Distribution and density of *Cubitermes* Wasmann (Isoptera: Termitidae) mounds in the northern Kruger National Park

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Meyer, V.W., L.E.O. Braack and H.C. Biggs. 2000. Distribution and density of *Cubitermes* Wasmann (Isoptera: Termitidae) mounds in the northern Kruger National Park. *Koedoe* 43(1): 57–65. Pretoria. ISSN 0075-6458.

This paper provides fundamental information on distribution and density of the genus *Cubitermes*, Wasm. quantified for future monitoring. After distribution trends have been established, changes in *Cubitermes* density over time can be brought into contention with other factors in the Kruger National Park, such as the impact of fire frequency, water distribution, and elephant density on these insects. At least ten 2 ha belt-transects were undertaken in each of the 20 northern landscape zones of the KNP. Termite mounds were recorded and their activity within was determined. *Cubitermes* accounts for 29.8% of all active termite mounds in the northern KNP, with an average density of 0.33 mounds/ha. *Cubitermes* favours the Nwambiya Sandveld (zone 32). These termites occur in high density in the Klipkoppies 1 land type (Gorge), but in low densities in the Phalaborwa 10–12, Bulweni 1–3, Letaba 1–7 and Pafuri 3–6 land types. *Cubitermes* mounds tend to occur in high numbers on the Nzhelele formation (Mn) (sandstones; quartzite; basalt). Mounds of this genus in the Far North are highly concentrated on the Gaudam and Moriah soil series of the Hutton form, suggesting that these termites prefer very sandy soils with medium to coarse particles.

Key words: termite mounds, Isoptera, Termitidae, Termitinae, *Cubitermes*, Kruger National Park.

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Introduction

Termites are pivotal in nutrient cycling and decomposition (e.g. Pomeroy 1978; Lamotte & Bourlière 1983; Nkunika 1986; Nutting *et al.* 1987; Martius 1994). A clear account of what is and isn't known in the Kruger National Park (KNP) regarding these insects was previously given (Meyer *et al.* 1999).

The distribution and density of *Macrotermes* Holmgren and *Cubitermes* Wasmann populations were determined as part of a broader programme to monitor the influence of fire (Braack *et al.* 1997), water (Pienaar *et al.* 1997) and elephant (Whyte *et al.* 1997) on biodiversity in the KNP (Intermediate Disturbance Hypothesis). Fire management policy in this wildlife sanctuary has moved from a rigidly-applied triennial burn of all *ca.* 400 land-blocks (making up the roughly two million hectare KNP) during the 1950s to 1970s to a more natural lightning-induced fire policy that has been followed in recent years. Basic information on the impact of these burn applications, as well as other experimental fire, water and indirect stocking regimes on termites, vegetation, reptiles and other organisms is required in order to monitor changes in population structure (e.g. juvenile:adult and male:female ratios coupled with fecundity) and hence abundance (density) of these ecosystem components.

Elephant impact in the KNP, especially in high density zones such as the area roughly occupied between the Olifants and Mooiplaas rest camps across the width of the park, may influence the termite community.

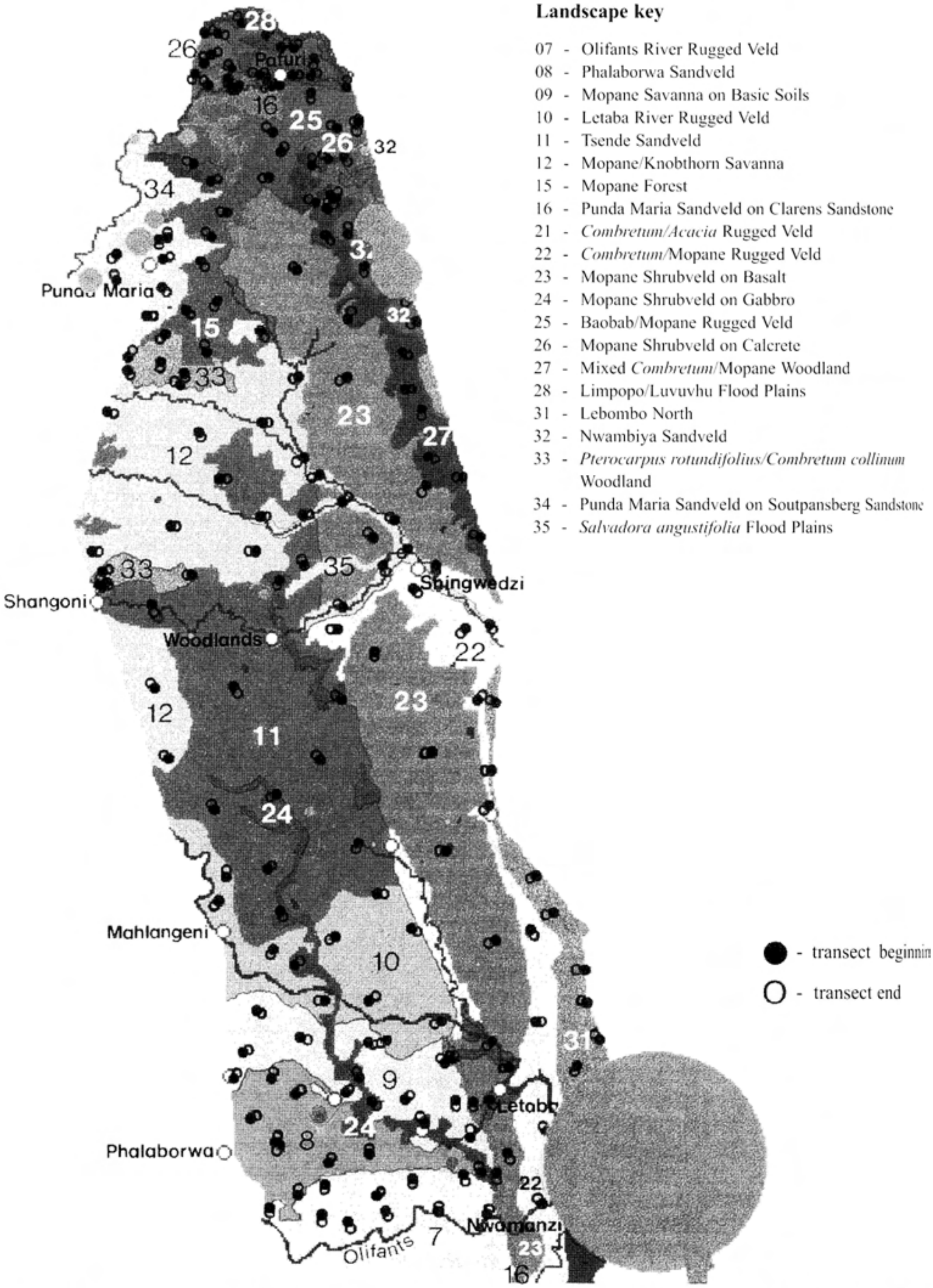

Fig. 1. Distribution and abundance of active *Cubitermes* Wasmann mounds, overlaid on landscapes of the northern Kruger National Park (based on transect plots). (The bigger the discs, the larger the depicted abundance; especially note highly clumped densities in zones 31 and 32; paired filled and unfilled circles denote transects.) [A colour image, for enhanced viewing, is available at http://hammer.prohosting.com/~victorm/cub_map.htm]

Elephants bring down branches from the tree canopy adding litter to the veld, while their faeces supplement the detritus reservoir. Species of *Macrotermes* are responsible for fragmentation of the litter (wood), while *Cubitermes* species are geophagous (soil-feeding) on the detritus and humus in the topsoil (Ferrar 1982a; Nkunika 1986; Fraser 1993). *Macrotermes* may also utilise dry dung of other herbivores as food (Wood 1978; Nkunika 1986; Fraser 1993). Increased dung surrounding artificial water-holes, due to the aggregation of herds, may patchily increase termite density. Termite activity in turn improves the compacted soil by aeration (Sands 1965). The important role that termites play as prime movers of organic content into foci should be recognised (Trapnell *et al.* 1976; Okwakol 1980).

The present study on *Cubitermes* was undertaken concurrently with a similar study on *Macrotermes* (Meyer *et al.* 1999) to improve insight and understanding of the overall distribution and density of mound-building termites in the northern KNP. Species of *Cubitermes* construct small, columnar domes with a porous appearance (Meyer 1997), while *Macrotermes* species generally have large cones (Coaton & Sheasby 1972; Nkunika 1986). Subsoil is used for mound construction (Hesse 1955; Bodot 1967; Coaton & Sheasby 1972; Pomeroy 1976). Inactive *Cubitermes* mounds when crushed are used by some people of rural Giyani (outside the KNP) to reinforce their mud floors (Z.D. Mhlongo, field assistant and local resident *pers. comm.*). *Cubitermes* is the second-most abundant mound-building genus in the northern KNP, constituting almost 30 % of the total mound-building termite assemblage in the area (Meyer *et al.* 1999).

Traditionally, conservation policies focussed mainly on the mammal community because of its high visibility, tourism value, and the potential of some species to drastically alter local habitats. Establishment of data as basis for monitoring invertebrates was hitherto poorly prioritised. The purpose of this study was to determine the distribution and density of the genus *Cubitermes* in the KNP, while other studies addressed *Cubitermes* dynamics elsewhere (e.g. Ferrar 1982b; Benzie 1985; Bignell *et al.* 1991). We conducted this study to establish baseline data for monitoring purposes.

Methods

Study area

The northern KNP (also referred to as the 'North') makes up approximately 981 000 ha (*ca.* 52 %) of the park, and is located between 22°19'21"S and 24°02'30"S (Meyer 1997; Meyer *et al.* 1999). The vegetation is characterised by the pod-bearing *Colophospermum mopane* (Fabaceae: Caesalpinioideae) (Acocks 1988; Coates Palgrave 1988). The area has a mean annual rainfall of approximately 500 mm and an average elevation of 375 m (Dent *et al.* 1987).

In this study, we used the following land classifications of the KNP: landscapes (Gertenbach 1983), land types (Venter 1990), geology (Geological Survey 1981, 1985), and soil types (Harmse *et al.* 1973). Landscapes are based on associations of geomorphology, soil, vegetation patterns, fauna and climate. Land types are areas having a distinctive hillslope profile (consisting of land units, e.g. crest, scarp, midslope, footslope, and valley bottom) with their own characteristic morphometric, soil and vegetation variables. Geology (a national classification) denotes the rock types of the different geological formations. Soil types are only for the area north of 23°15'S (*ca.* 6.4 km south of Shangoni), referred to as the 'Far North'. This classification is based on the binomial system (form–series) (Soil Classification Working Group 1988), as opposed to the taxonomic system (form–family) (Soil Classification Working Group 1991) of South Africa.

Sampling

Cubitermes mounds were systematically surveyed during 1995, in 206 belt-transects of 1 km x 20 m (i.e. 2 ha strips) in different directions across the study area (Fig. 1). Transects were evenly and widely located across each landscape, with no bias towards a particular landscape (equivalent number of transects in each landscape, independent of its area). Approximate transect localities were mapped out before entering an area so as to avoid bias. A major factor affecting transect placement was practicality, i.e. transects had to be accessible from roads and firebreaks. Transects started approximately 30 m

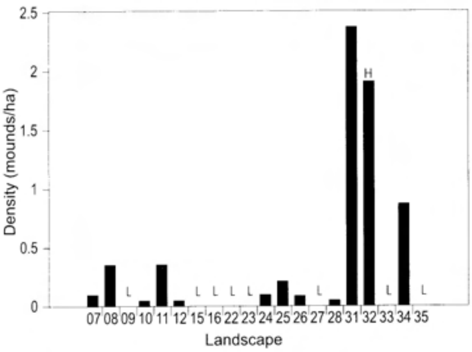

Fig. 2. Density of active *Cubitermes* mounds in different landscapes of the northern KNP. (Statistically significant high and low ranks are respectively annotated with 'H' and 'L'.)

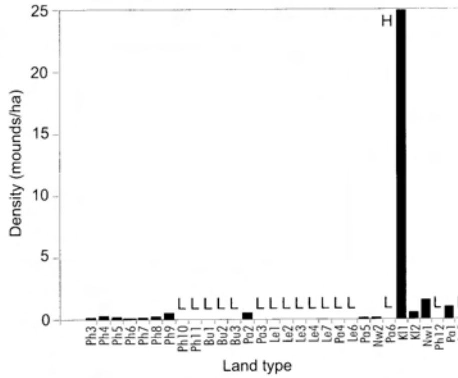

Fig. 3. Density of active *Cubitermes* mounds in different land types of the northern KNP. (Statistically significant high and low ranks are respectively annotated with 'H' and 'L'.)

from roads to exclude possible disturbed areas, since roadside banks were sometimes preferred sites for mounds (Pomeroy 1977). For soil types of the Far North, 97 transects occupied the zonated area.

The total number of mounds on each transect was recorded, and each mound's termite activity was confirmed by exposing its interior. Species-level identifications could not be carried out, as the genus *Cubitermes* requires taxonomic revision. The number of mounds in the entire study area was estimated by weighting the number of mounds by the area they occupied. For comparison, a non-weighted procedure was also carried out.

Analysis

The effect of different land classifications on mound density was assessed by Kruskal-Wallis one-way ANOVA (analysis of variance by ranks), and subsequent Dunn multiple comparison analysis (Zar 1996). The Dunn analysis makes provision for experimental groups (i.e. zones or types) with unequal sample sizes to be compared. Bonferroni adjustment to significance levels was applied when multiple testing was carried out on the same data (Johnson & Wichern 1992).

Results and discussion

Weighted and non-weighted density estimates of active *Cubitermes* mounds in the northern KNP are 0.33 mounds/ha (33/km^2) and 0.35/ha (35/km^2), respectively.

The Kruskal-Wallis tests revealed significant differences in *Cubitermes* mound counts between landscapes (H = 64.2; P < 0.0001; n = 206; k = 20), land types (H = 65.4; P < 0.001; n = 206; k = 30), geology (H = 43.3; P < 0.01; n = 206; k = 17) and soil types (H = 58.3; P < 0.05; n = 97; k = 37). The Dunn test has not revealed extra significant differences (internally) for active and inactive mound counts between the respective zonations. Significantly low counts were ties.

Landscapes

The H_0 was rejected for high-ranking landscape zone 32 against the low-ranking zones 9, 15, 16, 22, 23, 27, 33 and 35 (Fig. 2). (Zone 31's mound density was not significantly different from the lowest ranking densities.) Landscape zones 22, 23 and 27 have basaltic soils. The Lebombo foothills of landscape 22 are sodium-enriched, while zone 27 has a mixture of sand and gravel. Landscape 9 has a mixture of amphibolite, granite, gneiss, gabbro and dolerite. Amphibolite weathering generally leads to loamy clay soils, while gabbro produces highly clay soils. The Ecca shales of zone 15 produce medium clay soils with a high salt content (especially sodium). Andesite, tuff, schist and amphibolite give rise to clay loam soils in zone 33.

Land types

This classification system revealed that *Cubitermes* mounds occur in high densities in the Gorge land type (Kl1), but are low in density in the Phalaborwa land types (Ph10–12), the Bulweni land types (Bu1–3), the Letaba land types (Le1–7), and the Pafuri land types (Pa3–6) (Fig. 3). When these areas are compared to landscapes (Fig. 1), Kl1 concurs with the area of zone 31 directly east of Olifants camp, whereas Ph10–12 roughly correspond to zones 12 and 33, Bu1–3 to zones 15 (southern part) and 16 (southern intrusion), Le1–7 to zones 22, 23 and 24, and Pa3–6 to zones 15 and 16 (northern parts), as well as to 25, 26, 28 and 34.

Geology

Cubitermes mounds tend to occur in high numbers on the Nzhelele formation (Mn) (sandstones; quartzite; basalt), but in low numbers on the Gravelotte group (Zgx) (metalava; amphibolite; schist), the Letaba formation (Jl) (basalt; limburgite), the Sibasa formation (Ms) (basalt), the Fundudzi formation (Mf) (sandstones; conglomerate; shales; basalt), the Clarens formation (Tr) (sandstone; siltstone; grit; conglomerate), the Malvernia formation (K) (conglomerate; sandstone; limestone; marl), as well as on Timbavati gabbro (Nt) and the Giyani group (Zya) (schist; amphibolite) (Fig. 4). (Mound densities for the Jozini (Jj) and Wyllies Poort (Mw) formations were not significantly different from the geology types with low mound density.)

Soil types

Mounds of *Cubitermes* are highly concentrated on the G4 soil type (Fig. 5). (G2 counts were not significantly different from the lowest ranking counts.) The G4 soil type comprises a specific area of the Nwambiya Sandveld (landscape 32), and represents the Gaudam soil series as dominant and the Moriah series as sub-dominant (Table 1). Both are classified under the Hutton soil form, which has orthic A (topsoil: 0–30 cm) and red apedal B (subsoil: 30–130+ cm) horizons, free of definite structure and waterlogging, with a low clay-forming potential. Hutton series occur across South Africa under various climatic conditions (Soil Classification Working Group 1988).

General

The slightly higher results produced by the non-weighted procedure might be regarded as an overestimation, since proportions of areas were not considered. Because inactive mounds are indicators of historic termite density, they could enhance the results gained from active mounds (current density). However, no significant differences were detected for any land classification between high and low inactive mound counts. It must be mentioned that the significantly low

Table 1

Properties of the Gaudam and Moriah soil series of the Hutton form[a]

Eutrophic in B21[b] horizon (non-calcareous)	Predominant sand grade of B21[b] horizon (grades: coarse; medium; fine)	Clay content of B21[b] horizon (clay particle < 0.002 mm)
Gaudam	Medium (0.5–0.2 mm)	0–6%
Moriah	Coarse (2.0–0.5 mm)	0–6%

[a] Compiled from Soil Classification Working Group (1988).

[b] Upper layer of typical B2, below transitional B1 (BA); accumulating leached chemicals from A through illuviation (e.g. Plaster 1985).

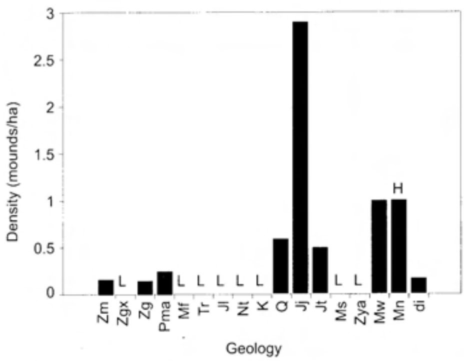

Fig. 4. Density of active *Cubitermes* mounds based on geology of the northern KNP. (Statistically significant high and low ranks are respectively annotated with 'H' and 'L'.)

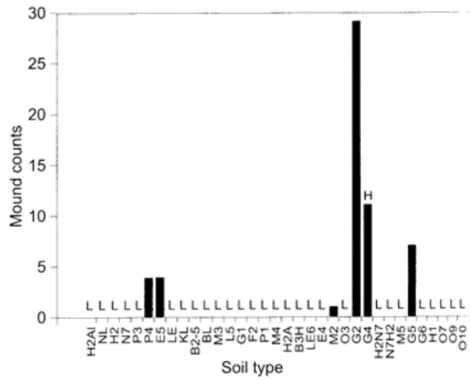

Fig. 5. Number of active *Cubitermes* mounds sampled on different soil types of the far northern KNP (Statistically significant high and low ranks are respectively annotated with 'H' and 'L'.)

mound densities are zeros, and that one or two Type I errors may be expected due to multiple testing at the 95 % confidence level.

Because *Cubitermes* is geophagous, the expectation is that they will be distributed in relation to soil type. A possible reason why higher significance with respect to mound density was obtained for geology ($P < 0.01$) than for soil ($P < 0.05$), may be due to the fact that a variety of soils tend to form from similar parent material (J.A. Holt, Principal Research Scientist, CSIRO Land and Water, Australia *pers. comm.*). An increase in variability is thus obtained with regards to soil ($k = 37$), but not geology ($k = 17$). Hence the reduced significance for soils. Furthermore, soils were only tested for the transects situated in the Far North, thereby limiting the analyses for soil types ($n = 97$) more than for geology ($n = 206$). Similarly, because there are fewer landscapes ($k = 20$) in the area studied than land types ($k = 30$), a decrease in variability and higher significance may be expected for landscapes ($P < 0.0001$) than for land types ($P < 0.001$).

The fact that the landscape and geology analyses did not reveal significantly high-ranking mound density for the Lebombo North (zone 31) and the Jozini formation (Jj), which appeared to be high (Figs. 2 & 4), may be attributed to high variation around the mean. The Kl1 land type (Gorge) (Fig. 3), however, a peculiar area better defined individually, allowed the detection of significantly high density. The large remainder of the Lebombo North (i.e. Klipkoppies) is therefore not preferred by *Cubitermes*. This is possibly because of granophyre intrusions from the late Tertiary and Quaternary periods occurring in the Gorge, which are similar in age to the sand deposits of landscape zone 32. Klipkoppies (Kl2) mainly has rhyolite and dacite (Venter 1990).

No clear correlations could be found to explain mound density in the low-ranking landscapes. However, it does appear as if the deep and sandy soils of the Nwambiya Sandveld (zone 32) (Fig. 2) are favoured by species of *Cubitermes*. The G4 soil type (Fig. 5), supporting significantly high density of mounds, confirms this. (Due to a high variance, G2's density was not significantly different from other densities.) It also appears that species of *Cubitermes* do not occur in high densities if the soil contains high concentrations of salts, especially sodium salts. This is reflected by their low occurrence in landscape zones 15 (Mopane Forest), 22 (*Combretum*/Mopane Rugged Veld) and 35 (*Salvadora* Flood Plains) (Fig. 2), being brackish at places and having a high salt (esp. Na) content (Gertenbach

1983). No termites were found by Josens (1983) on halomorphic (brackish) soils (neutral and/or alkali salts present). Sands (1965) found species of *Cubitermes* dominating 'shallow grey soils overlying the ironstone crust'. However, we found no *Cubitermes* mounds (except for one case of co-inhabitance with *Macrotermes*) in landscape 33, where banded ironstone occurs (Gertenbach 1983).

From our geostatistical analysis, based on the classification of Harmse *et al.* (1973) and Soil Classification Working Group (1988), we conclude that species of *Cubitermes* prefer very sandy soils (containing less than 10 % clay), having medium to coarse particles (Table 1). It was stated in Meyer *et al.* (1999) that 'coarse-textured soils containing little silt and clay are unsuitable for mound construction'. This mainly refers to the wood-feeding *Macrotermes* species, as the detritus and humus-consuming *Cubitermes* species construct their mounds with an excreted paste (Ferrar 1982a; Josens 1983; Fraser 1993; Meyer 1997; Holt *pers. comm.*). In further support of this, *Cubitermes* mounds in Nigeria had higher sand and silt composition, but lower clay content and penetration resistance than *Macrotermes* mounds (Maduakor *et al.* 1995).

The eastern basaltic areas of the northern KNP (mainly landscapes 22 and 23) are contrasted with the well-drained areas of the western granitic landscapes (Fig. 1). Areas with impeded drainage, either because of waterlogged soils (e.g. montmorillonitic clay of zone 23) or because of little surface run-off due to topography (e.g. concave flood plains of zone 35), support low termite abundance (Meyer *et al.* 1999).

The Northern Botanical Reserve (Zambatis *et al.* 1997) (occupying most of the Far North) includes a high density zone for *Cubitermes* (i.e. Nwambiya Sandveld). The Nwambiya Sandveld and the K11 land type (Gorge) are two of a series of pristine wilderness areas officially acknowledged by the KNP management as the purest form of wilderness since the mid 1970s (Venter *et al.* 1997). Density and distribution of termites in these zones should be monitored and compared with that in other zones of the KNP, where different management practices are implemented (especially fire frequency and elephant population density), so as to determine the long-term impact of such management practices.

Although landscapes were the *a priori* functional units for this study, overlaid termite data onto various other zonation classifications (i.e. land types, geology, soil types) in comparison with each other overall proved that *Cubitermes* abundance could be better explained by soil type than any other characteristic of the ecosystem, with the exception of landscape morphometry. In light of this, detailed local soil classing and subsetting should be carried out and future surveys should include simple soil tests at various sections of the transects, as well as records of the terrain morphological units (crest, valley bottom, etc.). Total soluble salt (TSS) concentrations should also be determined. Successive studies could thus be used for monitoring, proposed with 5–10 year intervals. Moreover, determination of population numbers within mounds, their biomass and consumption, will provide improved insight of the ecological role and impact of these insects within the Kruger National Park. The main objective of the KNP mission statement is 'to maintain biodiversity in all its natural facets and fluxes' (Pienaar *et al.* 1997). After prolonged monitoring, thresholds of potential concern (TPCs) (e.g. Whyte *et al.* 1997) can be determined for the Isoptera too, by so doing ensuring their survival from genes to landscapes (Noss 1990) in an ever-changing biosphere.

Acknowledgements

We gratefully thank Dr Colleen Ebersohn, Vivienne Uys, Dr Freek Venter, Dr John Holt, Dr Rina Grant, Naledi Maré, Colleen Wood, Danie Krynauw, Petri Viljoen, Naciosse Baloyi, Alfred Nkuna, Richard Mashabane and Zama Mhlongo for their advice and assistance. The South African National Parks and

Technikon Pretoria provided logistical support and the Plant Protection Research Institute identified the specimens. The Foundation for Research Development is acknowledged for funding, while Towmaster is thanked for a donation of front protection bars on the research vehicle and Pertec International for the loan of a GPS.

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