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Quantitative characterization of a subtropical dry forest termite community (Isoptera: Kalotermitidae, Rhinotermitidae, Termitidae)

JOHN A. GENET,[1] KRISTEN S. GENET[1], THOMAS M. BURTON[1] & PETER G. MURPHY[2]

[1]Department of Zoology, [2]Department of Botany and Plant Pathology, Michigan State University, East Lansing, MI 48824, U.S.A.

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Given the variety of nesting locations (e.g., arboreal, epigeal, subterranean) and range of colony sizes exhibited by termites, a quantitative sampling scheme must incorporate multiple techniques in order to ascertain the abundance of all termite species in a particular area (Eggleton & Bignell 1995). A protocol for sampling the termite community of a subtropical dry forest is presented here. This protocol utilizes the colony as the sampling unit because, as a result of their reproductive division of labor, the effective population size of social insects is better represented by the abundance of colonies rather than the abundance of individuals. Previous studies investigating the abundance of termite colonies have been restricted to species that construct epigeal mounds (e.g., Redford 1984) or arboreal nests (e.g., McMahan 1996). Therefore, the main objective of this paper is to report the abundance of colonies for an assemblage of termite species with a variety of nest types. Colony densities for species belonging to the primitive family Kalotermitidae are presented here for the first time.

The majority of southwestern Puerto Rico is classified as subtropical dry forest life zone (*sensu* Holdridge 1967) by Ewel & Whitmore (1973). Annual precipitation in this life zone is seasonal and ranges from 600 mm in the west to 1000 mm in the east. Guánica Commonwealth Forest, situated within the center of the dry forest life zone, represents one of the best remaining examples of subtropical dry forest in the world (Murphy & Lugo 1990). It is comprised of three major intergrading plant associations: coastal scrub forest, deciduous forest and semievergreen forest. Deciduous and coastal scrub forest account for most forest cover, with semievergreen forests restricted to ravines and sinkholes (Lugo *et al.* 1978). Therefore, two deciduous-forest sites and one coastal-scrub site were selected in order to characterize termite communities in this subtropical dry forest. The two deciduous-forest sites differed in their history of human disturbance. One of the deciduous-forest sites is a mosaic of recovering and relatively unimpacted forest stands while the other site is located in an area that has received a minimal amount of human disturbance over the past 60 years.

This quantitative survey of the termites of Guánica Forest was conducted during the summer of 1997. Previous collections of termites from Puerto Rico (Jones & Scheffrahn, unpublished) documented 10 species (3 families, 8 genera) from the island's subtropical dry forest life zone. Due to the variability in size and location of the termite colonies found in this region, two sampling regimes

Correspondence to : Kristen S. Genet, Department of Zoology, 203 Natural Science Bldg., Michigan State University, East Lansing, MI 48824, U.S.A.; Tel : (517) 355-6474; Fax : (517) 432-2789.

were necessary to obtain accurate arboreal estimates of abundance. A belt transect method was used to quantify the abundance of arboreal colonies, while subterranean and drywood colonies were sampled using a quadrat method.

Nasutitermes costalis (Holmgren) and *N. acajutlae* (Holmgren) build large, conspicuous arboreal nests which have been estimated to contain up to several hundred thousand individuals (Clarke & Garraway 1994; Weigert 1970). In the subtropical dry forest life zone, *N. acajutlae* constructs ellipsoidal nests that are larger (some exceeding 1 m in height) and at a greater height above the ground than nests of *N. costalis* (Genet 1999). Both species were sampled using 100 m x 10 m belt transects. A colony was counted only if its primary nesting chamber was within the belt transect (e.g., foraging galleries within the belt transect did not constitute a colony).

The locations for establishing the belt transects were determined by randomly selecting points on a map within an arbitrarily delineated 1 km^2 representing the extent of each site. Using topographic maps the sites were stratified using four aspect categories (N-, S-, E-, W-facing slopes) and one category for ravine areas. The number of samples selected from each category was largely determined by the proportion of the total area that each category represented within the site. A total of six transects was established within each of the three sites.

The other termite species have less conspicuous nesting locations, such as within small pieces of wood or underneath rocks and logs. Colony abundance for these species was determined by exhaustively searching three 2 m x 2 m subplots randomly selected from within each of eight 10 m x 10 m plots. Six of the 10 m x 10 m plots coincided with the first 10 m segment of each belt transect, and two additional plots were established at randomly selected sampling points. All dead wood within a subplot, including standing dead wood and dead branches up to a height of 2 m, was dissected and searched in the field. The litter layer was then searched, and all rocks were cleared in order to locate subterranean nests.

Whenever possible, soldiers and winged reproductives (alates) were collected from each colony and field-preserved in 80% ethanol for later identification. One soldierless species (*Anoplotermes* sp.) was identified to genus using characteristics of the workers since alates were rarely found within the nest. Identifications were made using the taxonomic key of Snyder (1956).

Abundance estimates for each species are presented as colony densities (colonies ha^{-1}), not the number of individuals ha^{-1}. Certain assumptions were necessary in order to estimate the colony densities of subterranean species. For instance, termites belonging to the genus *Heterotermes* have foraging territories that likely extend 10 m or more from the nest (R. Scheffrahn, personal communication). If these species were detected multiple times within the same 10 m x 10 m plot, then these termites were considered foragers from the same colony, and only one colony was recorded for the entire plot. Thus, the results reported here represent conservative estimates for *Heterotermes* sp. colony density. The above assumption was not applied to the other subterranean species as nothing is known of the foraging territories for these species.

A total of eight species from seven genera and three families was encountered within Guánica Forest during this study. Two of these species (*Anoplotermes* sp. and *N. costalis*) were not detected by the sampling regime, but were collected opportunistically from Guánica Forest during this study. *Caribitermes discolor* (Banks), a species common to the moist and wet life zones of Puerto Rico, had not been previously documented from the island's subtropical dry forests. *Incisitermes incisus* (Silvestri) and *Neotermes mona* (Banks), although previously reported to occur in this region (Jones & Scheffrahn, unpublished), were not present in any of the samples and were not observed in Guánica Forest during this study.

In terms of colony density, *Procryptotermes corniceps* (Snyder) was the most abundant species at all three study sites (Table 1), however, the size of their colonies generally does not exceed a few thousand individuals (Genet 1999; Jones *et al.* 1995). Due to the inconspicuous location of its nests, concealed entirely within the wood on which it is feeding, the abundance of *P. corniceps* could easily be underestimated if a sampling design does not include methods which specifically focus on quantifying kalotermitid species. *Nasutitermes acajutlae* did not have colony densities greater than 10 ha^{-1} at any of the study sites (Table 1). These estimates are similar to the colony densities reported for *N. acajutlae*

Table 1. Mean termite densities (colonies ha^{-1}) at the three study sites within Guánica Forest.

Species	Nest Type[1]	Coastal Scrub	Deciduous Forest	
			Impacted	Unimpacted
Kalotermitidae				
Incisitermes bequaert (Snyder)	W	–	104.2	–
Procryptotermes corniceps (Snyder)	W	1041.7	2187.5	3437.5
Rhinotermitidae				
Heterotermes sp.[2]	S	12.5	12.5	12.5
Termitidae				
Caribitermes discolor (Banks)	S	–	–	208.3
Nasutitermes acajutlae (Holmgren)	A	4.8	4.8	9.7
Parvitermes wolcott (Snyder)	S	–	416.7	312.5

[1]W = colony entirely enclosed within wood, S = subterranean, A = arboreal.
[2]The taxonomy of this genus in the West Indies is currently unresolved (see Shreffrahn *et al.* 1994).

(0.47 ha^{-1}) and *N. costalis* (4.5 ha^{-1}) in the subtropical wet forest life zone at El Verde, Puerto Rico (McMahan 1996).

The sampling protocol used in this study represents a relatively rapid procedure for quantitatively characterizing termite communities. The average amount of time required to search a 2 m x 2 m subplot was 1.5 person-hours and it took a maximum of 2 person-hours to establish and sample belt transects in very dense underbrush. This protocol could also be supplemented with wooden baits or soil pits in order to better estimate the abundance of subterranean termites.

The quantitative assessment of termite communities requires sampling at multiple spatial scales in order to account for the diverse nesting behavior of multiple species. A sampling design which incorporated belt transects with nested subplots was used to quantify abundance of an assemblage of termites in a subtropical dry forest. This design coupled with modifications specific to the local termite community and habitat characteristics could be implemented to rapidly assess colony densities in other regions.

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