of various field and plantation crops, with irrigation for the crops from the Tunga and Bhadra rivers. The semimalnad zone (elevation 640 to 800 m) of Western Ghats has occasional chains of hills covered with semideciduous vegetation and a few plantation crops. The annual average rainfall is 150.0 cm. This semimalnad zone was once covered with trees and forests but is now mostly a mosaic of degraded forest habitats interspersed with pastures, plantations, and occasional pockets of undisturbed evergreen forests. The rainforest zone of the district is covered with vegetation throughout the year and has no appreciable areas of cultivation or crops (Basu et al. 1996). The elevation is from 826 to 1,200 m, and the annual rainfall averages 271.9 cm. The locations within each habitat selected for sampling were Navile (N 13°58′, E 75°34′; elevation 611 m) in the maiden zone, Kannangi (N 13°48′, E 75°18′; elevation 698 m) in the semimalnad zone, and Agumbe (N 13° 29′; E 74° 04′; elevation 826 m) in the rainforest.

Sampling. A standard and rapid method known as the belt transect method (Davies 1997, Eggleton et al. 1997) was used for sampling termites at the three sites. Sampling was conducted at monthly intervals from September 2014 through August 2015. Briefly, the transect measured 100 m in length and 2 m in width and was divided into 20 contiguous sections, each 5×2 m in size. When sampling, all the probable microhabitats of termites (i.e., mounds, logs, fallen trees, living trees up to height of 2 m, sticks, leaf litter, and vegetation) within each of the 20 sections were examined and searched for termites. Soldiers and workers were collected and labeled with the section number and transported to the laboratory where they were counted, labeled, and placed in 75% (v/v) ethyl alcohol. Specimens were eventually identified to species by using the keys of Roonwal and Chottani (1989), Chottani (1997), and Kalleshwaraswamy et al. (2013). Voucher specimens were placed in a permanent collection in the Insect Systematics Laboratory, Department of Entomology, University of Agricultural and Horticultural Sciences, Shivamogga, India.

Data analysis. The number of species encountered in the transect was used as an indicator of relative abundance of species within each habitat. Percent occurrence of each species was calculated in the three habitats, and temporal changes in species diversity were calculated. Termite species richness were calculated using Shannon's diversity index (H), Simpson's diversity index (D), Evenness (E), Margalef's diversity index (Dmg), and Menhinick's index (Dmn), and diversity analysis was conducted with alpha diversity, beta diversity, and gamma diversity, as described by Magurran (1988).

Results and Discussion

The species observed differed among the three habitats sampled (Table 1). Twenty-two species were identified from the 438 samples collected from the sites during this study. Those 22 species represented 4 subfamilies (Macrotermitinae, Amitermitinae, Nasutitermitinae, and Termitinae) and 8 genera in the family Termitidae. Eighteen species were collected at the rainforest site in the Western Ghats region, 14 species were collected in the semimalnad habitat, and 9 species were collected in the maidan habitat. Species diversity indices were higher in the rainforest habitat than in either the semimalnad or the maidan habitat.

Of the 22 species, 6 (*Odontotermes adampurensis* Akhtar, *O. boveni* Thakur, *O. yadevi* Thakur, *Nasutitermes anamalaiensis* Snyder, *N. krishna* Bose, and *Grallatotermes grallatoriformis* Holmgren and Holmgren) were collected exclusively from the rainforest habitat, 2 species (*O. bhagwathi* Chatterji and Thakur, *Nasutitermes* sp.) were found only in the semimalnad habitat, and 2 species (*O. assmuthi* Holmgren and *Speculitermes sinhalensis* Roonwal and Sen-Sarma) were found only in the maidan habitat. Twelve species occurred in both the rainforest and the semimalnad habitats; seven species were common to both the rainforest and the maidan habitats, and seven species occurred in both the semimalnad and maidan habitats (Table 1). Forest areas are known to have a greater abundance of

Table 2. Relative abundance of termite species collected in a comparative study of three habitats of Shivamogga District, Karnataka, India, 2014–2015.

Subfamily/Species	Species Composition (%)		
	Rainforest	Semimalnad	Maidan
Subfamily Macrotermitinae	16.74	74.90	94.14
Odontotermes obesus	10.03	60.32	51.90
O. feae	0.95	1.01	35.65
O. anamallensis	1.19	4.65	0.00
O. bellahunisensis	2.01	5.00	0.00
O. adampurensis	0.17	0.00	0.00
O. boveni	0.34	0.00	0.00
O. horni	0.61	2.11	1.48
O. bhagwathi	0.00	0.21	0.00
O. assmuthi	0.00	0.00	1.28
O. yadevi	0.32	0.00	0.00
Odontotermes sp.	0.11	0.18	0.00
Microtermes obesi	1.01	1.42	3.83
Subfamily Amitermitinae	19.93	12.12	0.423
Microcerotermes pakistanicus	13.68	8.44	0.003
M. fletcheri	6.25	3.68	0.00
Speculitermes sinhalensis	0.00	0.00	0.42
Subfamily Nasutitermitinae	52.34	8.63	0.00
Nasutitermes anamallaiensis	11.40	0.00	0.00
N. indicola	39.21	8.05	0.00
N. krishna	0.32	0.00	0.00
Nasutitermes sp.	1.11	0.58	0.00
Grallatotermes grallatoriformis	0.32	0.00	0.00
Subfamily Termitinae	5.94	1.21	3.44
Pericapritermes sp.	3.42	0.10	3.00
Dicuspiditermes gravelyi	2.52	1.11	0.44
Unidentified workers	5.37	3.14	1.99

Table 3. Termite assemblage occurrence by month in a comparative study of three habitats of Shivamogga District, Karnataka, India, 2014–2015.

Month	Rainforest	Semimalnad	Maidan
September	*Odontotermes feae*	*O. horni*	*O. feae*
	O. obesus	*O. bellahunisensis*	*O. obesus*
	O. horni	*O. obesus*	*M. obesi*
	Microcerotermes pakistanicus	*O. anamallensis*	
	M. fletcheri	*Microtermes obesi*	
	Nasutitermes anamallaiensis	*M. pakistanicus*	
	N. indicola	*N. indicola*	
		Pericapritermes sp.	
October	*O. feae*	*O. horni*	*O. feae*
	O. obesus	*O. bellahunisensis*	*O. obesus*
	M. pakistanicus	*O. obesus*	
	M. fletcheri	*O. anamallensis*	
	N. indicola	*O. feae*	
		N. indicola	
November	*O. obesus*	*O. horni*	*O. feae*
	O. anamallensis	*O. bellahunisensis*	*O. obesus*
	O. boveni	*O. obesus*	*M. obesi*
	O. adampurensis	*O. anamallensis*	
	M. pakistanicus	*O. feae*	
	M. fletcheri	*M. pakistanicus*	
	N. anamallaiensis	*N. indicola*	
	N. indicola		
December	*O. bellahunisensis*	*O. horni*	*O. feae*
	O. obesus	*O. bellahunisensis*	*O. obesus*
	O. anamallensis	*O. obesus*	
	M. pakistanicus	*O. anamallensis*	
	N. anamallaiensis	*O. feae*	
	N. indicola	*M. obesi*	
	N. krishna	*M. pakistanicus*	

Table 3. Continued.

Month	Rainforest	Semimalnad	Maidan
	Grallatotermes grallatoriformis	*M. fletcheri*	
		N. indicola	
January	*O. obesus*	*O. horni*	*Odontotermes feae*
	O. horni	*O. bhagwathi*	*O. obesus*
	M. pakistanicus	*O. obesus*	*Pericapritermes* sp.
	M. fletcheri	*O. feae*	
	N. indicola	*M. fletcheri*	
		N. indicola	
February	*Odontotermes feae*	*O. horni*	*O. feae*
	O. obesus	*O. bhagwathi*	*O. obesus*
	M. pakistanicus	*O. obesus*	*Pericapritermes* sp.
	M. fletcheri	*O. feae*	
	N. anamallaiensis	*M. pakistanicus*	
	N. indicola	*M. fletcheri*	
		N. indicola	
March	*O. obesus*	*O. horni*	*O. assmuthi*
	M. pakistanicus	*O. obesus*	*O. horni*
		M. pakistanicus	*O. obesus*
		N. indicola	*M. fletcheri*
April	*O. obesus*	*O. horni*	*O. assmuthi*
	Odontotermes sp.	*O. obesus*	*M. fletcheri*
	M. fletcheri	*N. indicola*	*Dicuspiditermes gravelyi*
May	*Odontotermes* sp.	*O. horni*	*O. assmuthi*
	M. pakistanicus	*O. obesus*	*Speculitermes sinhalensis*
	N. anamallaiensis	*M. pakistanicus*	
June	*O. yadevi*	*O. bellahunisensis*	*O. assmuthi*
	M. pakistanicus	*O. obesus*	*O. horni*
	N. anamallaiensis	*Odontotermes* sp.	*O. feae*
		M. pakistanicus	
		N. indicola	

Table 3. Continued.

Month	Rainforest	Semimalnad	Maidan
July	*M. pakistanicus*	*O. bellahunisensis*	*O. assmuthi*
		O. obesus	*O. horni*
		M. pakistanicus	*M. fletcheri*
		Nasutitermes sp.	*S. sinhalensis*
August	*O. yadevi*	*O. obesus*	*O. assmuthi*
	M. pakistanicus	*Odontotermes* sp.	*O. feae*
	N. anamallaiensis	*M. obesi*	*M. obesi*
		M. pakistanicus	
		M. fletcheri	
		N. indicola	
		Nasutitermes sp.	

termite species as compared to plantations or other disturbed habitats (Shanbhag and Sundararaj 2013). Previous studies also have shown that termite diversity usually decreases following habitat conversion (Jones and Eggleton 2000, Luke et al. 2014).

Of the nine species from the maidan region, six are active foragers and five also occur in the semimalnad and rainforest zones, which are wood-destroying species that could reach pest status. The maidan zone is more disturbed by agricultural and human activity than the other two zones. It is, thus, not surprising that the disturbed maidan habitat had fewer species than the two relatively undisturbed habitats. Furthermore, the occurrence of the five species in all three habitats may indicate that these species are relatively resistant to, or at least adaptive to, anthropogenic activities. All five are wood-destroying species, which are reportedly more resilient to disturbance and habitat conversion than other soil-inhabiting fauna (Eggleton et al. 2002, Jones and Eggleton 2003). Less biomass of decomposing matter, leaf litter, and native flora may also negatively impact termite species diversity and abundance in the maidan habitats.

The semimalnad habitat, on the other hand, is one that is in transition from previously forested areas to agricultural production. The intermediate levels of termite species abundance and diversity in this habitat, in comparison to the other two habitats, clearly underscores the need for conservation efforts to preserve biodiversity and ecosystem health. This is also reflected in Basu et al. (1996) who reported 10 species collected from undisturbed forest habitats, 6 species collected from acacia plantations, and 4 from slightly disturbed forest habitats. Leaf and wood litter biomass is linked to termite diversity (Ali et al. 2013, Mugerwa et al. 2011). Changes in soil compaction and composition with disturbance are also likely to affect termite nesting and feeding negatively (Eggleton et al. 1997).

Of the four subfamilies represented in these collections, Nasutitermitinae dominated in the rainforest habitat, with 52.34% of the total collected, whereas, Macrotermitinae dominated the semimalnad (74.9%) and maidan (94.14%) habitats (Table 2). The abundance of Macrotermitinae in Western Ghats corroborates findings of Varma and Swaran (2007). In the rainforest of the Western Ghats, the most abundant species was *N. indicola* comprising 39.21% of the total collected (Table 2). Species of the *Nasutitermes* genus require moist environments and organically rich soils (Acda 2013), and, thus, the rainforest conditions support the occurrence of *Nasutitermes* spp. Other notable species were *Microcerotermes pakistanicus* Ahktar (13.68%), *N. anamallaiensis* (11.4%), and *O. obesus* Rambur (10.03%).

Odontotermes obesus (60.32%) was found to be the most abundant species in the semimalnad habitat, followed *M. pakistanicus* (8.44%), *N. indicola* (8.05%), and *O. bellahunisensis* Holmgren and Holmgren (5.0%). Similarly, *O. obesus* was also the dominant species in the maidan habitat, constituting 51.9% of the total collected.

Over the duration of the study, the maximum number of species collected in the rainforest habitat was collected in November and December (8), with the least number collected in July (1) (Table 3). *Microcerotermes pakistanicus, O. obesus, N. anamallaiensis*, and *O. boveni* were the most prevalent species over time, whereas *O. adampurensis* was collected only in November.

In the semimalnad habitat, the greatest number of species was collected in December (9) with the fewest collected in April and May (3). Here, *O. obesus* was the most prevalent species over time, followed by *N. indicola, M. pakistanicus*, and *O. horni* Wasmann. In the maidan area, four species were collected in March and July, with *O. feae* being the most frequently observed, followed by *O. obesus* and *O. assmuthi*. *Dicuspiditermes gravelyi* (Silvestri) was recorded only in April. The greatest number of species collected in maidan was in November (5), with the fewest collected in August (2).

Species diversity and richness varied across the three habitats. Shannon's diversity index (H) clearly showed that the rainforest habitat (1.62) was more diverse than the semimalnad (1.43) or the maidan (1.13) habitats. Simpson's diversity index also revealed a similar trend with a diversity value of 0.72 for the rainforest, 0.60 for the semimalnad habitat, and 0.58 in the maidan area. It is known that Simpson's diversity index is more weighted on dominant species compared to Shannon's diversity index. In order to get more reliable values, the use of both of the species richness indices can be justified, as there was a variation in species composition and also the dominant species recorded was different in the habitats selected. Results of Margalef's diversity index yielded 1.14 for the rainforest, 1.12 for the semimalnad site, and 0.79 for the maidan habitat. Menhinick's diversity index was 0.06 for the rainforest and semimalnad habitats and 0.05 for the maidan region. These indices further demonstrate that, as expected, species diversity and richness are greater in the rainforest of the Western Ghats than either the semimalnad or maidan habitats. Similarly, termite species were more evenly distributed in the rainforest (0.63) than in the semimalnad (0.56) and maidan (0.51) habitats (Table 4). We postulate that this can be attributed to the most termite assemblages having a more diverse range of food resources (e.g., wood, soil, and leaf litter) and nesting strategies (mound, arborial nests, and nests of wood) (Dawes 2010). Using Margalef's diversity index, Menhinick's diversity index, Shannon's diversity index,

Table 4. Measures of species diversity and richness in a comparative study of termite fauna in three habitats of Shivamogga District, Karnataka, India, 2014–2015.

Parameter	Rainforest	Semimalnad	Maidan
Total number of termites	38,331	46,227	24,170
Number of species	18	14	9
Shannon's diversity index (H)	1.62	1.43	1.13
Simpson's diversity index (D)	0.72	0.60	0.58
Evenness (E)	0.63	0.56	0.51
Margalef's diversity index (Dmg)	1.14	1.12	0.79
Menhinick's diversity index (Dmn)	0.06	0.06	0.05

and Simpson's diversity index, Shanbhag and Sundararaj (2013) found that forest habitats were more species rich and diverse than plantations,.

In conclusion, the results of our study, coupled with the results from previous studies, demonstrate that termite species diversity and abundance are linked to historical usage of the land and human activities that alter the landscape and the ecosystem. Land use patterns had an observable impact on the termite species composition and abundance, thus, indicating an overall negative impact on biodiversity and ecosystem health. Conservation efforts should be adopted and implemented to avoid habitat alteration and loss in the rainforests of Western Ghats.

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