STUDIES ON POPULATIONS AND FEEDING HABITS OF TRINSRVITERMSS GEHINATUS (WASMANN), (ISOFTERA) AND ITS SIGNIFICANCE IN PASTURES IN THE SOUTHERN GUINEA SAVANNA ZONE OF NIGERIA

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ABSTRACT

The main objective of this study was to assess the damage to grazed pastures in the Mokwa area of the Southern Guinea savanna zone of Nigeria by Trinervitermes geminatus (Wasmann) (Isoptera, Termitidae, Nasutitermitinae) and to determine its role as a competitor with grazing livestock. In Nigeria, T. geminatus is the only species which cuts down standing grass and at the same time is sufficiently abundant to be considered a potential threat.

T. geminatus builds domed-shaped mounds which are highly aggregated and serve as breeding and storage sites. Some of these mounds are subsequently abandoned and are either eroded away or are reoccupied by the non-mound building species of the same genus or other termites notably Cubitermes sp., Promirotermes sp. and Microtermes spp. During the rainy season, new mounds are constructed and old mounds are enlarged.

Population density of T. geminatus was estimated in grazed and ungrazed areas of a secondary woodland, as well as in a primary savanna woodland. Populations were low (203/m ; 232 mounds/ha) in the areas of study and seasonal fluctuations in them were indicated. Decrease in population during the dry season, coincided with the period of active foraging and intense predation, and they increased during the rains. Following the flight of alates in July/August, populations again declined.

The foraging habits of T. geminatus and the quantity of grass removed were investigated. Foraging in the Mokwa area was in early morning or late afternoon and lasted about 2-3 hours. It was greatly influenced by environmental factors such as rain, soil surface temperatures and relative humidity. Grass production was estimated at approximately 3000 kg/ha/annum, and of this quantity cattle consumed approximately half the annual prod-

uction 48%).

A method was developed for quantifying the amount of grass harvested by T. geminatus, and following this method, the quantity of grass removed by this species was estimated as representing 3.5% of the total annual grass production. Therefore, the quantity of grass removed and hence made unavailable for cattle consumption was insignificant in this locality. Although, field and laboratory investigations on the choice of grass indicated a strong preference by T. geminatus for Andropogon gayanus, a grass species equally preferred by cattle, they hardly competed for it in the Mokwa area. It is however suggested that the impact of grass harvesting by T. geminatus would be relatively greater in areas with high populations of termites and in overgrazed pastures especially during periods of drought when grass production is lowered by poor management or low rainfall.

TABLE OF CONTENTS

	Page
ABSTRACT	2
INTRODUCTION	8
SECTION I. GENERAL DESCRIPTION OF THE BIOLOGY OF TRINERVITERMES SPP.	9
1. Distribution of Trinervitermes and other grass-eating termites	10
2. Species, nest building and size distribution of mounds ...	12
3. Mound density and population	14
4. Grass harvesting and storage	15
5. Damage to pastures	16
SECTION II. STUDY SITE, VEGETATION ANALYSIS, ABUNDANCE AND SPATIAL DISTRIBUTION OF MOUNDS	19
1. Materials and methods	20
1.1 Study site, history, climate and soil	20
1.2 Experimental layout	23
1.3 Botanical analysis of experimental area	26
1.4 Grass production measurements	26
1.5 Abundance and spatial distribution of T. geminatus mounds	28
1.6 Number of mounds/colony	28
1.7 Plant tissue analysis of stored grass in mounds, standing grass and grass litter	30
2. Results	31
2.1 Botanical analysis of study area	31
2.2 Measurement of standing grass biomass, litter biomass, rate of decomposition	31

		Page
2.3	Abundance of mounds	33
2.4	Mortality loss and recruitment of mounds	39
2.5	Enlargement of old mounds	40
2.6	Spatial distribution of mounds	40
	2.6.1 Frequency and size distribution of mounds ...	42
	2.6.2 Number of mounds/colony	46
	2.6.3 Results of field observation on surface area occupied by T. geminatus	49
2.7	Relationship between nest size and quantity of food stored	49
	2.7.1 Percentage of larvae and quantity of food stored	50
	2.7.2 Quantity of food stored in mounds at study site	52
2.8	Nutrient composition in mound stored grass, standing grass and grass litter	52
3.	Discussion	57
SECTION III.	MOUND POPULATION ESTIMATES OF T. GEMINATUS	62
1.	Materials and methods	63
1.1	Whole mound sampling	63
1.2	Mound core sampling	63
1.3	Extraction of termites	64
	1.3.1 Heat extraction	64
	1.3.2 Manual extraction	64
1.4	Determination of the number of termites/mound ...	64
	1.4.1 Determination of the proportion of each caste in total population	65
1.5	Colony development in T. geminatus	65

	Page
2. Results	68
2.1 Correlating nest size and numbers	68
2.2 Percentage of caste composition at different sampling periods	76
2.3 Timing of major events during colony development ...	79
2.4 Numbers, biomass of caste in mound population ...	81
2.4.1 Estimation of potential production in T. geminatus	83
2.4.2 Production/biomass ratio in T. geminatus ...	84
3. Discussion	85
SECTION IV. FORAGING AND GRASS CONSUMPTION	89
1. Materials and methods	90
1.1 Laboratory food preference studies	90
1.2 Measurement of amount of grass harvested and carried back to the nest	90
1.2.1 Measurement of grass cut down but left as litter	93
1.2.2 Measurement of the amount of grass consumed while foraging	95
1.3 Age determination in the worker caste	95
1.3.1 Measurement of the head width and apical tooth of grass carriers and grass cutting workers	96
1.4 Relating foraging cycle to subsoil and soil surface temperatures	96
2. Results	98
2.1 General observations on foraging behaviour	98
2.2 Field observation on food selection	100

		Page
2.3	Reaction to disturbance	100
2.4	Laboratory choice experiments	101
2.5	Monitoring the activity of various categories of workers in a foraging party	107
2.6	Age determination in grass and non-grass carrying workers	114
2.6.1	Head width and apical tooth measurements of grass carrying and grass cutting workers ...	114
2.7	Harvesting rates and quantity carried back to the nest	116
2.7.1	Quantity of grass cut down and left as litter	126
2.7.2	Quantity of food ingested while foraging ...	128
2.8	Relating foraging cycle to subsoil and soil surface temperatures	133
2.8.1	Foraging frequency at different soil surface temperatures (Morning and Evening activity) .	137
2.8.2	Differences between nest temperature and soil surface temperature and how these affected daily foraging pattern	137
2.8.3	Relative humidity and effect on foraging ...	142
3.	Discussion	145
GENERAL DISCUSSION		149
SUMMARY AND CONCLUSIONS		156
ACKNOWLEDGEMENTS		165
REFERENCES		167
APPENDICES		178

INTRODUCTION

Damage to pastures by grass harvesting termites and probable competition with grazing livestock has never been assessed in Nigeria. Such an assessment was made possible with the establishment of a Termite Research Project, based at Mokwa in the Southern Guinea savanna zone of Nigeria, and jointly financed by the Overseas Development Ministry in the United Kingdom and the Institute for Agricultural Research of the Ahmadu Bello University, Zaria, Nigeria.

The overall aim of the termite project was to study termite populations in crops and pastures, with a view to assessing their status as pests. The aim of this particular study, was to investigate the role played by the grass harvesting termite T. geminatus (Wasmann) (Isoptera, Termitidae, Nasutitermitinae) in grazed pastures.

The work principally involved measuring population density, seasonal foraging activity and harvesting rates of T. geminatus with a view to assessing its significance in the pasture ecosystem, and in particular its role as a competitor with grazing livestock.

SECTION I. GENERAL DESCRIPTION OF THE BIOLOGY OF TRINERVITERMES SPP.

1. Distribution of Trinervitermes and other grass-eating termites

In tropical and subtropical grasslands, and savanna woodlands, grass-eating termites are abundant and widely distributed. In Africa, the most common and widely distributed grass eating termites are various species of Hodotermes, Microhodotermes and Trinervitermes, together with certain Macrotermitinae such as Macrotermes sp. and Odontotermes sp. (Naude, 1934; Emerson, 1938; Coaton, 1951, 1954; Anon., 1960; Sands, 1961; Hartwig, 1955, 1966 and Harris, 1961).

In Australia similar grass-eating termites abound, such as species of Amitermes and Drepanotermes, some Nasutitermitinae, such as Nasutitermes and Tumulitermes and Schedorhinotermes (Saunders, 1969; Watson & Gay, 1970; Wood & Lee, 1971). In Central Asia and the Indian subcontinent some species of Anancathotermes eat grass while in the semi arid grasslands of the South Western United States and in South America, Gnathamitermes and Syntermes, fall within the category of grass harvesters (Harris, 1961; Bilova, 1949; Luppova, 1958; Weesner, 1970; Bodine & Ueckert, 1975).

In West Africa several species of Trinervitermes occur with T. geminatus as the most abundant in some areas (Sands, 1965). The range extends from the near coastal forest savanna mosaic to the sub-desert steppe around 10°-12°N (Sands, 1965a).

In Nigeria, Sands (1961) identified five species which were widely distributed. Their distribution extends from North of the rain forest into neighbouring countries to latitude 15-16°N (Sands, 1965a). Other grass eating termites such as Macrotermes subhyalinus (Rambur) occurs throughout various savanna regions northwards to the borders of the Sahara desert (Ruelle, 1970) and various species of Odontotermes are present throughout the country (Sands, unpublished data).

In spite of the wide distribution of Trinervitermes and other grass eating termites in Nigeria, there has been little information on their local distribution in relation to soils and vegetation. Sands quotes Kemp (1955) as studying the distribution of termites in relation to vegetation zones and soil condition in Tanzania, and Harris (1963) made analysis of termite numbers found in soil cores from various vegetation types in the Congo.

A brief survey of parts of North West, North Central and Kano States of Nigeria, by the Termite Research Team, indicated a close relationship between soil type and distribution of Trinervitermes sp. (Wood & Ohiagu, 1975). In areas surveyed, the majority of soils were derived either from rocks of the basement complex or from sandy aeolic sediments interspersed with aqueous deposits along river valleys. In the Rima-Sokoto river basin, the deposits were of fine-sand texture (Sombroek & Zonneveld, 1971), 1 metre to several metres deep. In the areas surveyed there were vast portions where Trinervitermes did not occur, possibly because these soils did not favour mound building.

Macrotermes spp. on the other hand occurred throughout this area and constructed large mounds. Trinervitermes spp. were only found sparsely distributed in areas where erosion had stripped off much of the sand cover, on certain loamy terrace deposits and to some extent on the Sangiwa cover sand deposits, which were relatively poorly sorted and contained significant amounts of silts (6%) and clay (8%) (Sombroek & Zonneveld, 1971). In contrast, soils developed on the basement complex supported large numbers of Trinervitermes mounds. This contrast was readily seen on the Sokoto-Zaria road a few miles South West of Talata Mafara, where the landscape changed from the flat depositional basin with few or no Trinervitermes mounds to more undulating country of the basement complex where Triner-

vitermes mounds were abundant. Both Odontotermes spp. and Macrotermes subhyalinus were evident in all the areas. Wood and Lee (1971) noted that the distribution of Amitermes vitiosus in Northern Australia was related to soil texture, more abundant mounds being built in areas of increasing clay proportion, as against less abundant mounds in sandy or sandy loam soils.

Similar relationship of soil structure and abundance of large mounds of Macrotermitinae was noticed in the Congo by Sys (1955) and Meyer (1960).

In relation to vegetation, the abundance and distribution of termite mounds has been noted by several workers. Vegetation not only provides the source of food, but also has an important impact through its effect on the amount and distribution of shade (Lee & Wood, 1971). Calaby and Gay (1956), observed that the distribution of Coptotermes acinaciformis followed closely the distribution of Eucalyptus sp. which provided shade. Sands (1965a) studied the abundance and distribution of termite mounds in relation to vegetation in Northern Nigeria and noted that T. geminatus built 90% of all its nests in fully exposed sites while 75% of the mounds of T. oeconomus and T. occidentalis were found in shaded areas. Wood and Lee (1971) showed that mound building Amitermes lauvensis in Australia, built most mounds in completely and heavily grazed areas (210-268 mounds/ha), where less number of mounds were built in undisturbed (28-58 mounds/ha) and highly grazed (142-154 mounds/ha) savanna woodlands.

2. Species, nest building and size distribution of mounds

The genus Trinervitermes belongs to the subfamily Nasutitermitinae in which the head capsule of the soldier caste has been modified into a tube and the mandibles greatly reduced or atrophied. The five species which occur in Nigeria are present in the Nokwa area, and are as follows:

T. geminatus (Wasmann)

T. occidentalis (Sjostedt)

T. oeconomus (Tragardh)

T. togoensis (Sjostedt)

T. trinervius (Rambur)

Their nest building, structure and size distribution were studied by Sands (1961a, 1961b, 1965a, 1965b). T. geminatus T. trinervius and T. oeconomus build low domed shaped mounds. On the other hand, T. togoensis and T. occidentalis do not build mounds of their own but occupy abandoned mounds of other species. Mound building commences after a rain (Plate 3) or shower enough to soak the soil, or else if the subsoil is moist, building could commence. Old and abandoned mounds are subject to erosion and new mounds are recruited during the rainy season. The rate at which mounds are eroded and replaced must be of pedological importance (Lee & Wood, 1971). The internal structure of the mound consists of a frame work of curving floors and pillars (Sands, 1961) which are lined with black or brown faecal material. The genus is polycalic, each colony consisting of several mounds which vary from large sized mounds used for breeding and other smaller surrounding mounds which serve as temporary shelters from which termites can mount foraging expeditions to areas remote from the breeding colony (Plate 1).

The mounds of T. geminatus are highly aggregated while those of T. oeconomus appear to be randomly distributed (Sands, 1965).

A study of mound building termites in Australia (Wood & Lee, 1970) showed that eleven out of the 13 populations studied were overdispersed, and where slight aggregation was indicated, overdispersion occurred within the aggregation.

3. Mound density and population

Densities of termite mounds in different habitats have been listed (Wood & Lee, 1971). Murray (1938) estimated mound densities of about 534/ha for T. trinervoides in a South African savanna. Harris (1961) estimated mounds of Trinervitermes spp. to be of the order of 35-50/acre. Bouillon & Mathot (1964) estimated mound density of Cubitermes exiguus at 650/ha while Sands (1965b) estimated mound density of T. geminatus in an area near Zaria at 753/ha. Estimates of 350 mounds/ha have been made for Drepanotermes spp. in Australia (Watson & Gay, 1970) and Josens (1972) working in Lamto, in the Ivory Coast estimated 65 nests/ha for Trinervitermes sp.

Estimates of population of mound building and subterranean termites are few and there are no reliable estimates of the total numbers of any habitat (Lee & Wood, 1971). This has been attributed to the difficulty in sampling termite populations which are cryptic and very aggregated (Wood, 1975). In spite of these difficulties, several attempts have been made in estimating populations of mound building species. Sands (1965a), estimated the population of T. geminatus in the open savanna woodland of Nigeria to be of 494-1235.5/m^2.

Lee and Wood (1968) estimated the population of the mound building Nasutitermes exi tiosus in Australia at 600/m^2. Bouillon (1970) obtained an estimate of 519/m^2 for Cubitermes exiguus. Josens (1972) estimated the population densities of several species of Trinervitermes in the Ivory Coast, T. geminatus 128/m^2, T. togoensis 13.2/m^2, T. trinervius 3.3/m^2 and T. oeconomus at 7.0/m^2. Lepage (1974) working in the Sahelian savanna estimated populations of different species of termites, T. geminatus 2.4-8.3/m^2 and T. trinervius at 12.1-23.3/m^2, and in Malaysia Matsumoto (1975) estimated four mound building species at a density of 1330/m^2.

4. Grass harvesting and storage

Several genera of the grass-eating termites harvest and store grass in their nests. Trinervitermes is one of several termite genera in which grass eating has been developed as a specialized habit. For four species which occur in Nigeria, grass is the main item of diet (Sands, 1961; Ohiagu & Wood, 1976). The termites climb up standing grass which is cut down into small pieces and carried back to the nest, (Plate 2). T. geminatus, T. trinervius and T. togoensis feed mostly in this way. In other parts of the world, species such as Hodotermes mossambicus in South Africa (Coaton, 1954), Drepanotermes sp. in Australia (Watson, 1970) and Amitermes sp. (Ratcliffe et al., 1952), not only attack standing grass but also collect various types of plant debris lying on the surface. Other species such as Macrotermes subhyalinus and Odontotermes sp. feed largely on plant material lying on the surface of the soil. The habit of storing grass is however not general in the West African species of Trinervitermes (Sands, 1961a), but in T. geminatus is a coadaptation with the habit of seasonal foraging which is very active during the dry season and almost ceases in the wet season (Sands, 1965c).

There has been little published quantitative data on the amount of food stored in the nests of grass-harvesting termites. Watson et al (1970) estimated that moderately sized nests of Drepanotermes perniger in Australia stored about 200-500 g of dry grass and leaf litter when foraging ceased in early winter, and that larger nests (of unspecified sizes) contained more than 1 kg of grass. In the Ivory Coast (Bodot, 1967b) noted that T. trinervius which foraged all the year round stored no food in the nest.

The sizes of the fragments stored in the nests varied with the species (Lee & Wood, 1971). Sands (1961a) showed that T. geminatus stored larger fragments (6.26 mm) than T. trinervius (3.76 mm) and T. togoensis (3.97 mm).

In Australia, Lee and Wood (1971) studied three grass harvesting species and determined the length of grass fragments stored by Nasutitermes triodiae (8.61 ± 0.51 mm) and Drepanotermes rubriceps (6.50 ± 0.23 mm). Watson (1969) noted that Schedorhinotermes derosus - a harvester termite in Northern Australia felled grass and cut them into pieces of average length (9 mm) but ranging from (3-17 mm). The harvested and stored grass not only served as food during adverse foraging conditions but also served an insulating function (Coaton, 1958; Watson, 1970; Lee & Wood, 1971).

It is unknown whether other organisms utilized the food stored in the nests, but indications are that inhibitory substances produced by termites (Lee & Wood, 1971a) could impede the growth of other organisms in the nests.

5. Damage to pastures

In areas where grass-eating termites are found in large numbers, they have been acknowledged as perhaps the most important herbivores in denudation of range lands (Lee, 1972). Damage to pastures by termites occasionally resulting in almost complete denudation and accelerated erosion has been reported from various parts of the world. In South Africa, Naude (1934) reported that veld destruction was largely due to Hodotermes sp. and that extensive denudation occasioned by harvesters probably had considerable bearing on erosion and loss of rain water by run off. Coaton (1948, 1951, 1954), Hartwig (1955), Nel (1967), Van Ark (1967) and Hickens (1971) have all identified H. mossambicus as a pest in the dry districts of South Africa. Anon (1960) observed that certain areas in Zululand, had a 20% reduction in carrying capacity before control measures were instituted.

In the semi arid regions of Central Asia and in Turkemenia in the U.S.S.R., (Bilova, 1949; Luppova, 1958; Hickens, 1971), bare areas caused by the nest of Anancathotermes sp. occupied 20% of the surface and also caused 20% of loss of pasture. Saunders (1969) noted that in the low-

rainfall inland areas of Northern Queensland, grass-eating termites rendered almost valueless areas of low cattle carrying capacity. Drepanotermes rubriceps and D. perniger were said to have caused denudation in South West Queensland (Watson & Gay, 1970).

In the mulga lands of Australia, lasting denudation, caused by the combined effects of drought, grazing pressure and nesting habits of D. perniger have been reported (Watson, Lendon & Low, 1973). These authors further suggested, that where denudation and erosion had occurred, the hard tops of the nests impeded the recovery of the system. The desert termite Gnathamitermes tubiformans (Buckley) was reported as destroying large areas of growing vegetation on grazing lands in the South Western part of the United States (Synder, 1949, Weesner, 1970; Bodine & Ueckert, 1975). Over-grazing leads to intense competition between cattle and termites and by creating more open spaces influences the establishment of new termite colonies (Harris, 1961). Locusts and grasshoppers can also denude large grassland areas, but their effects, though spectacular, are sporadic and may not be as significant as those of termites (Lee, 1972).

Observations made on an area of sown grassland in Mokwa (Wood & Ohiagu, 1976), indicated the potential danger of denudation from the activity of Macrotermes subhyalinus and Odontotermes spp. These scavenging species are capable of killing off dry grass tussock, that would otherwise grow following rains and thereby create erosion hazard by baring the soil surface. It was estimated that 9 kg of grass was removed in a period of 2 months from an area of 0.1 ha by these two species. Odontotermes sp. and Macrotermes sp. were said to have destroyed areas of pasture (Andropogon gayanus) in the North Western State of Nigeria. As a result extensive areas had to be resown after the drought ended in 1974 (Johnson, Ohiagu & Wood-Tour reports 1974). At the Shika experimental station in the Northern

one aspect of this complex.

... therefore been confined to

SECTION II. STUDY SITE, VEGETATION ANALYSIS, ABUNDANCE AND SPATIAL DISTRIBUTION OF MOUNDS

1. Materials and methods

1.1 Study site, history, climate and soil

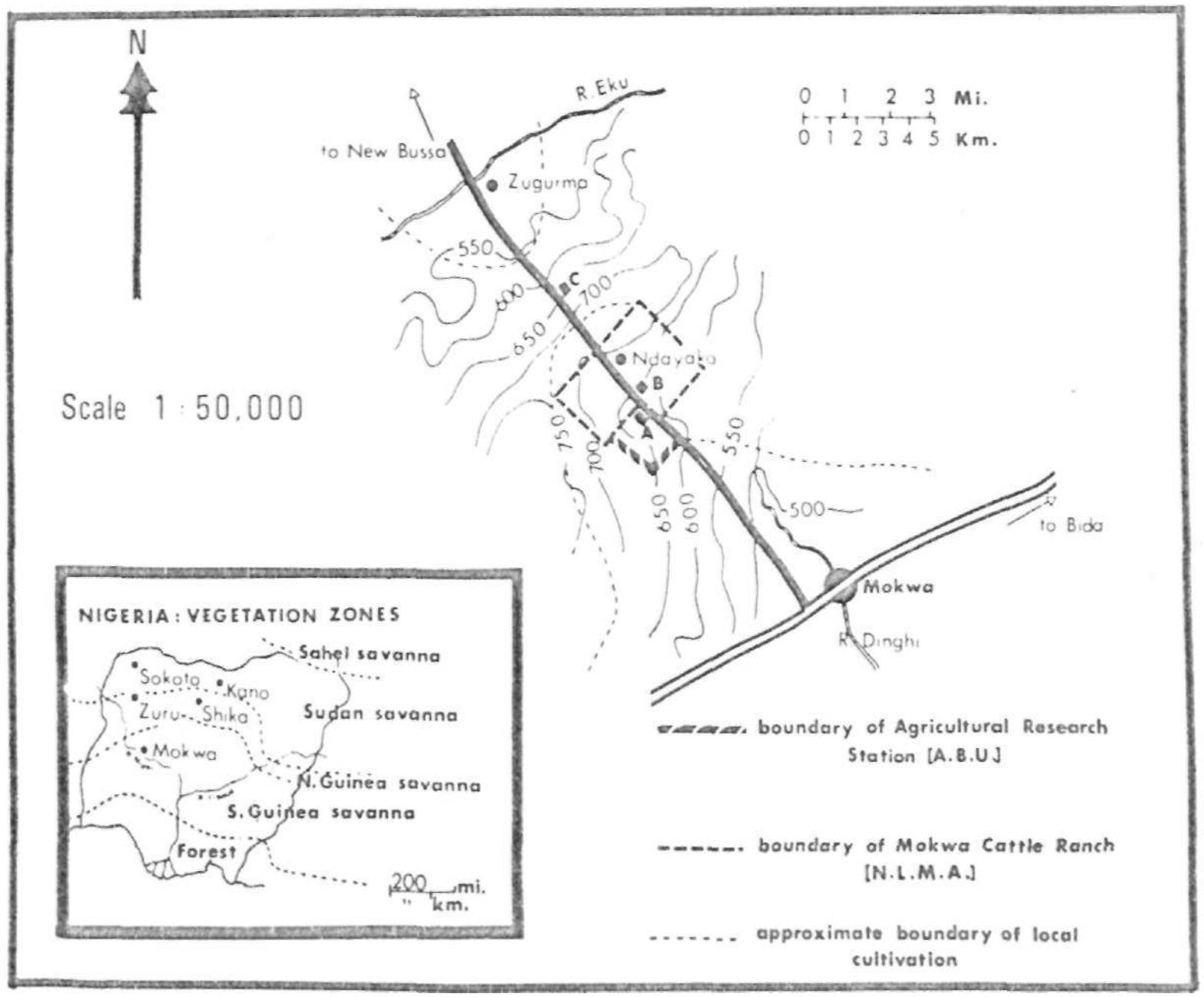
The study site, represented as B (Fig. 1), covers an area of about 2.5 hectares and is in a zone of regrowth savanna woodland belonging to the Mokwa Cattle Ranch (Nigerian Livestock and Meat Authority). This site was chosen for two reasons (a) There was a substantial higher density of Trinervitermes mounds compared with other areas in the locality. (b) The area was large and uniform enough, for setting up large sized experimental plots envisaged for the study and was within good distance for herdsmen, when animals were required from the cattle ranch, for grazing the plots.

It is located approximately 12 kilometers north of Mokwa ($9^{o}18'N$, $5^{o}5'E$). Mokwa, with an altitude of 230 m is close to the southern boundary of the Southern Guinea savanna (Fig. 1), and has a mean annual rainfall of 1175 mm, and a pronounced wet and dry season; with the latter extending approximately from mid October to mid April.

The area is gently undulating and is occupied by soils of the Kulfo association which are developed on coarse-grained Nupe Sandstone (Valette, 1973). The site occupies a mid-upper slope position on undifferentiated red ferrisols which have a sandy surface layer, with low water retention capacity and clay content gradually increasing with depth. The area was cleared during the 1949-53 Colonial Development Corporation groundnut scheme (Baldwin, 1957), and cultivated for two years. When this project collapsed, the land reverted to bush and since 1959, when it was partially recleared, has been used for grazing cattle.

The dominant species of grass is Andropogon gayanus Kunth var. bisquamulatus (Hochst) Hack; and Hyparrhenia dissoluta (Nees ex stend) C. E. Hubbard. Other species present include Ctenium newtonii (Hack) and

Figure 1.


N
Scale 1 : 50,000
R Eku
to New Bussa
Zugurma
550
600
650
700
C
B
Ndayako
750
700
650
600
550
500
to Bida
Mokwa
R. Dinghi
0 1 2 3 Mi.
0 1 2 3 4 5 Km.
NIGERIA : VEGETATION ZONES
Sahel savanna
Sokoto
Kano
Zuru
Shika
Sudan savanna
Mokwa
N. Guinea savanna
S. Guinea savanna
Forest
200 mi.
" km.
boundary of Agricultural Research Station [A.B.U.]
boundary of Mokwa Cattle Ranch [N.L.M.A.]
approximate boundary of local cultivation

Microchloa indica (Linn.f) Beauv. (Table 1).

Tree species present include Afzelia africana Smith ex Perr; Bukea africana (Hook.f) and Isoberlinia sp.

1.2 Experimental layout

The experimental layout (Fig. 2) consisted of four plots A, B, C, D, two of which were grazed (B and C) and two ungrazed (A and D). Each plot was separated from the other by a fence to prevent the intrusion of cattle into ungrazed plots. Similarly the periphery of the 2.5 hectare experimental area was fenced. Each plot was further divided into three blocks as follows:-

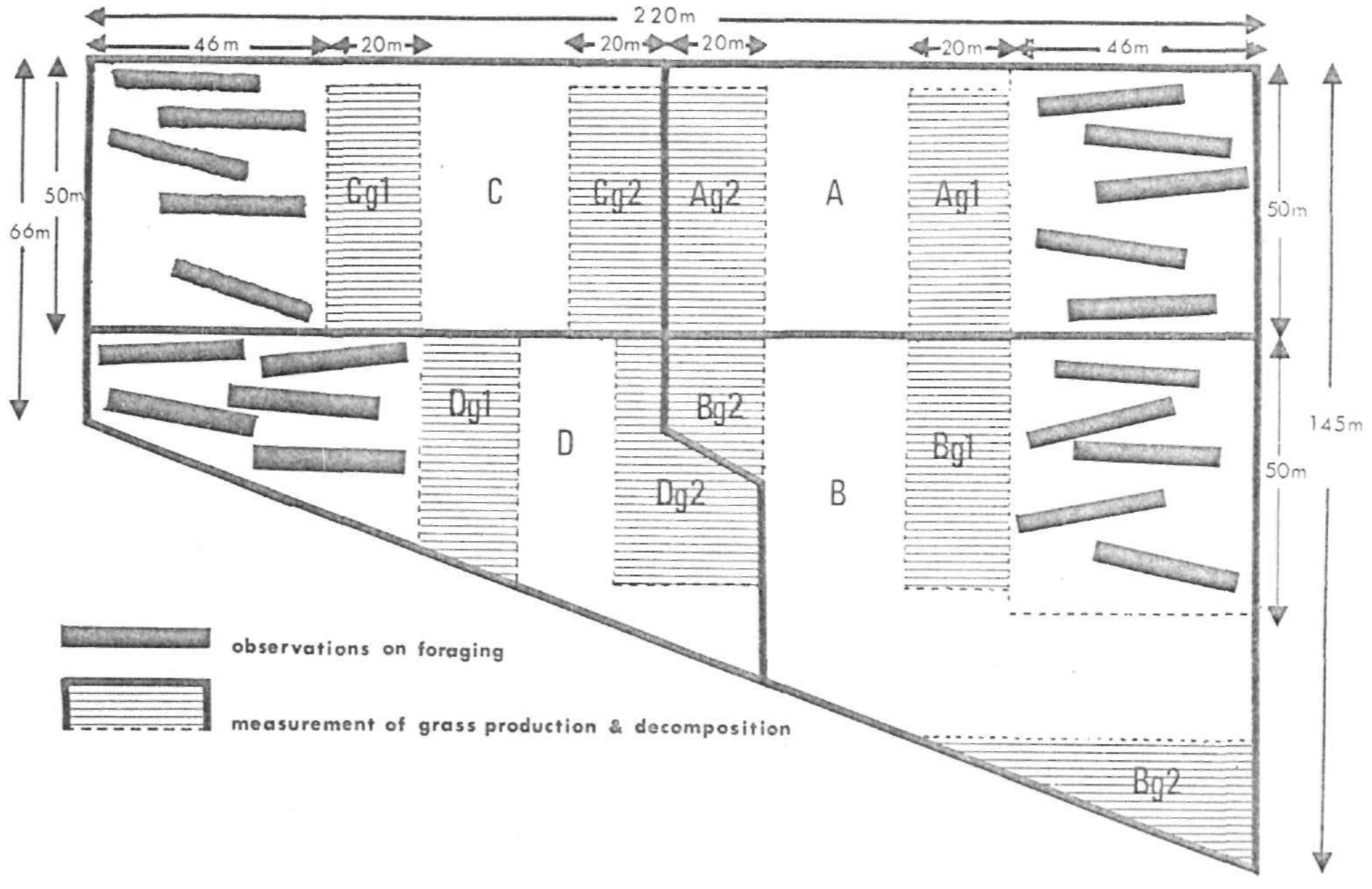
(a) A block measuring 45 m x 50 m per plot in which 5 strips, each measuring 3 m x 30 m were randomized and marked with iron pegs at 1 m intervals. Observations on foraging activity of T. geminatus were made in these five strips.

(b) Two blocks per plot, each measuring 20 m x 50 m (Ag1, Ag2; Bg1, Bg2; Cg1, Cg2; and Dg1, Dg2), in which grass production and decomposition were estimated.

Originally it was planned that grass production be estimated from one plot where termites were present, and also in a termite free (chlordane treated) plot. However, with the low population of termites eventually encountered in the area of study, this idea was discarded.

Within each of the grass production blocks, ten sub-blocks measuring 10 m x 10 m were marked out, and in each of these, two strips (1 m x 6 m) were randomized to provide one square metre sample to be clipped every two months. An area of 20 m x 50 m, acted as a buffer between the two grass production blocks in each plot.

Figure 2.


220m
46m
20m
20m
20m
20m
46m
50m
66m
Cg1
C
Cg2
Ag2
A
Ag1
50m
Dg1
D
Bg2
Dg2
B
Bg1
145m
50m
observations on foraging
measurement of grass production & decomposition
Bg2

1.3 Botanical analysis of experimental area

To complete the description of the habitat, an analysis was made of the vegetation by determining percentage cover using the 10 point quadrat method (Fenton, 1933; Greig-Smith, 1952a).

The quadrat consisted of two vertical wooden frames 1 metre in height, held 1 metre apart by a wooden crossbar. On the crossbar were 10 holes holding vertical pointed rods.

Each quadrat consisted of 10 measurements and 30 were randomised in the grass production as well as in the foraging blocks of each of the four plots respectively. In each of the foraging blocks with 5 strips (3 m x 30 m), all hits were recorded from six random positions of the frame/strip, while in the grass production blocks, the hits were recorded from three random positions of the frame for each of the sub-blocks measuring 10 m x 10 m. Measurement was done by lowering the pointed rods one at a time and as the fine end of the rod touched a species of grass, it was identified and recorded and the lowering of the rod was continued until the bare ground or leaf litter was hit on the way down. This procedure was for each of the ten rods in each quadrat. The cover was calculated from the following formula (Goodall, 1952).

$$\frac{\text{Number of times a species was hit}}{\text{Total hits on vegetation}} \times (100 - \text{Percent bare ground})$$

1.4 Grass production measurements

Grass production was measured by estimating standing grass biomass (W), litter biomass (L) and decomposition (L d) rate at intervals of two months. Grass production was calculated from $(W_1 - W_0) + \left[(L_1 - L_0) + Ld\right]$ where W_1 and W_0 and L_1 and L_0 were the dry weights of grass and litter respectively on successive sampling dates and Ld was the rate of decomposition for

the period between these dates. Litter production was calculated from (L_1 - L_0) + Ld. Preliminary studies were carried out to determine the total number of qudrats, $1m^2$ in area that would be required to give a reliable estimate of grass and litter biomass at the 5% level of accuracy. Calculation was based on the following formula (Southwood, 1962).

$$N = \left(\frac{ts}{D\bar{x}}\right) \quad \text{where}$$

N = Number of quadrats required

D = Level of accuracy required (5%)

t = Quantity obtained from tables

s = Standard deviation

$\bar{x}$ = Mean of samples taken

The preliminary study showed that 48 quadrats were adequate for this purpose. The area used for vegetation sampling, two in each block are shown in (Fig. 2). Each was divided into 10 plots each 10 m x 10 m, and on each sampling occasion two $1m^2$ quadrats were sampled within each plot. All the litter was carefully collected before the vegetation was clipped to a height of 1 cm from ground level and collected.

Decomposition rate was estimated from the loss in weight of pre-weighed cut samples of grass retained within wire cages. Five cages each containing 4.0 g of grass were located in each area (Ag1, Ag2 etc) (Fig. 2), and fresh samples were used for each two monthly period. The dimension of the wire mesh allowed access to foraging termites both Trinervitermes spp. and various subterranean Macrotermitinae, which were suspected of being a major factor in the removal of grass litter, particularly in the dry season. Samples of cut grass for decomposition were placed in the field in April 1974, so that the rate of decomposition for the period, February to April had to be estimated by an alternative method.

1.5 Abundance and spatial distribution of T. geminatus mounds

In December 1973/January 1974, mounds within the areas marked out for the study of foraging behaviour in the four blocks, were counted and numbered by narrow aluminium labels on which the number of each mound was engraved. The aluminium labels were attached by string to 1 metre iron rods fixed firmly in the soil beside each mound. Measurements of the height, basal circumference and two arcs at right angles were taken for each mound and recorded. Termites present in each of the mounds were identified and the mounds classed as active, (if occupied by T. geminatus), abandoned, or occupied by other termites including other species of Trinervitermes. Abandoned mounds were easily recognized by their poor state of repair and the absence of stored grass fragments. Identification of other Trinervitermes spp. were done through their solider castes.

Similar measurements were made in the Zugurma bush, (area C, Fig. 1) an area of undisturbed primary savanna woodland, 6 km from the study area, on 4 plots each measuring 30 m x 90 m, between September and October 1974. Identification of different Trinervitermes spp. was carried out in each plot and the number of mounds occupied by each species counted and recorded.

In December 1974/January 1975, number of mounds in the area was reassessed. New mounds built within these plots were identified, measured and counted. Old mounds, where new mound structures were added, were remeasured and recorded. The distance between nearest neighbours was obtained by measurement of mounds in plots A, B and C to provide information on the spatial distribution of mounds within the study area.

1.6 Number of mounds/colony

The tests were carried out in two plots at the experimental site. Each of the plots (B and C) had in several locations, some mounds that were

aggregated together. These mound aggregates were often separated from one another by a distance of several metres. The method consisted of testing soldiers from mounds making up these aggregates against one another as well as against soldiers from other aggregates in a different location. These tests were often carried out early in the mornings since the termites were less active at high day temperatures.

Mounds were slightly opened at the base and lightly tapped. This led to the immediate out-rush of soldiers (major and minor). Five major soldiers were collected from each of the mounds by means of very pliable tweezers into a series of labelled petri dishes which were covered at the base with filter paper. The termites were allowed to settle on the petri dishes to get used to the new environment. Soldiers from one mound (say, X) were released into a petri dish containing soldiers from another mound (Y). This process was repeated using soldiers from mound (X) to test soldiers from other mounds making up the aggregate. The mean distance between mounds of the same aggregate was measured and recorded. A negative response, which indicated that the soldiers mixed freely, suggested that the soldiers were of the same colony. A positive response represented by the incessant vibration of the head and the squirting of a sticky fluid from the fontanalle, indicated that soldiers did not mix freely and probably were from different colonies. The number of negative and positive responses were scored. The experiment was repeated using soldiers from mounds already examined to test soldiers from mounds in other locations. The distance between nearest neighbours of different aggregates was measured and recorded. Mounds which stood singly and widely separated were not tested nor were mounds abandoned and reoccupied by other termites including other species of Trinervitermes.

1.7 Plant tissue analysis of stored grass in mounds, standing grass and grass litter

Grass fragments stored in mounds from each 20 mound samples taken during the different sampling periods within the year, were bulked, and samples sent to the International Institute for Tropical Agriculture in Ibadan for plant tissue analysis. Similar samples from clipped grass and grass litter collected during grass production measurements were also sent for analysis. Analysis was carried out to determine total percent Nitrogen, Phosphorus, Potassium, Calcium, Magnesium and Organic carbon content of the samples. All samples sent for analysis were oven dried.

2. Results

2.1 Botanical analysis of study area

The results are shown in Appendices 1a - 1f. The mean percentage of each species in the foraging and grass production areas within a plot and the mean percentage total for each species in a plot are shown in Table 1. 15 grass species were identified in the study area. The identification of the different grass species was done at the Shika herbarium. There was variation in ground cover and species composition in the plots. Hyparrhenia dissoluta was the most abundant species in each of the plots with a mean total of 37.12 ± 7.0%. Next in abundance and of fairly even distribution in plot B, C and D was Andropogon gayanus with a mean total of 23.14 ± 1.9%, but it was much less abundant in plot A. Other grass species occur in varying amounts. Microchloa indica, a fine-leaved grass species, with an overall mean of 8.27 ± 2.05% was fairly abundant in plot A, B and C, but almost non-existent in plot D. Ctenium newtonii with a mean 7.33 ± 2.44% was more abundant in plot C (12.46%) and D (10.46%) than in plots A (4.03%) and B (2.36%). There was a fairly low proportion of small shrubs e.g. (Zornia glochidiata) with a percentage composition of 9.28 ± 1.70.

2.2 Measurement of standing grass biomass, litter biomass, rate of decomposition

The standing grass biomass, litter biomass and percent decomposition of grass sample for the ungrazed plots is shown in Table 2. The dry weight of litter decomposed during successive two month periods was calculated from the percent loss in weight of decomposition samples for that period and the litter biomass at the beginning of that period with the following exceptions:-

(a) Decomposition for the period February to April 1974, for which no measurement of L_d was made, was obtained from estimated litter disappearance

Table 1. Mean percent composition of species in study area.

Species	A	B	C	D	Mean % total
Andropogon gayanus Kunth.	17.60	23.18	26.49	25.29	23.14 ± 1.97
Hyparrhenia dissoluta Nees ex stend.	56.44	30.72	24.0	37.32	37.12 ± 7.0
Cymbopogon giganteus (Hochst) chiov.	0.97	3.73	1.15	0.30	1.54 ± 0.75
Ctenium newtonii (Hack)	4.03	2.36	12.46	10.46	7.33 ± 2.44
Eragrostis tremula (Hochst ex stend)	0.00	0.28	1.19	0.67	0.54 ± 0.25
Microchloa indica (Linn.f) Beav.	9.39	8.27	8.76	0.66	8.27 ± 2.05
Cyperus sp.	0.55	3.58	4.46	4.86	3.36 ± 0.98
Cynodon dactylon Linn. Pers.	0.00	0.00	0.00	0.61	0.15 ± 0.05
Bracharia brizantha (Hochst ex A. Rich) stapf	1.18	6.32	5.67	3.49	4.16 ± 1.16
Chloris gayana Kunth	0.00	1.16	0.06	0.34	0.39 ± 0.26
Imperata cylindrica Linn.	0.00	0.13	0.72	0.00	0.21 ± 0.06
Pennisetum pedicellatum Trin.	0.00	0.00	0.56	0.37	0.23 ± 0.14
Brachiaria jubata	1.01	0.00	0.31	0.00	0.33 ± 0.11
Rottboellia exaltata	0.00	0.62	0.00	0.09	0.18 ± 0.15
Digitaria diagonalis (Nees) stapf.	0.00	0.00	0.76	0.00	0.19 ± 0.19
Small shrubs	5.90	13.79	9.86	7.56	9.28 ± 1.70
Leaf litter	3.11	6.48	3.68	1.8	3.76 ± 0.98

($L_0 - L_1$) plus litter production ($W_0 - W_1$). Grass production was assumed to be zero, which is reasonable for the end of the dry season.

(b) When ($L_0 - L_1$) exceeded the calculated figure for decomposition as in April-June (e.g. Plot A, 422 exceeds 661 x 0.132), the former figure was used as a minimum estimate of decomposition and since litter production would be expected during this period, it could be small.

(c) When net litter disappearance, ($W_0 - W_1$) - ($L_0 - L_1$), was positive and exceeded the calculated value of Ld (e.g. Plot D, February 1975; 305 exceeds, 166 x 0.937) decomposition was calculated from ($W_0 - W_1$) + ($L_0 - L_1$).

Plots B and C were grazed in June and October at a stocking rate of 20 cattle/plot, and obviously grass production could not be calculated for these periods in the same way as for the ungrazed plots, $W_1 - W_0$ would include an unknown loss in standing biomass due to grass consumption by cattle. Theoretical figures for grass production on these plots were calculated assuming that the rate of growth would have been similar to that on plots A and D and related to the initial standing grass biomass.

The calculations are shown in Table 3. The two monthly production figures obtained in this way have been compared with the measured "production" figures for June-August and October-December to calculate the amount of grass consumed by cattle (Table 4).

2.3 Abundance of mounds

The results of mound counts taken in December 1973/January 1974 and December 1974/January 1975 are shown in Table 6. The total number of mounds in plot A (104), B (126), C (118) were significantly higher than in plot D (56) during 1973/74; but the percentage of abandoned mounds was fairly constant in all plots. The highest number of active mounds was

Table 2. **Biomass, production and decomposition (kg/ha) of grass and litter on two ungrazed plots.**

Plot and Season	Biomass		Litter decomposition		W_1-W_0	L_1-L_0	Production	
	Standing Grass (W)	Litter (L)	%	kg/ha			Grass	Litter
Plot A								
9th Feb. 1974	2997	1026						
10th April	2100	661		1262	897	- 365	0	897
6th June	2664	239	13.2	422	564	- 422	564	0
8th Aug.	3511	241	50.2	120	847	2	969	122
10th Oct.	4345	229	51.1	123	834	- 12	945	111
10th Dec.	4294	305	63.4	145	- 51	76	170	221
10th Feb. 1975	3778	662	88.4	270	- 516	357	111	627
Annual Total				2342			2759	1978
Plot D								
9th Feb. 1974	1517	319						
10th April	1018	206		612	- 499	- 113	0	499
6th June	1500	55	28.1	151	482	- 151	482	0
8th Aug.	2323	98	58.4	32	823	43	898	75
10th Oct.	3260	90	68.4	67	937	- 8	996	59
10th Dec.	3444	166	73.1	66	184	76	326	142
10th Feb. 1975	2960	343	93.7	307	- 484	177	0	484
Annual Total				1235			2702	1259

Table 3. Production of grass in two ungrazed plots as percent of initial standing biomass and calculation of theoretical values of production for two grazed plots.

Season	Ungrazed Plots		Mean of A & D	Theoretical Production of grazed plots	
	A	D		B	C
Feb. - April 1974	0	0	0	0	0
April - June	18.8	31.8	25.3	388	486
June - Aug.	32.3	59.2	45.8	703	878
Aug. - Oct.	31.5	65.7	48.6	746	933
Oct. - Dec.	5.7	21.5	13.6	209	261
Dec. - Feb. 1975	3.7	0	1.9	29	36

Table 4. Biomass, decomposition and theoretical production (kg/ha) of grass and litter on two grazed plots and estimated consumption by cattle.

Plot and Season	Biomass		Litter decomposition				Production			Consumed by cattle (T-M)
	Standing Grass (W)	Litter (L)	%	kg/ha	W_1-W_0	L_1-L_0	Litter	Grass measured (M)	Theoretical (T)	
Plot B										
9th Feb. 1974	1535	310								
10th April	1031	200		614	- 504	- 110	504	0	0	
6th June	1535	102	21.2	98	504	- 98	0	504*	388	
8th Aug.	1440	154	69.5	71	- 95	52	123	28	703*	675
10th Oct.	1971	322	71.1	129	531	168	297	828*	746*	
10th Dec.	1689	154	78.6	253	- 282	- 168	85	- 197	209*	406
10th Feb. 1975	1880	211	96.4	148	191	57	205	396*	29	
Annual Total				1313			1214	2	640	1081
Plot C										
9th Feb. 1974	1919	437								
10th April	1288	282		786	- 631	- 155	631	0	0	
6th June	2250	157	23.1	125	962	- 125	0	962*	486	
8th Aug.	2145	82	54.3	85	- 105	- 75	10	- 95	878	973
10th Oct.	2493	457	56.5	46	348	375	421	796*	933	
10th Dec.	1823	333	63.4	290	670	- 124	176	- 494	261	755
10th Feb. 1975	2173	457	91.7	305	350	124	429	779*	36	
Annual Total				1637			1667	36	74	1728

* Figures used to calculate annual total (see text).

Table 5. Grass production, litter production and litter decomposition compared with grass consumption by cattle on grazed and ungrazed plots.

		Grass Production	Litter Production	Litter Decompostition	Consumption by cattle
Ungrazed					
	A	2759	1927	2342	-
	D	2702	1175	1667	-
Mean		2730	1551	2004	-
Grazed					
	B	2640	1214	1313	1081
	C	3674	1597	1637	1728
Mean		3157	1406	1475	1404
Overall mean (all plots)		2944	1478	1739	1404
Consumption by cattle calculated as % of total grass production		-	-	-	47.69

Table 6. Abundance, mortality and recruitment of T. geminatus mounds.

PLOT NO. AND TREATMENT	DATE OF CENSUS	TOTAL NO. OF MOUNDS	NO. ABANDONED	NO. ACTIVE	% ABANDONED	CALCULATED NEW DEAD	INCREASE DEAD	NEW ADDITION	MOUNDS LOST
A (Ungrazed)	1973-74	104	48	56	46.1	20	4	8	16
	1974-75	96	52	44	54.1				
B (Grazed)	1973-74	126	40	86	31.7	51	14	9	37
	1974-75	98	54	44	55.1				
C (Grazed)	1973-74	118	36	82	32.0	17	9	21	8
	1974-75	131	45	66	34.5				
D (Ungrazed)	1973-74	56	11	45	19.6	11	9	8	2
	1974-75	62	20	42	32.2				

recorded in plots B (86) and C (82), as compared with A (56) and D (45). The density of active mounds within the year was estimated at 269/ha.

In the 1974/75 mound census, the number of mounds decreased in plots A (96) and plot B (98) as compared with the number of mounds the previous year. Even though the number of mounds was lower than the previous years count by (28, plot B) and (8, plot A); the percentage number of abandoned mounds was fairly constant in both plots (A, 54.1) and (B, 55.1). In plot C (131) and D (62), there were more mounds in 1974/75 than in the previous year. The percentage number of mounds abandoned in plot D (32.2) was similar to that in plot C (34.5). The number of active mounds in plot D remained constant in both years. The number of active mounds/hectare during 1974/75 was estimated at 194, giving an overall mean number of active mounds in the study area for the period as 232/ha.

Most of the abandoned mounds were reoccupied mostly by T. togoensis and T. occidentalis. Other termite species found in the abandoned mounds included Cubitermes sp., Promirotermes sp. and Microtermes sp. Mounds of T. oeconomus were few in the study area and were mostly found in tree-shaded areas. Field observations occasionally showed some abandoned mounds of T. geminatus taken over by black ants (Crematogaster sp.) and other larger ants particularly Dorylinae sp.

2.4 Mortality loss and recruitment of mounds

The increase in abandoned mounds within the year in the various plots is given in (Table 6). This was calculated by subtracting the number of abandoned mounds in 1974-75 from those in 1973-74 counts. Plot A (4), had the lowest number as compared with plot B (14), C (9) and D (9). Within the year, new mounds were built and these were counted for the various plots as shown in Table 3. The highest number of newly formed mounds was

counted in plot C (21) as against A (8), B (9) and D (8). The number of mounds that died within the year (calculated new dead) was found by adding the number of the newly formed mounds within the year to the original active mounds in 1973/74 and subtracting the number of active mounds in 1974/75. The results indicated that 20, 51, 17 and 11 mounds died in plots A, B, C and D respectively within the year. The number of mounds lost was calculated by adding the new recruits to the total number of mounds in 1973/74 and subtracting from the total, the number of mounds counted in 1974/75. The highest number of mounds was lost in plot B (37), followed by 16 mounds lost in plot A. In plots C and D, 8 and 2 mounds were lost respectively.

2.5 Enlargement of old mounds

Since the number of old mounds with new additions per plot was negligible, it was not possible to make a comparison between grazed and ungrazed plots. Rather, measurements were made of a random sample of mounds within the experimental area in 1973-74 and 1974-75 to show the rate at which they increased in size within a year. Table 7 shows the results. The sum of arcs which incorporated the dimensions of height and basal circumference was taken as the simplest index of size. There was an increase in size of each of the 17 mounds remeasured within the year. This increase varied from 0.02 m to 0.94 m. The increase calculated as a percentage of original size in 1973/74 is shown in the last column in Table 7.

2.6 Spatial distribution of mounds

The mound density as obtained from 1974/75 census figures in plots A, B and C each of 0.25 ha, the mean nearest neighbour distance between mounds and the dispersion coefficient (a) is shown in Table 8. The relationship between density of mounds and the mean nearest neighbour distance is given

Table 7. Increase in size of random sample of mounds taken from all plots between January 1974 - January 1975.

Mound No.	Size (Arc I + II) m 1973-74 A	Size (Arc I + II) m 1974-75 B	B - A (m)	% Increase in size
30	1.21	1.66	0.45	37.19
40	1.23	1.79	0.56	45.52
47	0.25	0.60	0.35	140.00
64	0.37	0.98	0.61	164.86
72	0.72	0.74	0.02	2.78
73	0.66	0.69	0.03	4.55
86	1.41	1.50	0.09	6.38
90	0.78	1.40	0.62	79.49
109	0.77	1.52	0.75	97.40
136	0.89	1.15	0.26	29.21
162	0.49	1.11	0.62	126.53
163	0.59	1.02	0.43	72.88
174	1.18	1.42	0.24	20.34
205	0.36	0.53	0.17	47.22
258	0.79	1.15	0.36	45.57
304	1.25	1.88	0.63	50.40
342	0.66	1.60	0.94	142.42

Table 8. Mound density, mean nearest neighbour distances and dispersion coefficient.

Plot No.	Density Active Mounds 1974/75	Total area sq. m.	$\bar{x}$ nearest neighbour distance (m)	Dispersion Coefficient
A	44	2500	1.85	0.06
B	44	2500	2.65	0.12
C	86	2500	1.77	0.11

by $m = \frac{a}{\bar{r}^2}$ (Blackith, 1958; Waloff & Blackith, 1962; Sands, 1965; Wood & Lee, 1971).

where m = density of mounds

$\bar{r}$ = mean nearest neighbour distance

a = coefficient of dispersion

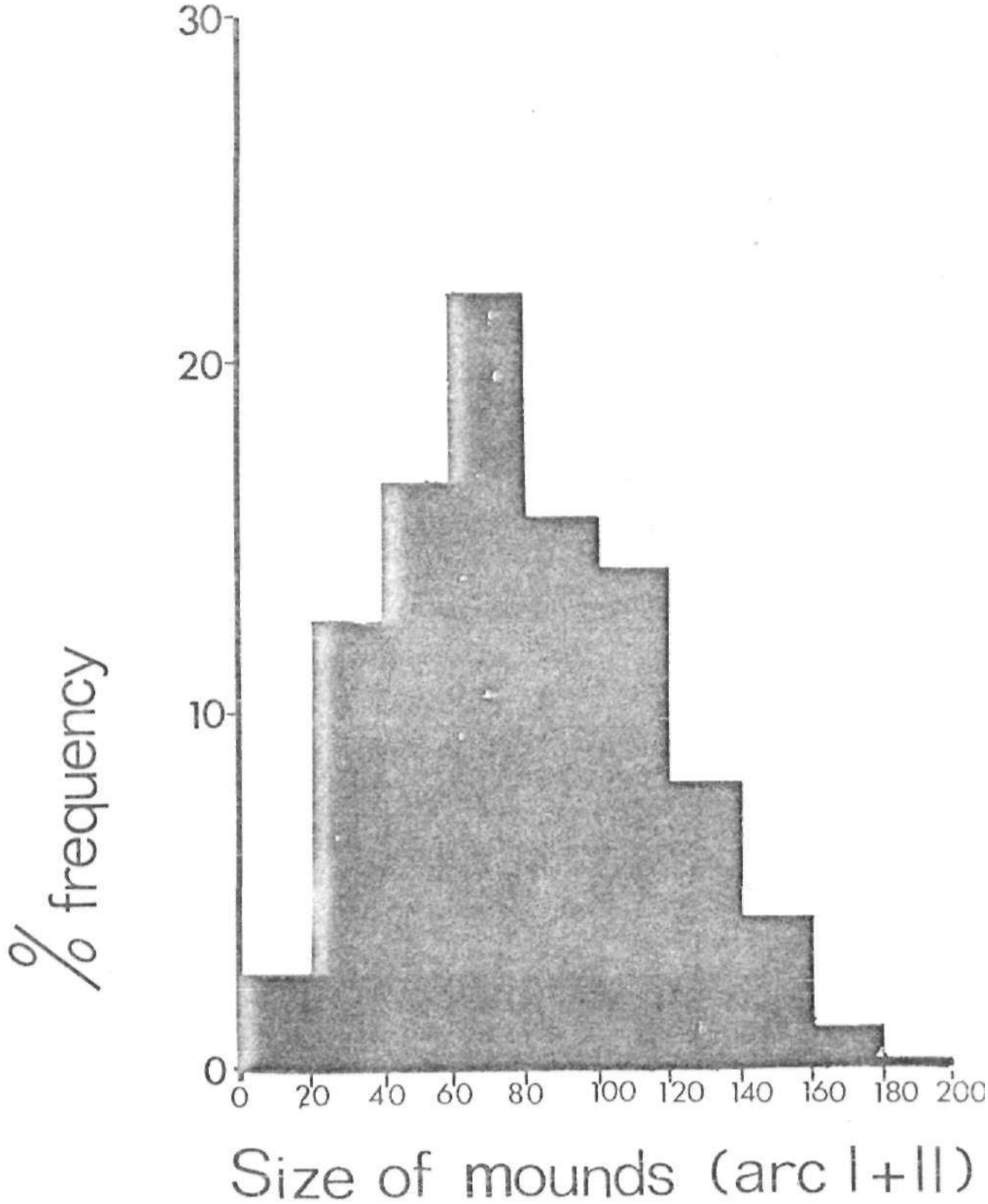
The mean nearest neighbour distance (m) as measured at the plots range from 1.77 m to 2.65 m. The dispersion coefficient calculated for the three plots gave values of 0.06, 0.12 and 0.11 with an overall mean of 0.097.

2.6.1 Frequency and size distribution of mounds

Measurements made of mounds at the plots in 1974-75 were used in determining frequency and size distribution of mounds. The various size ranges and percent frequency of occurrence is shown in Table 9 and Fig. 3. From the results, mounds in the size range of 61-80 cm made up 20% or more of the total mounds measured. Mounds in the size range of 41-60 cm and 81-100 cm occurred frequently 16% of the time. Mounds measuring 81-140 cm were considered to be medium sized mounds and these occurred quite frequently at the plots. However, very large mounds over 200 cm in size were not encountered but those in the range of 141-160 and 161-180 had a percentage occurrence of 4.2% and 1.2% respectively. The results indicated

Table 9. Size range, number of times encountered and percent frequency of occurrence.

Size-range (cm)	No. of times encountered	% Frequency
0 - 20	7	2.70
21 - 40	33	12.74
41 - 60	43	16.60
61 - 80	57	22.0
81 - 100	41	15.83
101 - 120	37	14.29
121 - 140	21	8.11
141 - 160	11	4.25
161 - 180	3	1.16
181 - 200	1	0.39
200	0	0


30
20
10
0
% frequency
0
20
40
60
80
100
120
140
160
180
200
Size of mounds (arc I+II)

that the different size groups followed a fairly normal distribution. Sands (1961) showed a frequency distribution which departed from normal in his area of study.

2.6.2 Number of mounds/colony

Tables 10 and 11, show results obtained from tests in two plots (B and C) at the experimental area.

In plot C, eight locations where mounds were aggregated were discovered and tested for mutual aggressiveness. The mean number of active mounds counted per aggregate varied from 3-9. In location four, the nine mounds discovered were more or less in a straight line ranging from small sized mounds to relatively big ones, with a mean distance of 3.22 m between them. These mounds were thought to be following a straight internal gallery of the colony. The overall mean distance within aggregates in the eight locations was 2.13 m; while the distance between nearest neighbours of aggregates varied from 6.4-10.7 m with a mean of 8.0 m. The number of mounds with negative responses varied from 3 to 9 with a mean of 4.8 and this figure was taken to represent the number of mounds constituting a colony in this plot.

In plot B, fewer locations (5) were discovered and tested. The number of mounds/aggregate, excluding mounds abandoned or occupied by other Trinervitermes spp. varied from 3 to 7. Mean distance within aggregates were estimated at 3.32 m, while distance between aggregates in different locations averaged 11.02 m. Both within and between aggregate distances were higher in mounds discovered in plot B than in C. The number of mounds with negative response and hence the number of mounds/colony varied from 2 to 6 with a mean of 4.5.

The mean number of mounds per colony for the two plots was

Table 10. Showing no. of mounds/aggregate, mean distance and no. of mounds/colony. Plot C.

Location	No. of mounds counted/aggregate	Mean distance between mounds within aggregate (m)	Distance between nearest neighbour of aggregates (m)	No. of mounds with -ve response	No. of mounds of other spps.	No. of mounds abandoned
1	7	0.84	-	5	1	1
2	4	1.38	6.4	4	-	-
3	5	3.47	8.2	5	-	-
4	9	3.22	8.6	9	-	-
5	5	1.99	7.5	4	-	-
6	3	1.80	6.8	3	-	-
7	4	1.84	7.8	3	-	1
8	6	2.49	10.7	5	-	1
Total	43	17.03	56.0	38	1	3
Mean	5.4	2.13	8.0	4.8	-	-

Table 11. **Showing no. of mounds/aggregate, mean distance and no. of mounds/colony.** **Plot B.**

Location	No. of mounds/aggregate	Mean distance within aggregates (m)	Distance between nearest neighbour of aggregates (m)	No. of mounds with -ve response	No. of mounds of other spps.	No. of mounds abandoned
1	6	2.35	-	6	-	-
2	3	6.03	7.2	2	-	1
3	7	2.07	11.2	4	2	1
4	7	3.13	10.2	4	1	2
5	7	3.02	15.5	6	-	1
Totals	30.0	16.60	44.1	22.0	3	5
Mean	6.0	3.32	11.02	4.5	-	-

estimated at 4.6. Sands (1965) suggested that a colony of T. geminatus was likely to consist of 3 to 6 mounds.

2.6.3 Results of field observation on surface area occupied by T. geminatus

In South Africa, (Naude, 1934; Coaton, 1948) suggested that the area occupied by mounds of T. trinervoides (Sjostedt) might be a significant proportion of the total available. However, no data were given to support this suggestion.

Measurements of T. geminatus mounds in the study area showed that the average area occupied by mounds of this species was 0.1 to 0.3 m^2. In the area of study with a mound density of 232/ha, and in an area near Zaria (Sands, 1965b) with a mound density of 735/ha, only 1.0 to 2.0% of the total area was occupied by mounds. Allowing for an extra 'bare' area around the base of the mound and also additional areas occupied by mounds of other species of Trinervitermes, the area occupied by mounds of this species will rarely exceed 2.0% of the total.

2.7 Relationship between nest size and quantity of food stored

The results of food stored in mounds sampled at the different periods within the year are given in Appendices 2a-2d; and summarized in Table 12. In the December/January (1973/74) series, the largest mound of size (201 cm) had no food store, but a mound about half its size (114 cm) contained 91.5 g of food stored. The highest quantity of food (172 g) was recorded in a mound of size (177 cm). During this sampling period 73% of the mounds contained some food store varying from 5 g to 172 g with a mean of 48 g/mound.

In the April/May sampling period, the largest mound of size (161 cm) contained the largest amount of food (64 g), while the smallest mound (43

cm) had no food store. 50% of the sampled mounds within this period contained quantities of grass varying from (4 g - 64 g) with a mean of 15 g/ mound. In the August/September series, 65% of the sampled mounds contained grass fragments with weights ranging from 5 g - 83 g with a mean of 37 g/ mound. The largest mound in the series (210 cm) had a food store (62 g) far below the small mound of size (95 cm) with a food store of (83 g). Conversely in the December 1974/January 1975 sampled series, all the mounds stored food, far in excess of those stored in the mounds at the same time in the previous year. The largest mound in the series (262 cm), though with a large quantity of grass stored (183 g) was not the mound with the largest quantity of stored grass, neither did the small mound (90 cm) in the series have the least quantity of stored material.

Similar results were obtained from mounds in the primary savanna woodland (Zugurma bush), where 70% of the mounds had food stored in them. The largest quantity of grass (211 g) was stored in a fairly large (200 cm) mound while the largest mound of the series (285 cm) contained only one-sixth of that quantity. These results indicated that there was no relationship between nest size and quantity of food stored.

2.7.1 Percentage of larvae and quantity of food stored

The percentage larval composition of mounds and quantity of food stored during the various sampling period are shown in Appendices 2a - 2e. In the December/January 1974 sampled series, the largest amount of food (172 g) was stored in a mound with a very low larval percentage (0.5%), while a mound with the largest larval composition (11.7%) had no food store. The mounds sampled at other periods within the year showed variable results. However, it would appear that an inverse relationship existed between percentage larvae in the mound and the quantity of food stored. This relationship seemed to be consistent with the observation (Sands, 1961) of

Table 12. Number of mounds, % mounds with grass and mean dry weight of stored grass per mound during different sampling periods.

Sampling Period	No. of mounds sampled	% mounds with food store	Quantity stored range (g)	Mean dry wt./mound (g)
Dec/Jan 1974	20	73.0	5.3 - 171.6	48.2
April/May 1974	20	50.0	3.5 - 63.6	15.5
August/Sept 1974	20	65.0	5.3 - 82.5	36.6
Dec/Jan 1975	20	100.0	8.1 - 323.3	142.9
Primary Savanna Woodland Zugurma Bush (Sept/Oct 1974)	20	70.0	4.5 - 72.5	46.6

the existence of a 'breeding' mound in a colony of Trinervitermes sp.

2.7.2 Quantity of food stored in mounds at study site

Since no obvious relationship existed between mound size and quantity of food stored, estimates of the quantity of food stored in mounds at the plots could not be calculated by relating mound size to the amount of food in the mound. However, the different size group of mounds followed a fairly normal distribution (Fig. 3), and it was assumed that 20 mound samples taken at random from this area during the different sampling period would follow a similar distribution. On this basis, the quantity of food stored in the mounds at the plots was calculated by multiplying the mean dry weight of food estimated for each sampling period (Table 12) by the mound density/plot in the study area.

The results are shown in Table 13.

The quantity of food stored in the grazed plots (B and C) was estimated at 17.70 kg/ha at a mound density of 317/ha, while in the ungrazed plots (A and D) food stored amounted to 10 kg/ha at a mound density of 173/ha. There was no significant difference in the amount of food stored per mound in grazed (55.8 g) and ungrazed (57.8 g) plots. Similarly there was no significant difference between the amount of food stored per unit area in grazed plots (1.77 g/m^2) and ungrazed plots (1.0 g/m^2). However, quantity of food stored per unit (1000 termites) of population was significantly greater in grazed plots (8.43 g/1000 termites) than in ungrazed plots (4.76 g /1000 termites) assuming the population density in the study area to be 2,0300000 termites per hectare.

2.8 Nutrient composition in mound stored grass, standing grass and grass litter

Tables 14 and 15 show the results of the analysis. Table 16 shows the

Table 13. Mean mound density, quantity of food stored in grazed and ungrazed plots.

	Grazed Plots (B & C)	Ungrazed Plots (A & D)
Mound density/ha	317	173
Mean dry wt. of grass stored kg/ha	17.70	10.0
Quantity of food stored /mound (g. .)	55.8	57.80
Food stored/unit area g/m^2	1.77	1.0
Food stored per 1000 termites (g)	8.43	4.76

Table 14. Plant tissue analysis - grass stored in mounds.

Site of Collection	Collection Date	% Total						C : N ratio
		N	P	Ca	Mg	K	Organic Carbon	
Ranch Area (Mounds 1-20)	Dec. 73/Jan. 74	0.91	0.06	.40	.17	.10	28.5	31.3
Ranch Area (Mounds 21-40)	April 1974	0.80	0.06	.30	.11	.10	28.5	35.6
Ranch Area (Mounds 41-60)	August 1974	0.57	0.04	0.25	.11	.10	28.0	49.1
Ranch Area (Mounds 61-80)	Dec. 74/Jan. 75	0.63	0.05	0.30	.17	.20	29.0	46.0
Primary Woodland Zugurma bush (Mounds 1-20)	August/Sept. 1974	0.46	0.04	0.25	0.19	.10	29.0	63.0

Table 15. Plant tissue analysis - standing grass and plant litter.

Collection Date	Site	Nature of sample	% Total						C : N ratio
			N	P	Ca	Mg	K	Organic Carbon	
June 1974	Plot D (Ungrazed)	Litter	.57	.05	.30	.15	.25	28.0	49.1
		Standing grass	.68	.07	.40	.22	.95	29.8	43.8
August 1974	Plot C (Grazed)	Litter	.51	.04	.25	.17	.20	29.0	56.9
		Standing grass	.57	.06	.40	.28	.90	27.5	48.2
October 1974	Plot D (Ungrazed)	Standing grass	.57	.05	.35	.17	.25	29.0	50.9
December 1974	Plot D (Ungrazed)	Litter	.46	.05	.35	.19	.30	29.0	63.0
		Standing grass	.34	.04	.40	.24	.60	29.0	85.3
February 1975	Plot D (Ungrazed)	Litter	.46	.04	.45	.20	.30	28.6	62.2
		Standing grass	.60	.06	.45	.24	.70	28.0	46.7
October 1975	Plot D (Ungrazed)	Litter	.46	.05	.55	.20	.20	29.0	63.0

Table 16a. Mean % total N, P, K, Ca, Mg, Organic Carbon and C : N ratio of stored grass, standing grass and grass litter during the dry season (October-April).

Nature of sample	N	P	K	Ca	Mg	O. Carbon	C : N ratio
Stored grass	0.78	0.06	0.12	0.33	0.15	28.66	36.74
Standing grass	0.50	0.05	0.52	0.40	0.22	28.67	57.33
Grass litter	0.46	0.05	0.27	0.45	0.20	28.86	62.75

mean figures for samples taken during the dry season (October-April), since foraging and storage were restricted to this period. Termites prefer their food dry and hence the stored material, standing grass and grass litter were low in Nitrogen (< 1%). The percentage Nitrogen in mound stored grass (0.78) was however higher than in standing grass (0.50) and grass litter (0.46) respectively. Percentage P, Mg and Ca were not significantly different in the samples, but percentage K, seemed to be much higher in standing grass (0.52) than in mound stored grass (0.12) and grass litter (0.27). Percentage organic carbon in the various samples were relatively constant. The C : N ratio was significantly lower in stored grass (36.74) than in standing grass (57.33) and grass litter (62.75).

3. Discussion

1. An initial visual estimate of the area indicated that the plots were fairly homogenous in species composition, but the vegetation analysis indicated variation in composition. Even though H. dissoluta was the most abundant species of grass in the area, accounting for over $\frac{1}{3}$ of the species present, its distribution within the plots was less than even, accounting for only 24% of the species present in plot C as against 56% in plot A. However, H. dissoluta together with A. gayanus accounted for 50% or more of the herbaceous vegetation in the area while the remaining 13 species accounted for about 30% of the vegetative cover. The results confirmed the suggestion (Kershaw, 1967) that in nature, plant communities were never fully homogenous.

2. The results of the grass production measurement indicated that standing grass was at a minimum in April. Rate of growth was approximately 500 kg/ha between April and June, but was almost doubled in June to August and August to October. There was a marked reduction in growth after October and at the end of the dry season, standing biomass fell due to litter production exceeding growth. Litter biomass was at a minimum at the end of the dry season. The rate of litter decomposition was greatest in the dry season and coincided with the period of intense foraging by certain Macrotermitinae (e.g. M. subhyalinus, Odontotermes spp.). Production on the grazed plots was similar to that on ungrazed plots but there was a significant difference in that there was notable growth and increase in standing grass biomass in the grazed plots, during December-January, almost certainly as a result of grazing in October to December. Cattle consumed 1404 kg/ha, approximately half (48%) the net production and an amount equivalent to that was being decomposed (Table 5). In contrast, on the ungrazed plots, more than two thirds of the net production was channelled through decomposer organisms.

3. The higher number of mounds recorded in the grazed plots (B and C, mean 114) as compared with the ungrazed plots (A and D, mean 82), could be attributed to the effect of grazing on the establishment of mounds. Sands (1965), found out from his studies on the effect of shade on the establishment of mounds of various species of Trinervitermes in Northern Nigeria, that T. geminatus mounds were more abundant in open or cleared grasslands than in shaded areas. It would therefore appear that the effect of grazing was to create open spaces for the construction of mounds in the grazed plots, but in the ungrazed plots, the tall grasses that resulted, created shade which limited the number of mounds established. The high number of dead mounds recorded in grazed plot B (51), would appear to have arisen partly as a result of the effect of grazing, and partly through "human interference" since plot B was used as the standard plot for fortnightly foraging observations. However plot C (grazed) showed a much lower number of dead mounds (17), comparable to those recorded in ungrazed plots A (20) and D (11) respectively. Number of mounds lost, through erosion aided by trampling and buffetting by cattle in grazed and ungrazed plots showed no particular trend, since as many as 37 mounds in plot B and 16 in plot A were recorded, as compared with only 8 and 2 mounds lost in plot C (grazed) and D (ungrazed) respectively. The mean number of active mounds estimated in the study area (232/ha) compared favourably with the mean of (251/ha) in two areas of the Northern savanna zone of Nigeria, (Sands, 1965). The results are also paralleled by those of similar mound building species (Amitermes vitiosus and Tumulitermes hastalis) in Australia (Wood & Lee, 1971) with mound densities of approximately 240 mounds/ha. Number of dead and abandoned mounds within 1974/75 was calculated at 100/ha, out of which 64/ha were lost through erosion aided by trampling and buffetting by cattle in grazed plots.

The number of newly formed mounds was greater in plot C (grazed, 21) than in ungrazed plots A and D with 8 mounds each. However, in plot B, a comparable number of mounds were recruited as in the ungrazed plots. If the mean number of recruited mounds in both grazed and ungrazed plots was expressed as a percentage of mean total of mounds in the plots there was no significant difference between the number of recruited mounds in grazed plots (B and C, 13.1%) and ungrazed plots (A and D, 9.7%), indicating probably that a longer period was required for the effect of grazing on mound recruitment to be noticeable.

The percentage addition to existing mounds did not seem to follow any particular trend. Some mounds were enlarged $1\frac{1}{2}$ times their original sizes (e.g. mounds 47, 64, 162 and 342). Other mounds had smaller additions ranging from 2.8% to 97%. Fifty percent of the mounds measured had enlargements exceeding half their original sizes. Englargement of mounds therefore appeared to result in the doubling or trebling of the size of the original mounds. Building of new mounds and the enlargement of old ones were often simultaneous activities most noticeable during the rainy season (Plate 3).

The coefficient of dispersion as indicated from the results showed a mean of 0.097, indicating aggregation in mounds of T. geminatus with approximately 4-5 mounds making up a colony. The results were consistent with those of Sands (1965), which showed that mounds of several species of Trinervitermes in Northern Nigeria were aggregated, even in the densest populations. Wood and Lee (1970), suggested that overdispersion could occur within the area occupied by the aggregation of mounds. The aggressive behaviour shown by T. geminatus when soldiers from different colonies were mixed together, would suggest overdispersion within the aggregation, probably leading to competition, but such competition for nesting site or

food was most unlikely in the study area. Nel (1968) noted aggressive behaviour between workers of different colonies of H. mossambicus leading to the apportioning of areas into colonial territories.

4. There has been little published quantitative data on the amount of food stored in the nests of grass harvesting termites. The only quantitative estimate was that reported by Watson et al (1970) on D. perniger - a grass harvesting termite in Australia. This species was said to have stored approximately 200-500 grams of grass per mound at an unspecified mound density. From my results, grazing did not appear to have any significant effect on the total quantity of grass stored per mound. However, the quantity stored per unit of termite population was significantly greater in grazed than in ungrazed plots. This difference could be attributed to the affect of grazing and trampling on the amount of grass litter produced. Trampling knocks down standing grass tussocks and together with grazing, contribute to large quantities of grass litter seen after each grazing activity. Grass fragments could then be easily picked up by foraging termites and stored in nests. Thus, the rate at which grass fragments are collected and stored seem to be greater per given unit of termite population in grazed than in ungrazed plots.

5. Attempts made to identify the various species of grass stored in mound failed, because of the difficulties involved in identifying dried grass fragments. However the more obvious species of Microchloa indica (thin leaved) and the hairy grass fragments of Andropogon gayanus were identified.

The low C : N ratio in stored grass might be partly due to the conditioning effect of microorganisms and partly by the favourable condition of temperature and moisture, which not only favoured the growth of micro-organisms but also tended to favour the mineralization of the Nitrogen

contained in the organic matter content of the mounds. Since plant tissues contain little Nitrogen (Lee & Wood, 1971), protein supplementation in T. geminatus, like many other termites, could be achieved through the eating of dead and injured members of the caste. Moore (1969) noted extensive cannibalism in termites, in cases of severe nitrogen deprivation, but Ratcliffe et al (1952) maintained that nest sanitation rather than protein conservation might be much more important, since little or no information existed on the incidence of cannibalism under natural conditions.

SECTION III. MOUND POPULATION ESTIMATES OF T. GEMINATUS

1. Materials and methods

1.1 Whole mound sampling

Mounds were selected at random from two adjacent areas close to the study plots. As a result of the time involved in excavating mounds, sorting and counting termites, sampling was limited to 20 mounds taken over a period of 1 month, at 3 monthly intervals during a 12 month period. Samples of mounds were taken early in the mornings, there being a higher proportion of the population in the mound at this time.

Measurements were made of the height, basal circumference and two arcs at right angles of each mound, and dug up to depths of 0.5-1 m in order to ensure that a greater proportion of the population were included in the mounds. Mounds were carefully lifted, and termites remaining in the underground galleries, collected and placed in polythene bags. One or two mounds were sampled each day depending on the size of the mound, each being taken to the laboratory for extraction and counting. A similar sample of 20 mounds was taken in the Zugurma plots between September and October 1974.

1.2 Mound core sampling

The method was based on that of Sands (1965b). The core equipment consisted of a tubular iron pipe of diameter 1.5" (3.6 cm), welded to an iron handle. From the welded end to the free end measured 7" (16.8 cm). The free end was sharpened so that it could easily cut into the mound. The iron pipe was hammered into the base of the mound and a core sample containing termites was obtained. Core samples were taken from 20 randomly chosen mounds which were measured, and later dug up, taken to the laboratory for extraction and counting.

1.3 Extraction of termites

1.3.1 Heat extraction

This method involved breaking up the mounds and placing the fragments in a heat extraction box measuring 3' x 1' x ¾" (86.4 cm x 28.8 cm x 21.6 cm). This is a modified Tullgreen funnel consisting of an upper lid fitted with six - 100 watt electric bulbs which formed the source of heat. The base of the box was made of wire gauze on which the broken mound fragments were placed. The base of the box was channeled into two large aluminium funnels, below which were receptacles in which the termites and grass fragments were collected. The heat extraction box was capable of accommodating fragments of one medium sized mound. These fragments were left for a period of 12-24 hours. This ensured that all the termites were driven out of their compartments into the receptacle. The termites and grass fragments were separated by flotation in water. The grass which floated on top were sieved off, dried and weighed, while the termites were removed and stored in 70% alcohol.

1.3.2 Manual extraction

The method consists of breaking the mound, a little at a time and removing the termites by means of aspirators. The termites were then stored in 70% alcohol. This method, even though tedious and time consuming, ensured that the various castes were removed fresh. Usually a team of 2-3 people were capable of handling one mound per day depending on the size.

1.4 Determination of the number of termites/mound

Two methods were adopted depending on the size of the mounds. (a) For small sized mounds, the number of termites were determined by direct counting of the inhabitants of the mound. (b) For large mounds, the method of Maldague (1964) was used. The method consisted of taking several

aliquot sub samples in 10 mm vials, counting the number of termites in each subsample and obtaining an average number per vial. The number of vial samples obtained from a mound population was then multiplied by the mean number of termites for aliquot subsample to give an estimate of the total number of termites in the mound. The constancy of the estimates was checked by allowing two different people to count 20 - ten mm vial samples. The mean and standard error for each individual count was obtained. The difference between the means and the standard error of the mean difference was calculated and a t-test showed no significant difference between means. Each 10 mm vial sampled contained approximately 558 $\pm$ 4.7 termites which was used as a multiplying factor.

1.4.1 Determination of the proportion of each caste in total population

Termites counted were mixed together thoroughly by shaking in a big conical flask. Five aliquot samples were taken from this mixture with 10 mm vials and the different castes in the samples were sorted out and counted. The total number of each caste from each of the five aliquot subsamples was summed, to give totals for all castes. From these figures (Table 16) the proportion of each caste and hence the % of each caste in the total mound population was calculated.

1.5 Colony development in T. geminatus

In T. geminatus the alates appeared in the nests in mid-June and flight took place late July or early August in the Mokwa area. The winged reproductives emerged from their nests, flew for a short period, fell to the ground and shed their wings. The female first assumed a 'calling' position which attracted the male, and the result was the formation of a tandem with the female in front and the male following very closely behind. They burrowed into the ground through some crack in the surface and

Table 16. Method of calculation % composition of castes in a sample population.

Example: Mound No. 61

Total population counted 11,236 termites

Sample No.	Major Sold.	Minor sold.	Workers	Nymphs	Larvae	Total
1	8	41	368	5	80	
2	12	18	252	4	47	
3	8	27	309	4	77	
4	16	30	323	1	108	
5	15	32	359	2	77	
Totals	59	148	1,611	16	389	2430
Propn. of total popn.	272.8	684.3	7449	73.98	1798	11235.9
% Composition	2.4	6.1	66.3	0.7	16.0	

constructed a nest chamber or copularium.

The incipient colonies were reared according to the method described by Sands (1965b). Handling of the termites was minimized by allowing the tandem pairs to crawl into tubes which were then plugged with cotton wool pending their introduction into the culture plates.

The culture apparatus consisted of two window glass plates 6" x 4" (15 cm x 10 cm) separated by $\frac{1}{4}$" wide glass strip round the perimeter. The space so formed was filled with sterile soil sifted and watered with about 3 cc of water per plate at intervals of 3-4 days. In this way soil moisture was maintained at approximately 10%. The culture plates were kept in a culture room with darkened windows with minimum fluctuation of temperature (mean 30°C). The plates were examined at 2 day intervals. 16 colonies were altogether established.

2. Results

2.1 Correlating nest size and numbers

A total of 80 mounds were sampled during the year from areas adjacent to the study plots. The results showing mound size and total number of termites per mound sampled during different occasions are shown in Appendices (2a - 2d). Results of a similar sample of 20 mounds taken between September-October 1974 from the Zugurma area is also shown in Appendix (2e). From the results, it would appear that a sample of 20 mounds taken on each sampling occasion was unlikely to reflect exactly the frequency of different mound sizes. In order to relate nest size to numbers, the log numbers of population were plotted against the size of mounds (sum of two arcs) at the different sampling periods. A linear regression equation was obtained for each sampling occasion (Fig. 4a - c). After the reassessment of the mounds in the various plots between December 1974 - January 1975, (to take account of the construction of new mounds and expansion of existing mounds, as well as the erosion of abandoned mounds), a similar regression (Fig. 4d) was calculated for the 20 mound samples taken during this period. A similar calculation was made for the 20 mound samples taken from the Zugurma bush, (Fig. 4e). The regression equations and the correlation coefficient calculated for the different sampling periods are shown in Table 17. The number of termites per mound in each plot at the different sampling occasions was calculated from the regression equations and these together with the various mound sizes are shown in Appendices (3a - 6b). Similar results for the 4 plots in the Zugurma area of primary woodland are shown in Appendices (7a - 7d).

As the size of termite population is a function of the mound density in a given area and the number of individuals per nest, the population density was calculated by multiplying the mean number of termites per mound

Figures 4a - 4d.

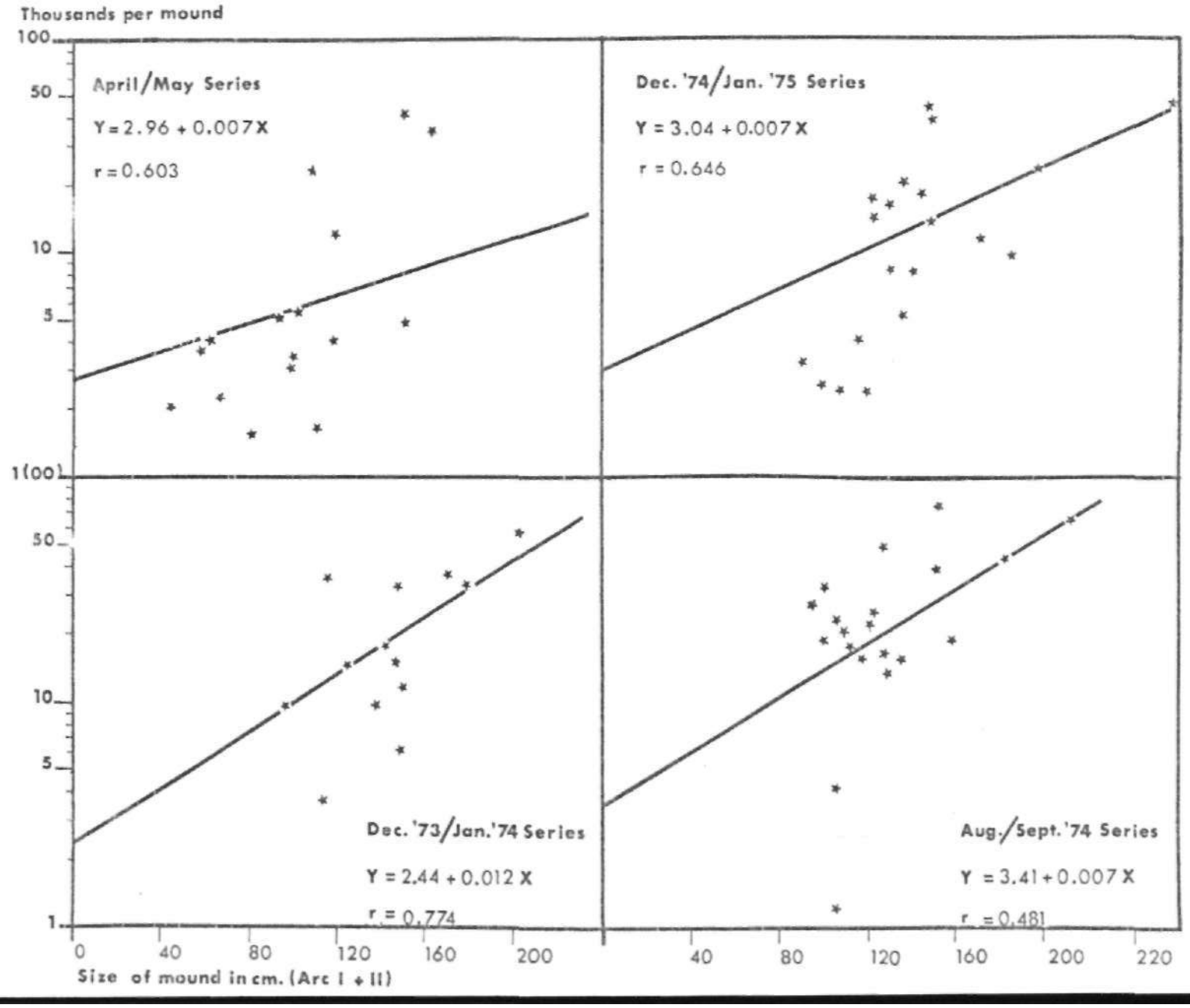


Figure 4e.

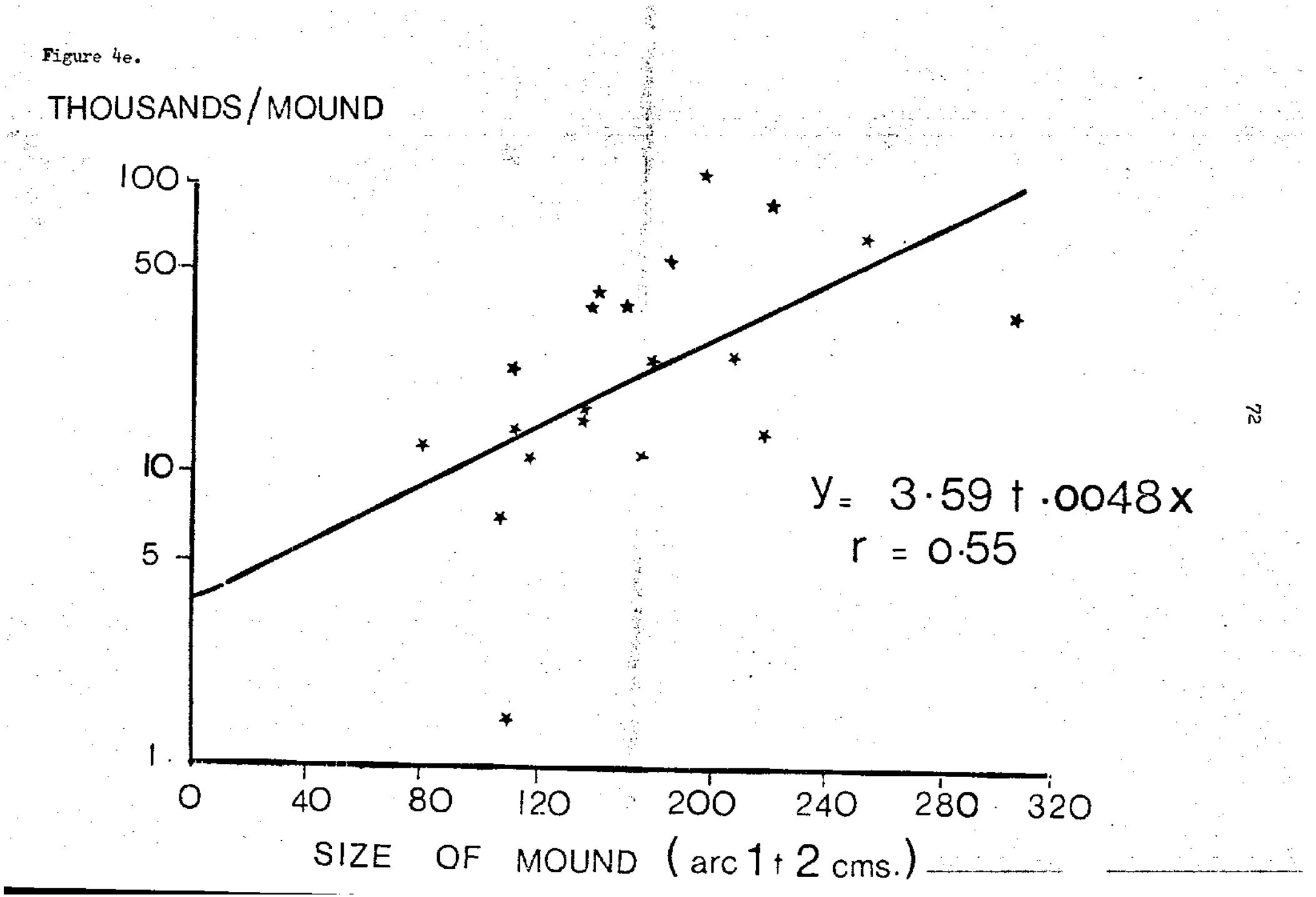

THOUSANDS/MOUND
100
50
10
5
1
0
40
80
120
200
240
280
320
SIZE OF MOUND (arc 1 t 2 cms.)
y = 3·59 t ·0048x
r = 0·55

Table 17. Regression equations and correlation coefficients obtained during the different sampling periods.

Sampling Period	Regression Equation	Correleation coefficient (r)	r^2
Dec./Jan. 1974	Y = 2.44 + 0.012X	0.774	0.599
April/May 1974	Y = 2.96 + 0.007X	0.603	0.364
Aug./Sept. 1974	Y = 3.41 + 0.007X	0.52	0.27
Dec./Jan. 1975	Y = 3.04 + 0.007X	0.65	0.42
Zugurma Bush (Primary Wood-land)			
Sept./Oct. 1974	Y = 3.59 + 0.0048	0.55	0.30

Y = Population

X = Size of mound (cm)

Table 18. Mound population density calculated from regressions at different sampling periods between 1973-1975.

Plot size 0.2 ha approx.

PLOTS & TREATMENTS	A (UNGRAZED)		B (GRAZED)		C (GRAZED)		D (UNGRAZED)	
Sampling Period	No. termites /mound calculated from regression	Population /m^2	No. termites /mound calculated from regression	Population /m^2	No. termites /mound calculated from regression	Population /m^2	No. termites /mound calculated from regression	Population /m^2
Dec./Jan. 1974	4099	114.8	3496	150.3	4306	176.5	6016	135.4
April/May 1974	3722	104.2	3478	149.5	3866	158.5	4104	92.3
Aug./Sept. 1974	11549	323.4	10399	447.2	11511	471.9	13799	310.5
Dec./Jan. 1975	5802	127.6	5771	126.9	6935	228.9	6126	122.5
Mean	6293	167.5	5786	218.5	6654	258.9	7511	165.1

Mean population ungrazed plots 166.33 ± 78.59

" " grazed " 238.7 ± 116.78

Mean all plots (203/m^2)

Table 19. Population estimate - primary woodland (Zugurma bush) (plot size 30 m x 90 m).

Plot Number	Species present	Mean No. of termites/mound calculated from regression	No. of mounds occupied/plot	Population /m^2
13	T. geminatus	13,045	40	193.3
	T. occidentalis	10,820	3	12.0
14	T. geminatus	15,087	56	312.9
	T. occidentalis	12,356	3	13.7
	T. togoensis	11,750	1	4.4
15	T. geminatus	10,792	49	195.9
	T. occidentalis	6,920	8	20.5
	T. togoensis	9,215	6	20.5
16	T. geminatus	11,939	45	199.0
	T. occidentalis	11,522	3	12.8
	T. togoensis	7,140	8	21.6
Mean	T. geminatus	12,804	47.5	225.0
	T. occidentalis	9,380	4.2	14.8
	T. togoensis	8,277	3.0	11.5

by the density of mounds per plot. The results obtained from the 4 plots in the study area as well as from the plots in the primary woodland (Zugurma plots) are shown in Tables 18 and 19 respectively. Graphs (Fig. 5) were plotted to show how termite populations in the different plots changed during the year.

2.2 Percentage of caste composition at different sampling periods

The proportion of the different castes and hence their percentage composition in the population per mound during each sampling period within the year including the Zugurma sample is shown in Appendices (2a - 2e) and summarized in Table 20.

Table 20. Percentage caste composition at different sampling periods.

Sampling Period	% Workers	% Soldiers		% Nymphs	% Larvae	% alates
		Major	Minor			
Dec. 1973 - Jan. 1974	66.6	4.6	11.7	0.88	3.26	0.00
April - May 1974	68.5	5.8	18.2	2.88	4.34	0.00
August - Sept. 1974	80.2	7.11	14.1	1.0	1.3	2.99
Dec. 1974 - Jan. 1975	72.06	10.1	13.7	0.33	4.81	0.00
Mean	71.0	6.9	14.4	1.28	3.4	-
Sept. - Oct. 1974 Zugurma Bush (primary savanna woodland)	81.5	8.8	7.8	0.0	2.7	0.00

Workers were the most numerous individuals in the colony ranging from 66-80% with a mean of 71.0%. The highest population of workers was recorded

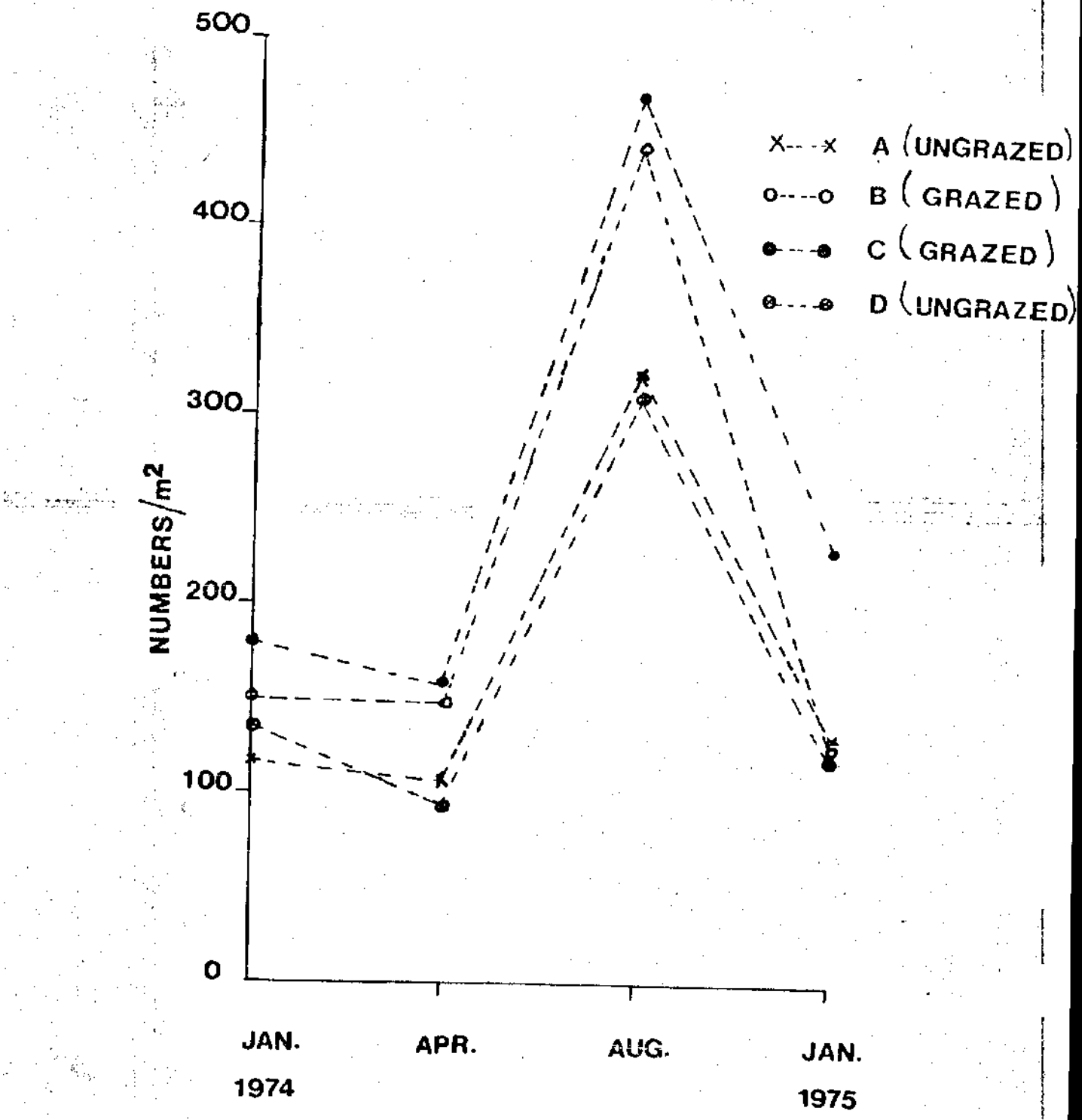

500
400
300
200
100
0
NUMBERS/m2
JAN.
1974
APR.
AUG.
JAN.
1975
A (UNGRAZED)
B (GRAZED)
C (GRAZED)
D (UNGRAZED)

Figure 5.

in August/September. The soldiers were next in numerical abundance comprising about 21% of the colony. The minor soldiers were in the majority (14%) as compared with the major soldiers (7%), giving a ratio of major: minor soldiers at 1:2. Except for the months of December/January 1974, when soldiers formed 16% of the population, their numbers remained fairly constant (23-24%) during the sampling periods. Worker: soldier ratio in the samples were on the average 3:1. Larval population were generally low ranging from (1.3%-4.8%) with a mean of 3.4% throughout the different sampling periods. Nymphs comprised on the average 1.28%, though a higher percentage was obtained in April/May with an average of 2.88% and insignificant proportions in December/January (< 1%).

Alates appeared in August in the Mokwa area. Mound counts taken at that period showed alates present in 6 out of the 20 mounds sampled and percentage of alates in the mounds ranged from (0.03%-8.3%) with a mean of 2.99%. The queen and king were rarely found in the mounds of T. geminatus except on two occasions when they were encountered in the sampled mounds.

In the 20 mounds sampled in September/October, in the primary savanna woodland, a similar picture was shown in caste composition. Workers constituted 76-87% of the entire population with a mean of 81%. Soldiers made up (16%) with major soldiers comprising 8.8% and minor soldiers 7.8%. Larval population was low (2.73%). In the course of sampling, some mound-sharing species such as (Formicidae) and other termites such as Microtermes sp. and Cubitermes sp. were observed. In one case, it was estimated that Microtermes sp. made up 12.8% of the total mound population.

2.3 Timing of major events during colony development

The timing of major events during colony development are shown in Table 21. Following the introduction of the reproductives into the plate

Table 21. Development time and commencement of foraging in T. geminatus.

Days from introduction of tandem pair to oviposition	Mean	3.7
	Range	3 - 5
Days from oviposition to first hatching of eggs	Mean	30
	Range	28 - 31
Days from hatching to the formation of 1st functional worker	Mean	24.6
	Range	23 - 27
Days from appearance of 1st worker to commencement of foraging	Mean	15.6
	Range	8 - 20

nests, seven pairs burrowed into the soil following a tunnel made for them at the centre of the plate nest, while the remaining nine pairs constructed their own tunnels close to the sides of the plates, and commenced the construction of the nest chamber (copularium). Some of the colonies constructed well rounded nest chamber about (2-3 cm) in diameter. There was intensive grooming between the parent imagos and oviposition commenced between 3-5 days after introducing the pair. The eggs were laid singly but were packed together to form egg clumps with an average of 10-20 egg per clump. These egg clumps were carefully removed towards the perimeter of the copularium and some were consumed by the reproductives. The first larvae were seen in the nest from 28 to 31 days. The larvae were tended by both parents and the queen continued to lay eggs.

The first functional workers with sclerotized mandibles were observed in the nest between 23-27 days after the hatching of the eggs. Nine of the 16 colonies became inactive probably due to their small nest chambers which

became overcrowded. As a result further observations on them were not carried out. In three of the remaining seven plates, brown headed minor soldiers emerged at the same time with the workers, but in the rest of the plates, minor soldiers emerged 1-4 days later.

Gallery formation was observed in only three plates and this occurred between 8-20 days after the formation of the functional workers. These tunnels radiated from the nest chamber towards the soil surface. Workers were seen extending their tunnels and covering the chamber walls and glass plate with soil, making observations fairly difficult. Ten grass fragments were placed by the front edge of the culture plate. It was observed that only one colony succeeded in dragging three grass pieces into their nest chamber. Further covering of the chamber walls made it impossible to make further observations.

These observations seemed to compare favourably with those of Sands (1965b). He observed that oviposition in his colony of T. geminatus commenced about 4 days after entry, with an incubation period ranging from a minimum of 26 days to a maximum of 42 days. First functional workers appeared between 26-36 days after hatching, with the excavation of the first tunnel occurring 3 weeks after the appearance of the workers in the nest.

2.4 Numbers, biomass of caste in mound population

Estimates of individual biomass of the different castes were made by weighing individuals taken from two mounds belonging to two different colonies. Mean percentage caste composition as determined from samples was used in calculating the number of each caste in total population.

The mean % caste composition and the individual biomass of the different castes are summarised in Table 22a. From the data, the numbers and

Table 22a. Caste composition and individual biomass.

Castes	% Composition	*Individual Biomass (mg)	
		Fresh wt.	Dry wt.
Workers	71.0	5.5	1.2
Major soldiers	6.9	3.4	0.7
Minor soldiers	14.42	0.8	0.46
Larvae	3.4	1.2	0.4
Alates	2.99	12.30	9.73

* Each figure represents mean weight from 10 samples each of 20 termites/ caste.

Table 22b. Number and biomass of termites in study area.

No. of termites/ha as calculated from regression = 2030000 (203/m^2).

No. of each caste/ha (using % caste composition)

	Workers	Major Sol.	Minor Sol.	Larvae	Alates
	1441300	140070	292726	69020	60900
Biomass g/m^2 (fresh weight)	0.800	0.047	0.023	0.008	0.075
" " (dry weight)	0.173	0.010	0.013	0.003	0.059

Total Biomass g/m^2 (fresh weight) 0.95

" " " (dry weight) 0.258

biomass of termites in the area of study has been calculated. At 0.0123 g or 12.3 mg/individual (wet weight) and 9.73 mg (dry weight), the winged reproductives were the heaviest termites. Workers weighed on the average almost 2 times the weight of major soldiers and 2.6 times as much as the minor soldiers. Individual larvae dry weight was small but with an overall mean of 0.4 mg. The biomass or standing crop of each caste in the population was calculated. On fresh weight basis, biomass of the termites was estimated at 0.95 g/m^2; 0.26 g/m^2 (dry weight). This represents 9.5 kg/ha live biomass or 2.6 kg/ha dry weight.

2.4.1 Estimation of potential production in T. geminatus

When the duration of larval development into mature worker is known, as well as the total larval population, it is possible to calculate the total production. Total production is calculated as the sum of the production of alates plus sterile castes and calculated as follows:-

Population of termites/ha (mound estimate) = 2,030000

Mean % larvae (as per samples) 3.4

No. of larvae/ha = 0.034 x 2030000 = 69020

Development time from larvae to mature functional worker as shown from laboratory culture = 24.6 days

No. of eggs hatching/day = 69020 ÷ 24.6

= 2805.69

No. of eggs hatching/yr = 2805.69 x 365

= 1,024,077.2

Larvae production = 102.41/m^2/yr

Alate Production:

% alates as per sample = 3.0%

Number of alates/ha = .03 x 2030000

= 60900

Alate production = 6.09/m^2

Worker/Soldier Production:

Worker/Soldier Production = Larvae Production - Alate Production

= 102.41 - 6.09

= 96.32/m^2/yr.

Ratio of Worker/Soldier has been shown to be 3:1

Worker production 72.24/m^2/yr

Soldier production 96.32 - 72.24

= 24.08/m^2/yr

Production Major/Minor Soldiers

Ratio of Major: Minor = 1:2

Major soldier production = 8.03/m^2/yr

Minor soldier production = 16.05/m^2/yr

2.4.2 Production/biomass ratio in T. geminatus

On dry weight basis, production in T. geminatus for the different castes was calculated using the individual dry weight biomass (Table 22a).

Workers	72.24 x 0.0012 g	=	0.087 g
Major soldiers	8.03 x 0.0007 g	=	0.006 g
Minor soldiers	16.05 x 0.00046	=	0.0074 g
Alates	6.09 x 0.00973	=	0.0593
Total production		=	0.1597

Biomass of workers + soldiers (Major and Minor) + larvae

= 0.1990 g

Production/biomass ratio = $\frac{0.1597}{0.1990}$

= 0.80

3. Discussion

1. An analysis of the data obtained from 20 mounds from which core samples were taken showed no correlation between number of termites in the core sample and total population in the mound ($r = 0.06$). As noted by Lee and Wood (1971), the core sampling method as adopted by Sands (1965b) was based on the assumption that the concentration of termites in the core sample was the same as that in the rest of the inhabited part of the mound. The lack of correlation as obtained from the results could be explained from the fact that core samples were taken from different sized mounds, where different proportions of the population were sampled. In large mounds, the core sampled termites in the outer portions of the mound, while in small mounds, the core sampled not only the outer portion but also the central portion of the nest with a high density of termites. The method proved unreliable and was subsequently not used in estimating mound populations.

2. The 'whole mound count method' used by Holdaway et al (1935), Gay and Greaves (1940), Maldague (1964), Bouillon and Mathot (1964), Gay and Wetherly (1970), Josens (1971) and Lepage (1974), gave a fairly reliable estimate of sampled mound populations. The coefficient of correlation (r, 0.77; r^2, 0.599), obtained from the December/January 1974 sampling between mound size and numbers in the mound, suggested that about 60% of the variation in the population could be accounted for by mound size. The correlation was significant ($p < 0.01$). The correlation coefficients for the other sampling periods (Table 17) were lower than those of December/January 1974, but were positive and significant at the 1% and 5% levels of probability. Although some large but old mounds were sometimes found with low populations, an indication that such mounds were in the process of being abandoned, the results indicated that the size of a mound could be regarded as a fairly good index of its population.

3. Mound populations calculated from the results indicated that populations in the various plots were low in December/January 1974 and remained low through April (Fig. 5). The highest population was recorded in the months of August/September. The figures obtained at this time of the year (rainy season) could be regarded as the most accurate estimate associated with most of the mounds in the study area, since foragers would be expected to be in the mounds at this period. The effect of grazing was not apparent on mound populations within the year, since there was no significant difference in population between grazed ($238.7 \pm 116.8/m^2$), and ungrazed ($166.3 \pm 78.6/m^2$) plots in the study area. The mean population density was calculated at $203/m^2$ in the study area with a mound density of 232/ha.

In the Zugurma plots of a primary woodland, T. geminatus was similarly the most abundant species with a mean population of $225/m^2$ at a mound density of approximately 175/ha. The population density in this area, even at a lower mound density compared favourably with those at the study plots with a mean density of 232/ha. The population of T. occidentalis and T. togoensis which generally occupied abandoned mounds were low and estimated at $14.8/m^2$ and $11.5/m^2$ respectively. As rightly noted by Holdaway, Gay and Greaves (1935), it was often impossible to find all termites associated with a mound, present in the mound at the same time. Mound populations, as indicated by the results, would therefore appear to be underestimated for the following reasons (a) There was an unknown population outside the mound at any sampling period and (b) The depth of penetration of the termites which often extended to about 2 metres; especially in the dry season.

4. Mound populations indicated seasonal variation in numbers and activity. The low populations in December to April coincided with the dry season which could have affected populations in two ways (i) Loss in numbers from

obtained a figure of 0.006 $g/m^2/yr$ (dry weight) for neuters of T. geminatus in the Sahelian savanna in Senegal. This figure is comparable to the calculated figure of 0.0104 $g/m^2/year$ obtained in the study area.

The calculated production: biomass ratio (0.8:1.0) compares favourably with Josen's (1972) figure of 1:1 for the same species in the 'derived' savanna zone of the Ivory Coast. The higher production: biomass ratio (10.2:5.4) obtained in the Macrotermitinae was attributed to the high production of Neuters in response to predation pressure, (Wood and Sands, in press).

mounds through active foraging, (ii) Deeper penetration of the termites into the soil as a result of the cold harmattan during the months of December through February. Foraging ceased in May/June with the onset of the rains and populations increased by 2-3 times by the end of the wet season (Aug/Sept). Foraging started in October/November and reduction in numbers during this period appeared to be a reflection on foraging activity. Sands (1965) obtained similar variable results in the Northern Guinea savanna zone of Nigeria.

5. Production in termite colonies takes two forms, alates and sterile castes; Wood and Sands (in press). Alates are produced over a short period annually during the rainy season (May-October) in the Mokwa area. These alates which have the potential for founding new colonies represent a loss in biomass and energy to the parent colony. Alate composition of approximately 3% obtained from the results agree with similar low figures for the same species ranging from 1-5% (Sands, 1965b; Josens, 1972). Higher percentages have been recorded in other termites, for example, Bouillon (1970) recorded 10% alate composition in Cubitermes exiguus, Pterotermes occidentis 30% (Nutting, 1966b); Odontotermes obesus (Rambur), 28-43.3% (Roonwal, 1960).

Sands (1965b) calculated an annual production of 240-470 alates/m^2 for T. geminatus in the Northern Guinea savanna of Nigeria. This figure is quite higher than the calculated alate production (6.09/m^2/yr) in the Mokwa area of the Southern Guinea savanna zone. On dry weight basis, alate production was calculated at 0.059 g/m^2/yr comparable with Josen's (1972) figure of 0.045 g/m^2/yr for the same species, quoted by Wood and Sands (in press).

Few measurements exist on the production of Neuters. Lepage (1974)

SECTION IV. FORAGING AND GRASS CONSUMPTION

1. Materials and methods

1.1 Laboratory food preference studies

Medium sized mounds of T. geminatus of about 0.25 m high and basal circumference of 0.8 - 1.0 m were dug up from the field in different locations and transplanted into wooden bins 120 cm x 120 cm x 22.5 cm, covered at the bottom and sides with corrugated iron-sheets. The bins were filled to depths of 22 cm with top soil free of grass fragments and the edges were smeared with vaseline to prevent the escape of foraging termite parties. The bins were kept in a room with more or less constant temperature, and watered once a week. Within 24 hrs termites established their galleries and commenced foraging on the surface of the bins.

Six different grass species - A. gayanus, H. dissoluta, P. pedicellatum, C. giganteus, M. indica and Cyperus sp. were tested for preference by T. geminatus. The grass species were presented in the form of artificial standing grass tussocks of standard lengths 10 cms and dry weight of 0.5 gms. The tussocks were arranged in two 3 x 6 randomised blocks at opposite corners of the bin with the mound in the middle (Plate 6).

Each block consisted of 3 rows with each row having a randomly located tussock of each species of grass. At the end of each days foraging, the remains of the attacked tussocks were dried, weighed and replaced with new tussocks weighing 0.5 g. Thus each day, the termites had a choice of equal quantities of each grass species. A control was set up with grass tussocks but no mound. The experiment was carried out over a period of eleven days with five mounds from different locations representing different colonies.

1.2 Measurement of amount of grass harvested and carried back to the nest

The selection of a random sample of foraging holes for observation was limited because of certain restrictions imposed through the foraging

behaviour of T. geminatus. As holes were not continuously used and as there were no permanent trails, it was not possible to make observations at permanently marked holes or to measure "traffic" past fixed reference points. A random selection had to be made separately for each foraging period. Initially attempts were made to select, from a predetermined area, a random sample of foraging holes and to count the number of pieces of grass carried down the holes during 5-minute periods at intervals of 30 minutes. Thus two observers could take observations at a maximum of 12 holes. After several trials, this method had to be abandoned as it was not possible to make the required number of observations at holes where activity was low without seriously disturbing the termites.

However, it became apparent after observing several holes on many different days that foraging activity at individual holes could be described in the form of a curve (Figs. 6a, 6b and 6c). The curves for different holes on the same day were similar in shape, being determined by the timing of onset, peak and cessation of foraging which were roughly synchronous, although the amplitude of the curves was determined by the level of activity at each hole. After several trials the following method described below was adopted.

The observations were made on four 0.25 ha areas set aside for studies of foraging by Trinervitermes (Fig. 2), one on each plot.

Within these areas 5 strips, each measuring 3 m x 30 m were laid at random and marked with pegs. At the beginning of the foraging period one observer systematically searched each strip and marked foraging holes that were open. When there were many holes open, usually every 3rd hole was marked giving approximately 15-20 marked holes in the five strips. If there was little foraging, it was necessary to mark every hole. A second

observer counted the number of pieces of grass carried down each marked hole in 5 minutes. Meanwhile, the first observer, having finished marking holes, commenced similar 5-minute observations on selected very active holes (usually 3 in number) and repeated these observations at intervals of 30 minutes. Thus for each foraging period the following data were obtained

(a) Single observations, at different times of the foraging period, at all marked holes. These observations, started shortly after foraging commenced, were usually completed part way through the foraging period. The duration of these observations were denoted by t_1.

(b) Repeated observations at 3 holes for the complete foraging period (t_2). As the onset, peak and cessation of foraging at different holes on any particular day were roughly synchronous, and independent of the level of activity then if

$\bar{x}st_1$ = mean of single observations over the period t_1

$\bar{x}rt_1$ = mean of repeated observations over the period t_1

$\bar{x}rt_2$ = mean of repeated observations over the entire period (t_2)

Then the mean harvesting rate for all marked holes over the entire period ($\bar{x}st_2$) was given by $\frac{\bar{x}st_1 \cdot \bar{x}rt_2}{\bar{x}rt_1}$ .....(1)

and the number of pieces of grass harvested per m^2 on the five strips of total area 450 m^2 over the entire foraging period t_2 in minutes was given by $\frac{\bar{x}st_2 \cdot n \cdot t_2}{450 \cdot 5}$ .....(2)

where n was the total number of holes opened.

In order to express the amount of grass harvested on a weight basis, pieces of grass being carried by workers were collected at random at a number of

different foraging holes. These were dried and weighed and the mean weight of grass fragments was calculated from varying samples of 100 fragments each. The foraging sampling described above was carried out in 4 plots, two of which were grazed and two ungrazed at fortnightly intervals. Observations were made on plot B (grazed), which was taken as the standard plot, during four successive days within a fortnight to determine the pattern of activity within this period. On the 4th day of sampling, in addition to the sampling in plot B, all other plots (A, C and D) were equally sampled. Thus within a fortnight, plot B was sampled on 4 successive days while other plots were sampled on the 4th day. The harvesting rate/m^2/ day was calculated for each of the plots on the 4th day from mean activity curves. The mean rate/m^2/day for the 4 days was calculated for plot B. Knowing the rate of harvesting/m^2/day for each plot and the mean rate/m^2/day for the standard plot, than the mean rate/m^2/day for the 4 days for plots (A, C and D) was calculated by proportion.

Example: Taking plot A.

Suppose A_4 = the rate/m^2/day in plot A on the 4th day

B_4 = the rate/m^2/day in plot B on the 4th day

$\bar{Bx}$ = the mean rate/m^2/day for plot B on the 4 days of successive observations

Then $\bar{Ax}$ which represents the mean rate/m^2/day for plot A for the 4 days is given by $\frac{\bar{Bx}}{B_4} \cdot A_4$ .....(3)

Similarly the mean rate/m^2/day for the 4 days of observations for plot C and D were calculated.

1.2.1 Measurement of grass cut down but left as litter

30 (0.5 m^2) quadrats were laid at random in areas within 3 plots (B, C and D) where foraging activity was mostly observed. Each quadrat was

Table 23. Method of calculating rate of grass harvesting by T. geminatus. Values of rt_1 and rt_2 are number of pieces of grass harvested/5 minutes/foraging hole and are obtained from the mean activity curve in Fig. 6a. (Symbols as in text)

5th March 1974

Time	$t_1 = 120$	$t_2 = 210$
	rt_1	rt_2
06.00	0	0
06.30	15	15
07.00	28	28
07.30	40	40
08.00	52	52
08.30	-	74
09.00	-	50
09.30	-	0
	$\bar{x}rt_1 = 27.0$	$\bar{x}rt_2 = 33.1$

$$\bar{x}st_1 = 33.8$$

$$\bar{x}st_2 = \frac{33.8 \times 33.1}{27.0}$$

$$= 41.5$$

cleared of litter and swept clean with broom. Quadrats were examined every four days within a fortnight between January to April 1975. All the grass cut down and abandoned by termites (easily recognised by the characteristic chewing marks left by the termites on grass fragments), were collected from each of the quadrats which were again swept clean. The fragments so collected were dried and weighed.

1.2.2 Measurement of the amount of grass consumed while foraging

Observations in the field indicated that worker termites returning to the nest had full crops, indicating ingestion of food while foraging. In order to quantify the amount consumed, measurements were made to determine weight differences between outgoing and incoming workers after foraging had commenced.

Fifty outgoing workers were carefully picked up with forceps at random just before the commencement of foraging. These were placed in a clean preweighed glass bottle. 30 minutes after commencement of foraging, 50 each of outgoing and incoming laden workers were again picked up at random and put separately in preweighed glass bottles. This process was repeated after 1 hour and $1\frac{1}{2}$ hour intervals respectively. The bottles with their contents were oven dried at $60^{o}C$ for two hours and reweighed. The weights of the different categories of workers during the different collecting periods were found. Weight differences between outgoing workers before commencement of foraging and ingoing laden workers at 30 minutes, 1 hour and $1\frac{1}{2}$ hours were obtained.

1.3 Age determination in the worker caste

Two criteria were adopted in determining age, firstly, mandibular wear measured by the length of the apical tooth of the left mandibles and secondly the head width, which could vary at each moult of the workers.

Random collections of both categories of workers were made from foraging parties in the field by means of fine forceps, kept in separately labelled tubes and taken to the laboratory for measurement. A total of 105 termites of each category were measured on different dates.

1.3.1 Measurement of the head width and apical tooth of grass carriers and grass cutting workers

In order to investigate whether any differences in function existed between workers that carried grass to the foraging hole and those that actually cut down standing grass tussocks, measurements were made of these two categories in the manner already described.

Fifty termites each were collected from grass carrying workers returning to the foraging hole and from termites on grass tussocks cutting down grass blades.

1.4 Relating foraging cycle to subsoil and soil surface temperatures

The effect of temperature on foraging cycle was investigated. Soil surface, subsoil and mound temperatures were measured between November 1974 - April 1975; at intervals which coincided with foraging observation periods. Temperatures were recorded by means of thermistor sensors connected to a Grant temperature recorder Plate 7. The thermistor sensors (temperature probes) were protected from outside influences by passing them through aluminium tubes open at both ends and cut into different lengths. This device made it easier to push the probes through the soil and mound structures. The Grant recorder was set in such a way that temperatures at the different sites were recorded at hourly intervals during each 24 hour period. The foraging cycle for each day and the hourly subsoil, soil surface and mound temperatures were recorded and the data looked at with two main objectives (a) To see whether foraging was related to sub-

soil and soil surface temperatures, and if so at what temperature ranges foraging occurred. (b) To investigate whether foraging was in response to changes in temperature as foraging occurred in the morning/or late afternoon when temperatures were either rising or falling.

2. Results

2.1 General observations on foraging behaviour

Mixed parties of workers, major soldiers and minor soldiers travel from the mound via subterranean galleries to the soil surface where they emerge through circular foraging holes approximately 4 mm in diameter. More rarely foraging parties emerge from holes cut at the base of the mound. The holes are opened at the beginning, and closed with a plug of soil at the end of the foraging period. Some holes were reused on successive days, whereas others were used only once and there appeared to be no way of predicting which holes would be used on any particular day. The foraging holes could be scattered throughout an area with no specific arrangement but quite often holes were seen arranged in a line stretching from the mound to varying distances away from the mound. Measurements of the distances between foraging holes, the distance covered by foraging holes and the number of holes, indicated that they were excavated at fairly uniform distances from one another ranging from 0.28 - 0.44 m. The mean number of foraging holes in a column was estimated at 21 and the distance covered by these holes was about 7 metres.

It was observed that the foraging holes were opened by workers breaking open the thin plug of soil. The first individuals to emerge were the minor soldiers which took up outward-facing positions on the edge of the hole. More minor soldiers and a few workers emerged, the workers often returning to the hole in the initial stages until eventually, a mobile foraging column, flanked by minor soldiers was formed. Usually 30-45 minutes elapsed between the breaking of the plug and establishment of active foraging. Usually, there was a single column from each hole which extended for distances of up to 2 to 3 m from the hole. The column was well defined, usually no more than 3-5 individuals wide, except at its

extremity where the termites spread out for the purposes of collecting grass. There might be as many as 500-800 workers on a single grass tussock (Plate 4) and often 40-50 workers might be occupied in cutting the same stem or blade of grass at different points. On grass blades of large diameter, (e.g. Andropogon gayanus), 3-4 termites were observed cutting at a point and the cutting time was estimated at 2-3 minutes; but on thin grass blades of (e.g. Microchloa indica), a single worker termite could cut down the grass within less than 1 minute. Lengths of grass could be severed near the base and fall to the ground with their load of workers, whereby the latter either commenced cutting it into shorter pieces, or they disbanded leaving the grass (often 20-30 cm long), lying on the ground.

The process of harvesting on any particular grass tussock did not appear to be well organised, as in addition to grass being 'wasted', smaller pieces could be picked up, put down and other pieces picked up, but at the end, a proportion (20-30%) of workers returning to the foraging hole carried back pieces of grass ranging in length from 2-20 m (Plate 5). Cessation of foraging was evidenced by a strong stream of workers, few of which carried grass, returning to the foraging hole. Meanwhile, the minor soldiers moved rapidly in all directions around the periphery of the column; their function appeared to be two-fold, firstly to protect the workers from marauding ants (Crematogaster sp. which were particularly active around foraging parties and frequently carried off workers that wandered away from the main foraging party), and secondly to 'round up' any straggling workers. Closure of the hole took only 2-5 minutes and occasionally a few individuals might be left outside where they were rapidly taken by ants.

These field observations led to the investigation of the activity of workers, and whether any age differences existed between grass and non-

grass carriers. Quantitative estimates were also made of the amount of grass cut down and carried back to the nest, amount cut down and left as litter and quantity consumed while foraging.

2.2 Field observation on food selection

Field observations on feeding were recorded whilst developing a method for quantifying the rate at which grass was harvested by T. geminatus. Field observations were mainly confined to the dry season. During this period, dead standing grass was more abundant than green grass. Observations indicated that Andropogon gayanus was the species most often attacked by T. geminatus. It foraged less commonly on the fine-leaved species, although as these were much less abundant, this was not indicative of any preference for A. gayanus. Also observations indicated a preference for the fine-leaved Microchloa indica by T. togoensis, though no quantitative data were available.

T. geminatus was observed feeding on most of the species listed (Table 1) and some low lying vegetation such as Zornia glochidiata. During the period of observation, harvesting was almost exclusively confined to dry grass. During periods when green grass was more abundant just at the beginning of the rains, sporadic foraging by T. geminatus showed a distinct preference by the termites for the dry grass and approximately 60-70% of the harvested pieces were in this category.

2.3 Reaction to disturbance

T. geminatus, like other species in the genus was very sensitive to disturbance and this imposed certain restrictions on attempts to quantify harvesting. Slight vibration of the ground or vegetation or too close an examination of the termites was often sufficient to cause severe disruption of foraging.

The first signs of disturbance was given by the minor soldiers leaving their flanking positions and running around rapidly in all directions. The final outcome however appeared to depend on the degree of disturbance and intensity of foraging. The foraging party might settle down or foraging might prematurely cease with the termites returning to their foraging hole which was then closed.

During the early stages of foraging, T. geminatus was very easily disturbed and the close presence of an observer (e.g. while attempting to monitor activity), might cause sufficient alarm to result in the hole being closed. However, once foraging was well established and several hundred individuals were out of the hole, observations could readily be made and individual termites collected without or with only temporary disturbance. The same reaction was observed in response to certain predators. Lizards and mantids were often observed moving from one foraging column to the next resulting in rapid closure of the foraging hole.

The curtailing of foraging in this way might have more impact on the colony than the loss of individuals to the colony. The following ants were observed preying on T. geminatus, Myrmicaria sp., Polyrachis sp., Crematogaster sp., Monomorium sp., Megaponera sp., and some species of Neuroptera (e.g. ant lion larvae) which constructed shallow 'pits' in which straying foragers were entrapped.

2.4 Laboratory choice experiments

Table 24a and Fig. 6a show the total and mean dry weights of each species collected by each termite colony for the entire duration of the experiment. A total of 33 gm of each grass species was supplied to each colony within an eleven day period. A greater weight of A. gayanus (7.4 g) and H. dissoluta (2.3 g) was harvested by termites in colony 1, than other

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colonies. Even though colony 3, harvested less A. gayanus (2.8 g) as compared with other colonies, it harvested a greater quantity of M. indica (2.6 g) compared with other colonies. Colony 5, harvested more of A. gayanus (4.3 g) and C. giganteus (2.3 g) than other grass species. Results also showed that T. geminatus harvested on the average 0.41 g/day of A. gayanus, 0.14 g/day H. dissoluta, 0.11 g/day C. giganteus, 0.18 g/day M. indica, 0.10 g/day P. pedicellatum and 0.10 g/day of Cyperus sp. respectively.

An analysis of variance was carried out on the results as shown in Table 24(b). There were variations in the mean quantity of each species harvested. Differences between means were highly significant at the 5% level of probability (F = 11.15). The standard error of the difference between any two means was calculated as 0.562 with an L.S.D. (1.173, t-test. A comparison of this figure, with the mean difference between species showed that the weight of A. gayanus eaten by T. geminatus was significantly greater than the weights of other species consumed. Mean dry weight differences between other grass species tested were not significant.

Table 25(a) and Fig. 6(b) show the number of times or frequency at which each grass species was attacked. A total of 66 tussocks of each grass species was presented to the termites within an eleven day period. During this time, T. geminatus attacked 40% of the tussocks of A. gayanus and 22% of M. indica respectively, while less than 20% of the other grass species were attacked, (H. dissoluta, 17.0%; C. giganteus, 10.6%; P. pedicellatum, 15.5% and Cyperus sp. 12.4%), during the same period.

An analysis of variance of the results (Table 25(b)) showed also a wide variation in the mean frequency of attack of each species, significant at the 5% level (F = 15.76). A standard error of 2.5 and L.S.D. (5.3) were

Table 24a. Dry weight of different grass species harvested by T. geminatus over an 11 day period.

Mound No.	Species					
	A. gayanus	H. dissoluta	C. giganteus	M. indica	P. pedicellatum	Cyperus sp.
1	7.404	2.291	0.710	2.296	0.883	1.214
2	3.510	1.350	1.640	1.600	1.730	1.140
3	2.775	1.690	0.110	2.565	1.130	0.820
4	4.800	1.400	1.160	2.050	0.260	0.890
Totals	22.769	7.941	5.890	9.834	5.743	5.644
Mean	4.554	1.588	1.178	1.967	1.149	1.129

Table 24b. Variance analysis of weights of grass species harvested by T. geminatus.

	Degrees of Freedom	Sum of Squares	Mean Square	F
Mounds	4	3.087	0.772	
Species	5	44.102	8.820	11.15**
Error	20	15.817	0.791	

S.E. for the difference between 2 means = 0.562

$t_{0.05}$ (2) 2.086

L.S.D. (0.05) = 1.173

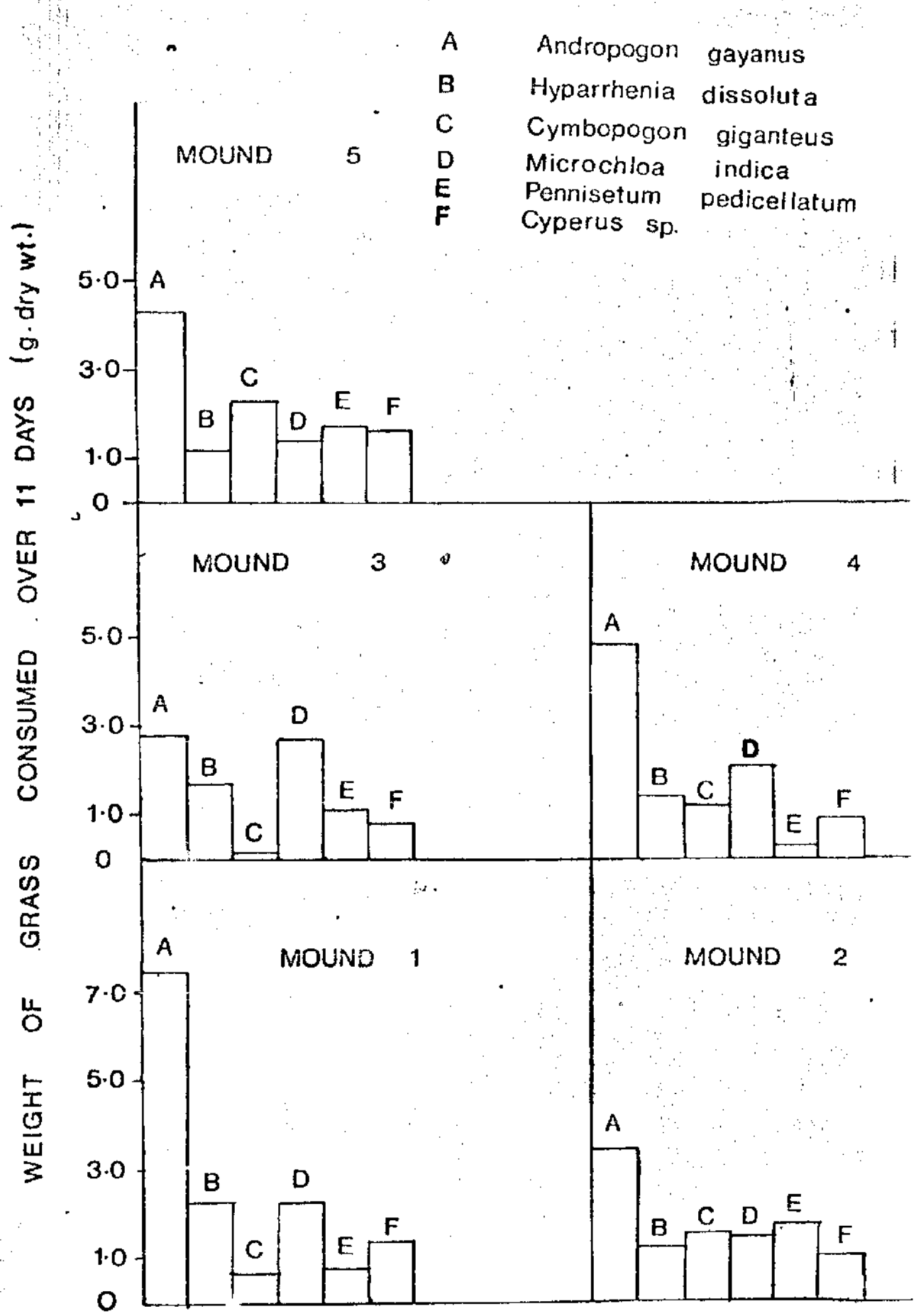

A Andropogon gayanus
B Hyparrhenia dissoluta
C Cymbopogon giganteus
D Microchloa indica
E Pennisetum pedicellatum
F Cyperus sp.
MOUND 5
MOUND 3
MOUND 4
MOUND 1
MOUND 2
WEIGHT OF GRASS CONSUMED OVER 11 DAYS (g. dry wt.)
5·0
3·0
1·0
0
7·0

Figure 6a.

calculated and the mean difference between species similarly showed that the frequency of attack was significantly greater in A. gayanus than other species.

Attack on M. indica was significantly greater than on C. giganteus and Cyperus sp. respectively, but there was no significant difference between M. indica, H. dissoluta and P. pedicellatum.

2.5 Monitoring the activity of various categories of workers in a foraging party

Field observations on several occasions indicated the presence of three categories of workers in a foraging party, namely outgoing, incoming laden and incoming unladen. Their pattern of activity during foraging was investigated. This was accomplished by two people sitting near a fairly active foraging hole with a stop watch and recording the number of outgoing, incoming laden and incoming unladen at time intervals, from the beginning of foraging till the end. One minute count was taken at intervals of 15 minutes for each category of workers.

Figs. 7(a) and 7(b) show graph of numbers of termites in each category counted per minute against time. With the onset of foraging, which normally started 30-45 minutes after the holes were opened, there was a high number of outgoing workers (54/minute) as compared with incoming laden (2/minute) and incoming unladen (35/minute). As the number of incoming laden and unladen increased, the number of outgoing workers declined. The flow of these two categories of workers often resulted in the blocking of the foraging hole, caused mainly by the incoming laden workers which occasionally carried unusually thick and long pieces of grass, which they successfully manoevered to the foraging hole, resulting in the disruption of the flow of outgoing workers.

Table 25a. Frequency of attack of each species by T. geminatus.

Mound No.	No. of times attacked: Species					
	A. gayanus	H. dissoluta	C. giganteus	M. indica	P. pedicellatum	Cyperus sp.
1	29	12	4	12	6	7
2	23	8	9	14	11	5
3	25	16	4	24	20	11
4	28	12	5	14	4	8
5	28	11	13	8	10	10
Totals	133	59	35	72	51	41
Mean	26.60	11.8	7.0	14.4	10.2	8.2

Table 25b. Variance analysis of frequency of attack of grass species by *T. geminatus*.

	Degrees of Freedom	Sum of Squares	Mean Square	F
Mounds	4	110.802	27.70	
Species	5	1276.167	255.233	15.76**
Error	20	323.998	16.200	

S.E. of difference between 2 means = 2.546

$t_{0.05}$ (20) 2.086

L.S.D. (0.05) = 5.310

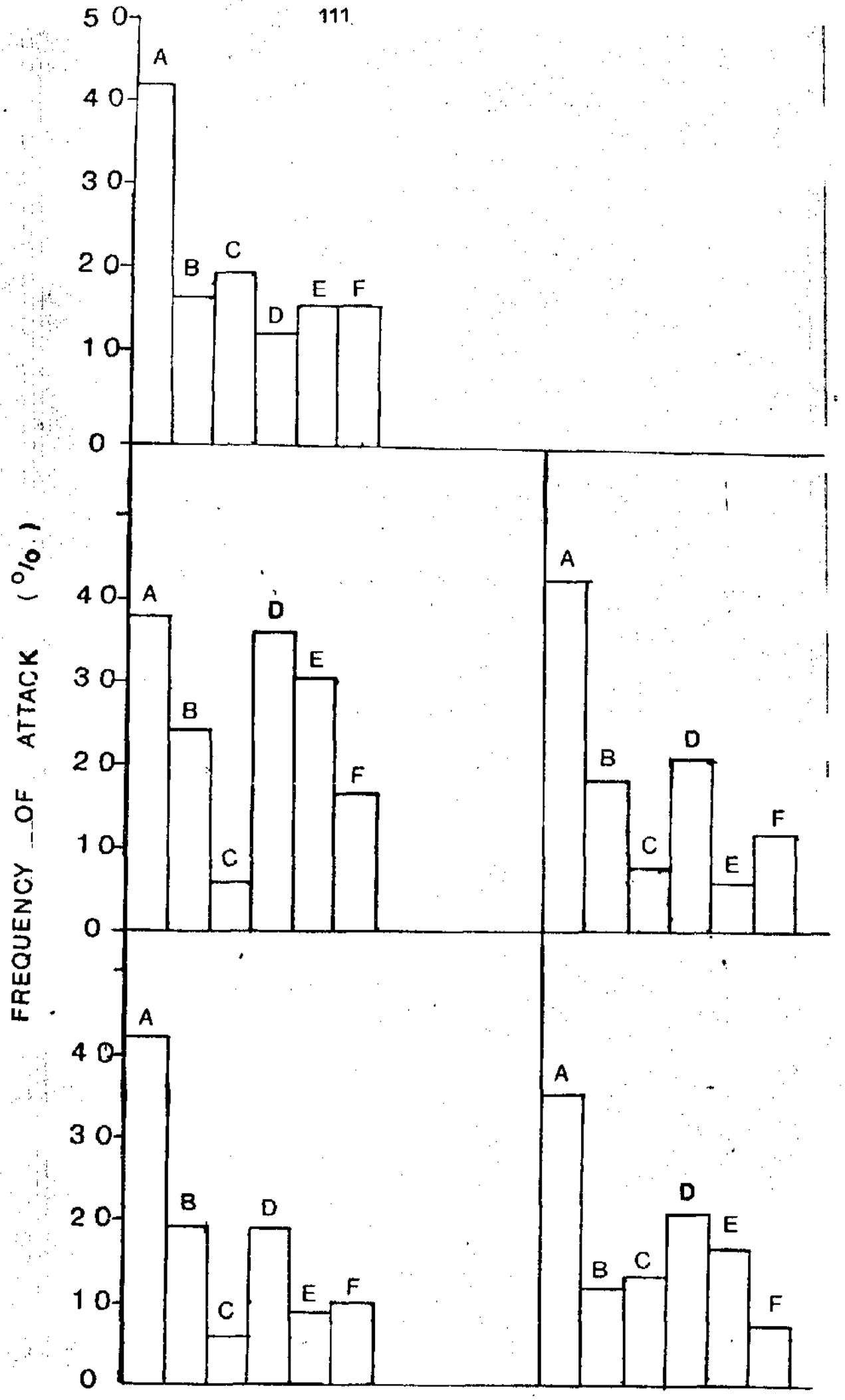
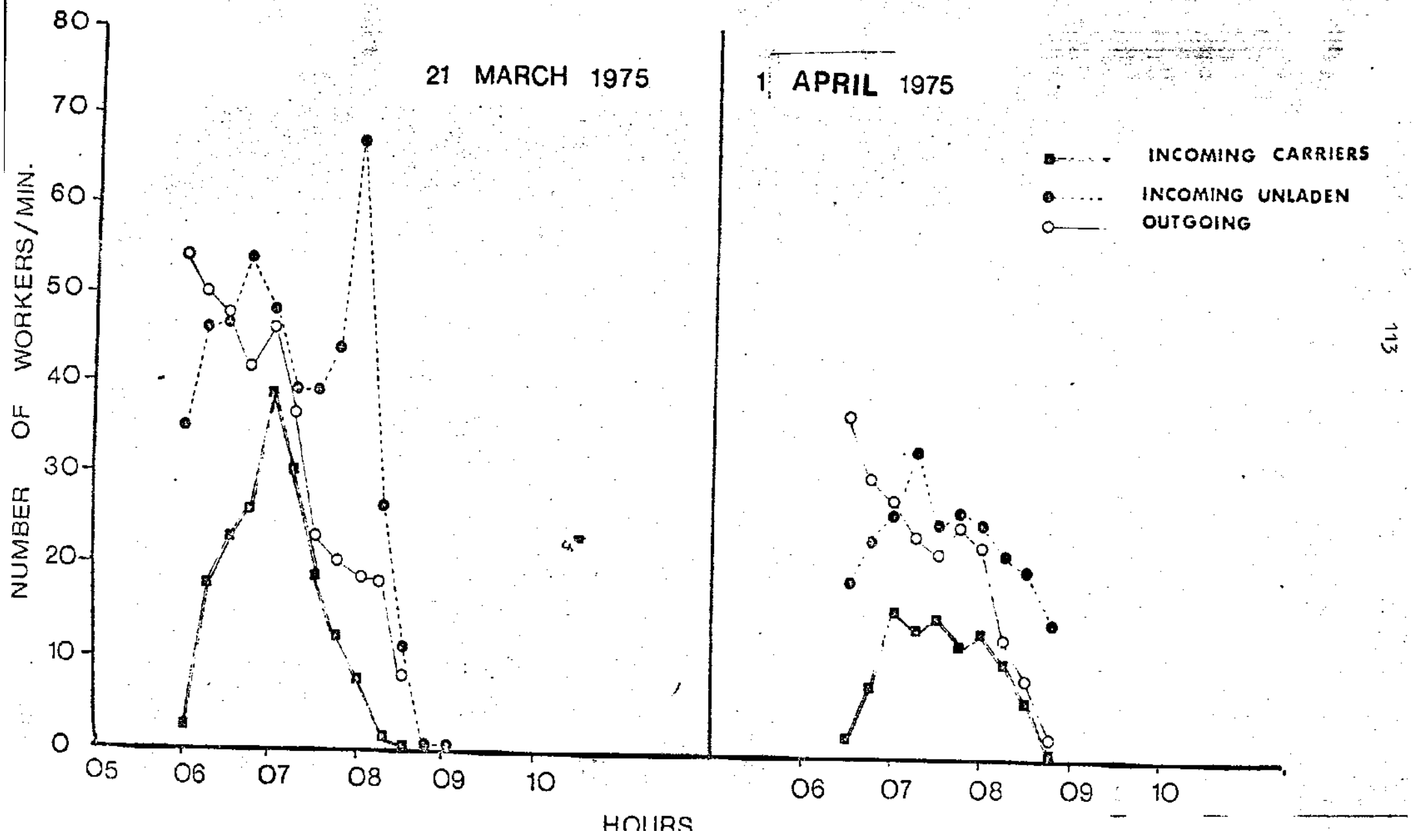


Figure 6b.

Figure 7a & b.


21 MARCH 1975
1 APRIL 1975
INCOMING CARRIERS
INCOMING UNLADEN
OUTGOING
NUMBER OF WORKERS/MIN.
80
70
60
50
40
30
20
10
0
05
06
07
08
09
10
06
07
08
09
10
HOURS

When foraging was about to end, there was a considerable increase (67/minute) in the number of ingoing unladen workers and a corresponding decline in the number of outgoing (18/minute) and incoming laden workers (7/minute). However, throughout the period of activity, the number counted per minute of ingoing laden was low compared with the other two categories. From these activity curves, it was possible to estimate the proportion of carriers (ingoing laden) in a foraging party to be about 28-30%.

2.6 Age determination in grass and non-grass carrying workers

The mean head width and apical tooth length of a total of 105 termites of each category measured at different dates is shown in Table 26(a). Mean head width of grass carriers varied from 1.48 ± 0.060 to 1.64 ± 0.045 mm with a mean of 1.59 ± 0.052 mm. Head widths for non-grass carriers varied from 1.49 ± 0.052 to 1.69 ± 0.055 mm with a mean of 1.61 ± 0.048 mm. The apical tooth lengths of the left mandible in the grass carriers varied from 0.066 ± 0.059 to 0.080 ± 0.067 mm with a mean of 0.072 ± 0.058 mm while those for non-carriers varied from 0.048 ± .017 to 0.052 ± 0.019 mm with a mean of 0.049 ± 0.018 mm.

The results indicated no difference in the head width of both categories of workers. However, the apical tooth length showed a significant difference. Non-grass carriers had a shorter apical tooth than grass carriers, indicating that the former were older. In some samples measured workers in this category had almost completely worn apical teeth of about 0.01 - 0.02 mm in length. The indications were that older workers with worn teeth could not carry grass fragments.

2.6.1 Head width and apical tooth measurements of grass carrying and grass cutting workers

The results indicated that the mean head width of grass carriers

Table 26a. Head width and apical teeth measurements of grass and non-grass carrying workers.

Date	No. measured	Grass Carriers		Non-Grass Carriers	
		Mean Head width (mm)	Apical tooth length (mm)	Mean Head width (mm)	Apical tooth length (mm)
1/ 5/74	20	1.48 ± 0.06	0.07 ± 0.049	1.63 ± 0.052	0.052 ± .019
22/ 5/74	25	1.62 ± 0.038	0.066 ± 0.059	1.63 ± 0.041	0.048 ± .0173
6/ 6/74	25	1.62 ± 0.063	0.080 ± 0.067	1.69 ± 0.055	0.048 ± .0197
11/11/74	35	1.64 ± 0.045	0.074 ± 0.055	1.62 ± 0.042	0.050 ± .0187
Mean		1.59 ± 0.052	0.072 ± 0.058	1.61 ± .048	0.049 ± .018

Table 26b. Measurements of the head width and apical tooth of grass carriers and grass cutting workers.

	Grass Carriers	Grass Cutters
No. measured	50	50
Mean head width (mm)	1.565 ± 0.076	1.623 ± 0.064
Mean apical tooth length (mm)	0.083 ± 0.0155	0.088 ± 0.0218

in the 50 termites measured varied from 1.44 mm to 1.68 mm with a mean of 1.565 ± 0.076 mm, while those of grass cutters varied from 1.48 mm to 1.76 mm with a mean of 1.623 ± 0.064 mm. The apical tooth measurements of grass carriers were similar to those obtained in the previous measurements, ranging from 0.06 to 0.10 mm with a mean of 0.083 ± 0.0155 mm. Grass cutters had apical tooth length which varied from 0.06 to 0.14 mm with a mean of 0.088 ± 0.0218 mm.

From the results it appeared that grass cutting and grass carrying was a function of the young workers. The function of the old workers in a foraging party remained unclear. However, field observations revealed that some of the foraging termites nibbled through the vegetation and removed the epidermal layer of the grass blades, and in this way ingested food into their guts. It would appear that the old workers equally participated in this activity during foraging.

2.7 Harvesting rates and quantity carried back to the nest

Harvesting rates at holes where repeated observations were made are shown in Figs. 8a, 8b, 8c. The mean activity curves calculated from this data are shown in Figs. 8a, 8b, 8c. The curves in Fig. 6a were for a day when the selected holes in addition to being similar in shape, were also

similar in amplitude. In contrast Fig. 8c illustrates curves obtained for 3 holes on a different day, with similar shape and different amplitude. For the purposes of calculating the mean rate of harvesting over the entire foraging period, the mean activity curve was extrapolated to zero foraging at the beginning and end of the foraging period. By reading off values for the rate of harvesting at equally spaced time intervals ($\frac{1}{2}$ hour was selected as a suitable interval), on the mean activity curve, it was possible to calculate the value of $\bar{x}rt_2$. The value of $\bar{x}rt_1$ could be similarly calculated. These calculations are illustrated in Table 23 for the mean activity curve shown in Fig. 8a.

The results of observations made on 4 plots for a period of 13 weeks (182 days) between May 1974 and April 1975 are shown in Appendices 8a-8h with the summary of the results shown in Table 27 for the different plots.

The length of the foraging period varied in all plots, being largely determined by the time foraging ceased as the onset of foraging (06.00 - 06.30) for morning foraging and (05.00 - 05.30) for the evening foraging period were fairly constant throughout the period. In plot B average foraging period varied from (105 - 293 with a mean of 177.3 minutes), plot A (120-210 with a mean of 166.5 minutes), plot C (65-255 with a mean of 173.4 minutes) and in plot D varied from (145-270 minutes) with a mean of 188.1.

The number of holes opened for foraging activity were quite variable in different plots; plot B (66-1452 holes/ha), A (66-990 holes/ha), C (66-1122 holes/ha) and plot D (44-726 holes/ha).

The curves of activity show a gradual build up of activity to maximum rates of harvesting followed by a relatively rapid decline until the holes were closed. The mean rate of harvesting ($\bar{x}st_2$) varied in the plots

Figure 8a.

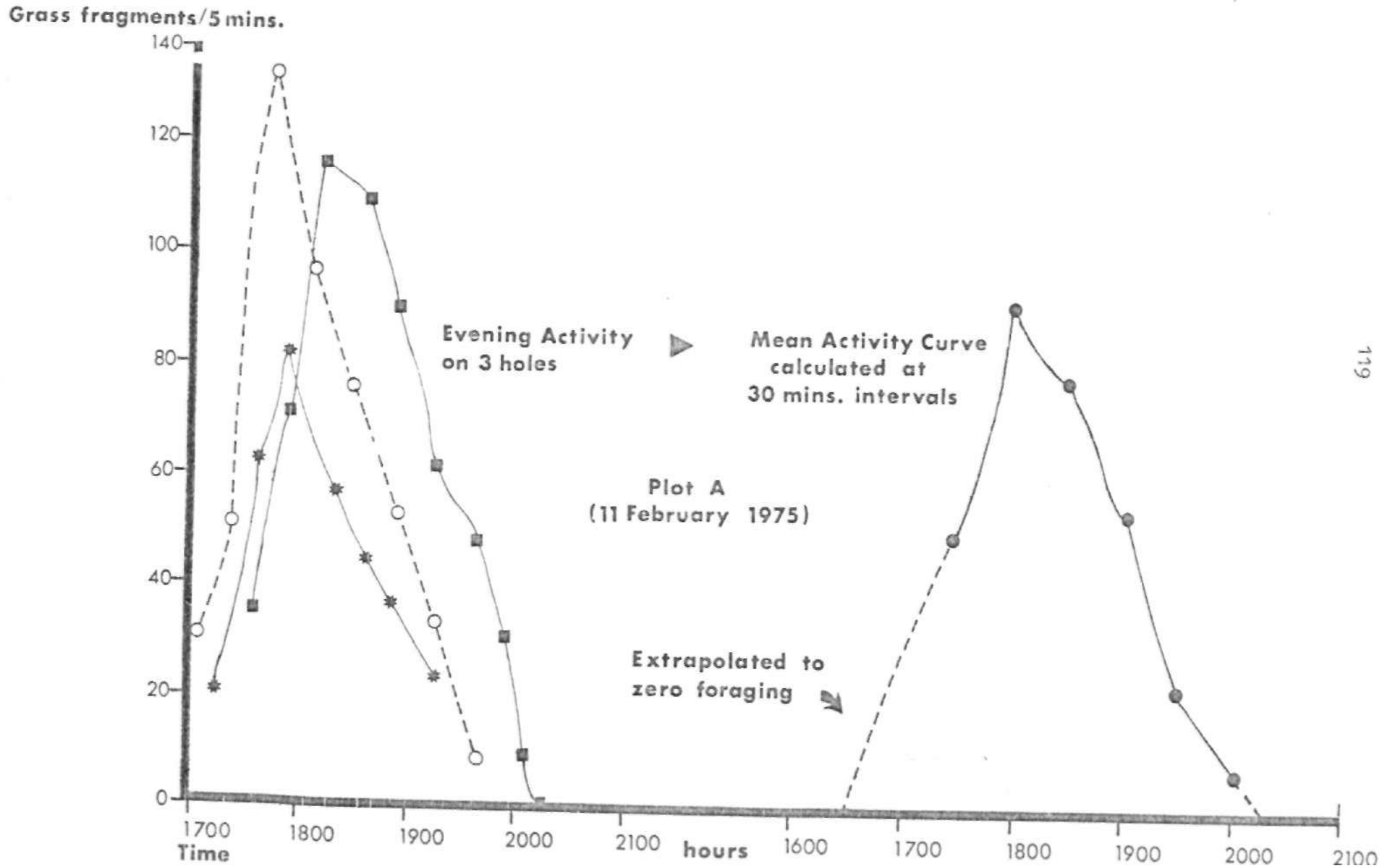

Grass fragments/5 mins.
140
120
100
80
60
40
20
0
Evening Activity on 3 holes
Mean Activity Curve calculated at 30 mins. intervals
Plot A
(11 February 1975)
Extrapolated to zero foraging
1700
1800
1900
2000
2100
Time
hours
1600
1700
1800
1900
2000
2100

Figure 8b.

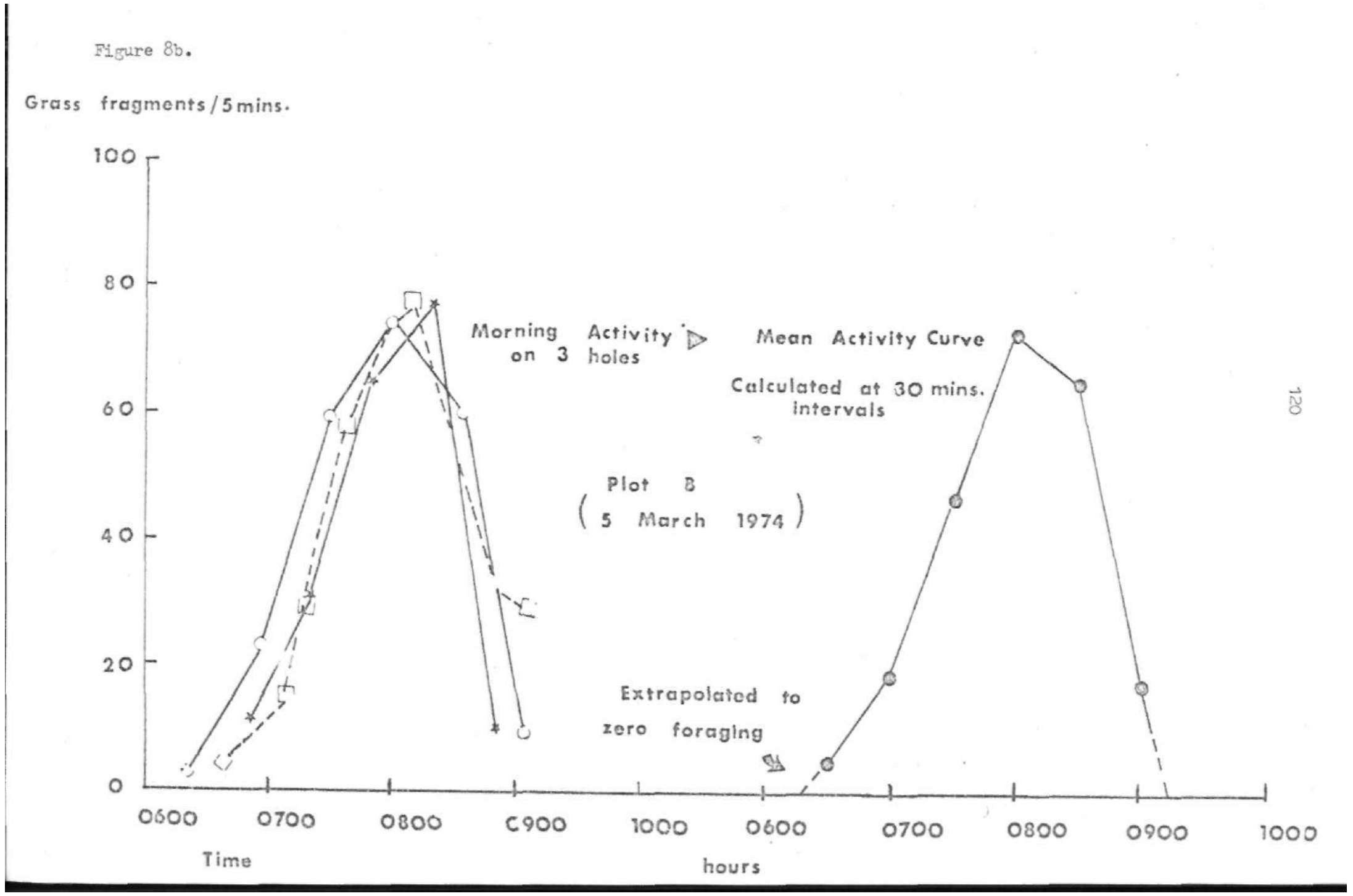
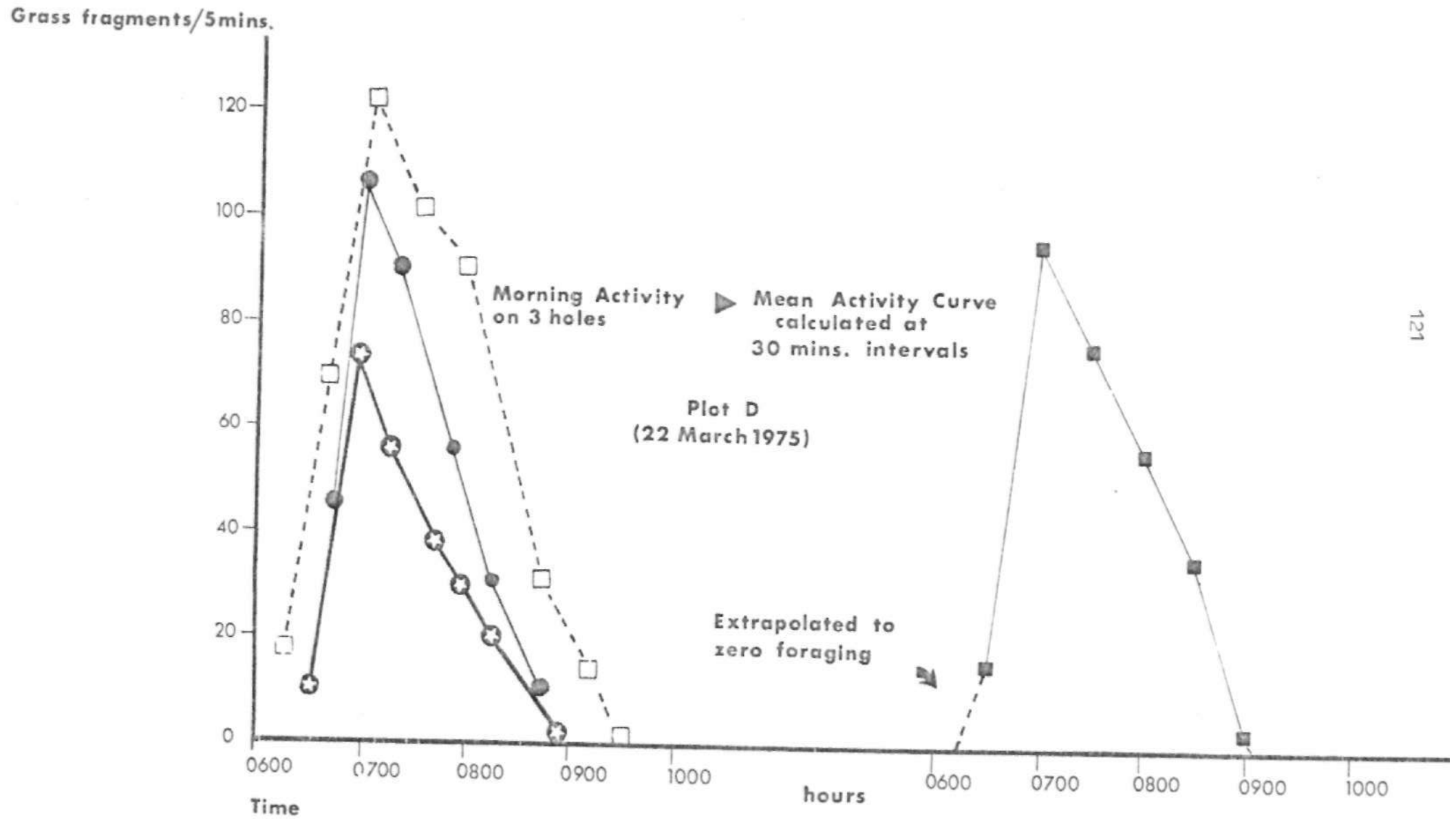

Grass fragments / 5 mins.
100
80
60
40
20
0
Morning Activity on 3 holes
Mean Activity Curve
Calculated at 30 mins. intervals
Plot B
(5 March 1974)
Extrapolated to zero foraging
0600
0700
0800
0900
1000
0600
0700
0800
0900
1000
Time
hours

Figure 8c.


Grass fragments/5mins.
120
100
80
60
40
20
0
0600
0700
0800
0900
1000
Time
Morning Activity on 3 holes
Mean Activity Curve calculated at 30 mins. intervals
Plot D
(22 March 1975)
Extrapolated to zero foraging
0600
0700
0800
0900
1000
hours

ranging from (8.76-46.3 pieces/hole/5 minutes) with a mean of 24.1 in plot B; C (9.58-51.29 pieces/hole/5 minutes) with a mean of 29; A (14.4-39.7) with a mean of 23.6, and in plot D (14.2-66.9) with a mean of 30.0 pieces/hole/5 minutes. At the peak of activity, harvesting rates on very active holes yielded counts varying from 160-220 pieces/hole/5 minutes. Harvesting rate/m^2/day calculated from equation (2) also indicated a wide variation with a range of 2.0/m^2/day to 121.8/m^2/day with a mean of 31.5/m^2/day in plot B; 3.6-47.4/m^2/day in plot A; 5.8-58.7/m^2/day in plot C, and 3.3-43.0/m^2/day in plot D.

The mean dry weight of 100 pieces of grass fragments collected from different foraging holes ranged from 0.10-0.21 g.

The mean dry weight harvested ranged from 0.0023-0.009 g/m^2/day for plot A with a mean of 0.0261 g/m^2/day; plot B, 0.011-0.167 with a mean of 0.045 g/m^2/day; plot C, 0.004-0.098 with a mean of 0.0362 g/m^2/day, and in plot D, 0.003-0.090 with a mean of 0.0253 g/m^2/day. The mean dry weight of grass/m^2 harvested at fortnightly intervals/month recorded throughout the year is illustrated in Fig. 9. In order to obtain the amount of grass cut down and carried back to the nest in each plot, the mean dry weight/m^2/day was multiplied by the total number of days 182 at which foraging activity was recorded throughout the year (Table 27). In the grazed plot B (81.9 kg/ha/yr) and C (65.9 kg/ha/yr) the mean quantity cut down was calculated as 73.9 kg/ha/yr, while in the ungrazed plots A (47.5 kg/ha/yr) and D (46.0 kg/ha/yr), the mean was 46.75 kg/ha/yr.

In the Zugurma area of undisturbed primary savanna woodland 2 days observations were made on the 13th and 14th March 1975 on 5 strips of the same dimensions as those in the experimental plots. The figures obtained during the two day period were compared with those from the standard plot

Table 27. Mean foraging time, number of holes/ha, rate of grass harvesting/m^2/day and the mean quantity harvested in g/m^2/yr during 182 days of foraging.

Plots	A	B	C	D
Mean foraging time (mins)	166.5	177.3	173.4	188.1
No. of holes/ha. (range)	66 - 990	66 - 1452	66 - 1122	44 - 726
Mean rate of harvesting pieces/ hole/5 mins.	23.61	24.14	28.99	30.03
Mean rate of harvesting/m^2/day	21.64	31.47	28.56	22.02
Mean dry wt/m^2/day (g)	0.0261	0.045	0.0362	0.0253
Amount harvested/ha/ yr. (kg)	47.5	81.9	65.9	46.0

Mean harvested grazed plots - 73.9 kg/ha/yr

" " ungrazed plots - 46.75 "

Mean quantity of grass cut down and carried back to the nest by T. geminatus 60.33 kg/ha/yr

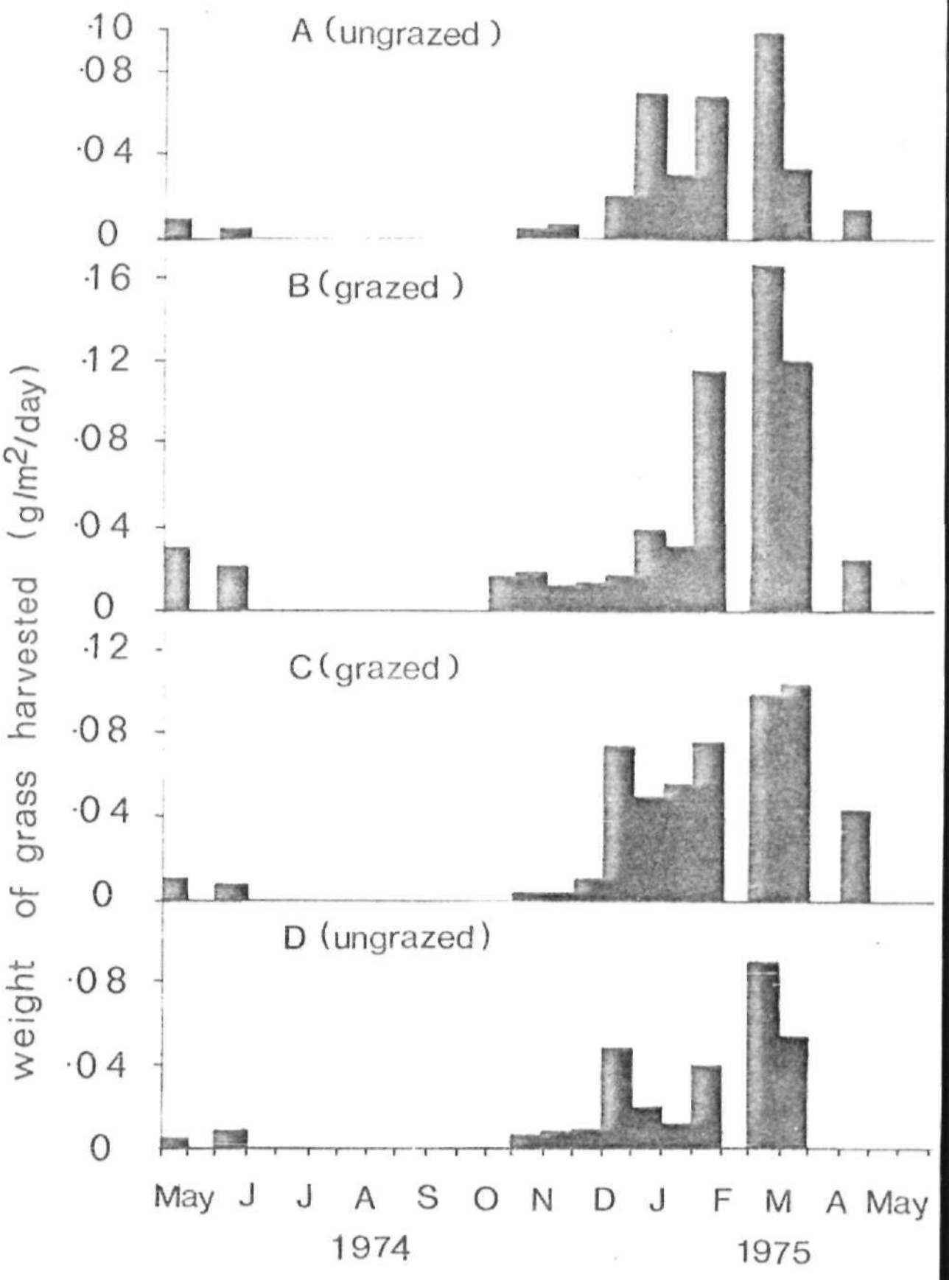

A (ungrazed)
B (grazed)
C (grazed)
D (ungrazed)
·10
·08
·04
0
·16
·12
·08
·04
0
·12
·08
·04
0
·08
·04
0
weight of grass harvested (g/m²/day)
May J J A S O N D J F M A May
1974
1975

Figure 9.

B on the fortnight of 19/3 - 22/3/75. The average foraging period was 180 minutes, average number of foraging holes was calculated at 814 holes/ha. The rate of harvesting varied from 14.7 - 19.9 with a mean of 17.3 pieces/ hole/5 minutes and a daily rate of 50. The mean dry weight of 100 pieces of grass fragments was 0.22 g and the mean dry weight harvested was 0.123 g/m^2/day. The quantity of grass harvested in the area for 182 days was calculated by

$$\bar{x} \text{ Zugurma for 182 days} = \frac{\bar{x} \text{ Zug. (19-22/3)} . \bar{x} \text{ plot B for 182 days}}{\bar{x} \text{ plot B (19-22/3)}}$$

$$= \frac{0.123}{0.120} \cdot 81.9$$

$$= 83.95 \text{ kg/ha/yr}$$

The quantity of grass harvested in the Zugurma bush plots by T. geminatus was comparable with the quantity harvested in the grazed plots.

2.7.1 Quantity of grass cut down and left as litter

The data obtained within each fortnight was compared with data for grass harvesting (i.e. grass cut down and carried back to the nest), during the same period, as shown in Appendix 9 and summarized in Table 28. The mean weight of grass for the six week period was calculated to get the quantity cut down, and was multiplied by the total number of foraging days to obtain the quantity cut down within the entire foraging period.

The mean dry weight cut down and left as litter within the period varied from 0.0046 g to 0.21 g/m^2/day with a mean of 0.0118 g/m^2/day. Quantity of grass cut down and carried back to the nest within the same period, from figures extracted from plots B, C and D on the same dates varied from 0.0327 g to 0.118 g with a mean of 0.0537 g/m^2/day. The

Table 28. Quantity of grass cut down and carried back to the mound and quantity cut down but left as litter January - April 1975.

Period	Mean quantity cut down and carried back (g/m^2)	Mean quantity cut down but left as litter (g/m^2)
22/1 - 25/1/75	0.0327	0.0210
5/2 - 8/2/75	0.0757	0.0049
19/2 - 22/2/75	0.0000	0.0079
5/3 - 8/3/75	0.1183	0.0162
19/3 - 22/3/75	0.09567	0.0162
2/4 - 5/4/75	0.0000	0.0046
Total	0.3222	0.0708
Mean wt g/m^2	0.0537	0.0118

quantity of grass cut down but left as litter for the entire foraging period of 182 days was calculated as follows using plot B as the standard plot.

$$\bar{x} \text{ cut and left for 182 days} = \frac{\bar{x} \text{ cut and left from Jan/April X quantity cut and carried back for 182 days (Plot B)}}{\text{quantity cut and carried between Jan/April}}$$

$$= \frac{0.0118}{0.0537} \times 81.9$$

$$= 17.99 \text{ kg/ha/yr}$$

Quantity left as litter represented 28.9% of total grass harvested.

2.7.2 Quantity of food ingested while foraging

Table 29. Weight of workers of T. geminatus at different times of the foraging cycle.

Category of workers	$\bar{x}$ dry wt. before foraging (g)	$\bar{x}$ dry wt. 30 mins after commencement of foraging (g)	$\bar{x}$ dry wt. 1 hr. after (g)	$\bar{x}$ dry wt. $1\frac{1}{2}$ hrs. after (g)
* Outgoers	0.086	0.096	0.106	0.084
* Ingoers (laden)		0.106	0.096	0.081

* Each figure represents a mean of 10 days record and 50 termites of each category.

Table 29 shows the results obtained from 10 days measurements. The results showed that weight differences between outgoing and incoming laden workers were only detectable 30 minutes after the commencement of

foraging (0.106-0.086 = 0.02 g/50 termites). The mean weight of the two categories remained constant 1 hour later, but there appeared to be a decrease in weight 1½ hours after foraging. This difference could be accounted for by loss of water and defeacation by the termites during feeding activity.

Since there were several unknown factors which could influence the quantity of food consumed e.g. (i) the number of times each termite returned to feed, (ii) whether or not they fed at the same rate on each occasion, the quantity consumed could be estimated making several assumptions.

(1) (a) Assume consumption in the first 30 minutes was carried out for full period of foraging.

(b) Assume individual workers went out once OR

(c) If individuals went out more than once, they fed at the same rate.

(2) Assume no feeding after 30 minutes. On the basis of the first assumption, using plot B as the standard plot

Mean rate of harvesting/m^2/day (as per plot B) = 31.47 pieces.

Weight of grass consumed in the first 30 minutes for full period of 182 days by laden workers

$$= 31.47 \times \frac{0.02}{50} \times 182 \text{ g/m}^2\text{/yr}$$

$$= 2.29 \text{ g/m}^2\text{/yr}$$

If the second assumption is applied, then it is necessary to know the % pieces of grass carried back in the first 30 minutes of foraging. This was calculated as follows using data in plot B.

Example On the 22/1/75,

The mean number of grass fragments harvested/5 minutes, in the first 30 minutes, as read from the mean activity curve for the day

= 4.6 pieces/5 minutes.

Total number of holes opened in the five strips each measuring 3 m x 30 m

= 17

Rate of harvesting/m^2/day in the first 30 mins. = $\frac{4.6 \times 17 \times 30}{450 \times 5}$

= 1.04 pieces/m^2/day

Rate of harvesting/m^2/day for the entire foraging period on 22/1/75

= 24.44 pieces

% rate of harvesting/m^2/day for the first 30 minutes = $\frac{1.04}{24.44}$

= 4.3%

The above calculation was made on 10 foraging dates selected at random from plot B data (Table 29(b)). The mean percent rate of harvesting for the first 30 minutes was calculated at 11.43%. Using this figure, the mean rate of harvesting in the first 30 minutes during the entire foraging period in plot B was estimated at 11.43% of 31.47

= 3.59 pieces/m^2/day

Quantity consumed by laden workers in the first 30 minutes of foraging

= $3.59 \times \frac{0.02}{50} \times 182$ g/m^2/yr

= 0.261 or 26.1 kg/ha/yr

In the case of non-carrying workers, their function in a foraging party remained unclear, as stated earlier on and no measurements were taken of this category of workers, but if it is assumed that they fed during foraging, then similar calculations could be made to determine the quantity consumed (a) during the entire period and (b) for the first 30 minutes. To

Table 29b. Rate of grass harvesting in the first 30 minutes after commencement of foraging. Calculation as in text.

Foraging Date	Total mean rate of harvesting/m^2/day	Rate/m^2/day first 30 mins. of foraging	%
22/ 1/75	24.44	1.04	4.3
6/ 2/75	37.02	5.49	14.8
16/11/74	26.59	3.73	14.04
19/ 3/75	54.33	2.40	4.41
8/ 1/75	24.62	2.98	12.13
8/ 3/75	79.70	4.80	6.03
21/12/74	12.89	3.00	23.27
7/ 2/75	84.58	6.72	7.95
29/11/74	5.6	0.99	17.78
22/ 3/75	75.07	7.18	9.57
		Mean %	= 11.43

Table 30. Total primary production in relation to consumption by cattle and *T. geminatus*.

	Grass production kg/ha/yr	Quantity consumed by cattle kg/ha/yr	Quantity removed by *T. geminatus* kg/ha/yr
	2944	1404	104.33
Consumption calculated as % of total grass production	-	47.69	3.54

do this, the proportion of non-carriers to carriers in a foraging party was determined from activity curves (Figs. 7a and 7b). From the graphs (Figs. 7a & 7b) the proportion of $\frac{\text{non-carriers}}{\text{carriers}} = \frac{2.8}{1}$

i.e. 72% of the foraging workers were non carriers while carriers only contituted 28%. On the basis of this figure

The quantity consumed by non-carriers for the full period

$= 2.29 \times 2.8$ g/m2/yr $= 6.42$ g/m^2/yr

Quantity consumed in the first 30 minutes assuming no consumption after this period

$= 0.261 \times 2.8 = 0.730$ g/m^2/yr

73.0 kg/ha/yr

2.8 Relating foraging cycle to subsoil and soil surface temperatures

Subsoil and soil surface temperatures together with periods when foraging occurred were recorded from November 1974 to April 1975 and are shown in Appendix 10 and Fig. 10.

Subsoil temperatures varied little during each 24 hour period and were represented in Fig. 10 as the daily mean of both foraging periods (morning and evening). In contrast, soil surface temperatures fluctuated more during each 24 hour period on some days. During the second quarter of November 1974, subsoil temperatures averaged 26°C (morning and evening), while soil surface temperatures varied from 21°-24°C during the same period. Foraging occurred at each of these periods (morning and evening). In the last quarter of the same month, subsoil temperatures varied from 24°-28.5°C (morning and evening periods), while soil surface temperature varied from 19°-22°C in the morning hours and from 20.5°-34.5°C during the evening period. Foraging during this quarter was restricted to the evening period, with warmer soil surface temperatures.

In the months of December and January, subsoil temperatures in the morning hours ranged from 22°-30°C and in the evening period from 25.5°-34°C. Soil surface temperatures in the morning hours ranged from a low of 16.5°-21.2°C and in the evening periods from 24.5°-33.6°C. Throughout this period, evening surface temperatures were warmer than morning soil surface temperatures and hence foraging was restricted to the evening period.

During the first quarter of the month of February, morning soil surface temperatures were between 20.6°-26°C, while evening soil surface temperatures were very high, mostly above 40°C. During this period, (except for the 5th February when foraging occurred in the morning and evening), foraging was restricted to the morning hours. During the third quarter of the month, morning soil surface temperatures were low (17.8-21.0°), and evening temperatures very high above 40°C, resulting in no foraging activity within this period. The cause of this lack of foraging activity was attributed to the resurgence of the cold harmattan winds within the period resulting in cold morning temperatures and hot evening temperatures.

Foraging patterns similar to those observed in the months of December and January were repeated during the month of March, when soil surface temperatures were moderate (25.60°-29.7°C) and evening soil surface temperatures high (35.20°-44°C). In April no foraging was observed during the first quarter partly because of high soil surface temperatures (morning, 29.30°-34.5°C) and (evening, 36.8°-48°C), and partly by the onset of the rains.

The results indicated that foraging activity was influenced by soil surface temperatures. A lower and upper temperature limits were also indicated. When morning soil surface temperatures were below 20°C, no foraging activity was observed. Similarly, when evening soil surface

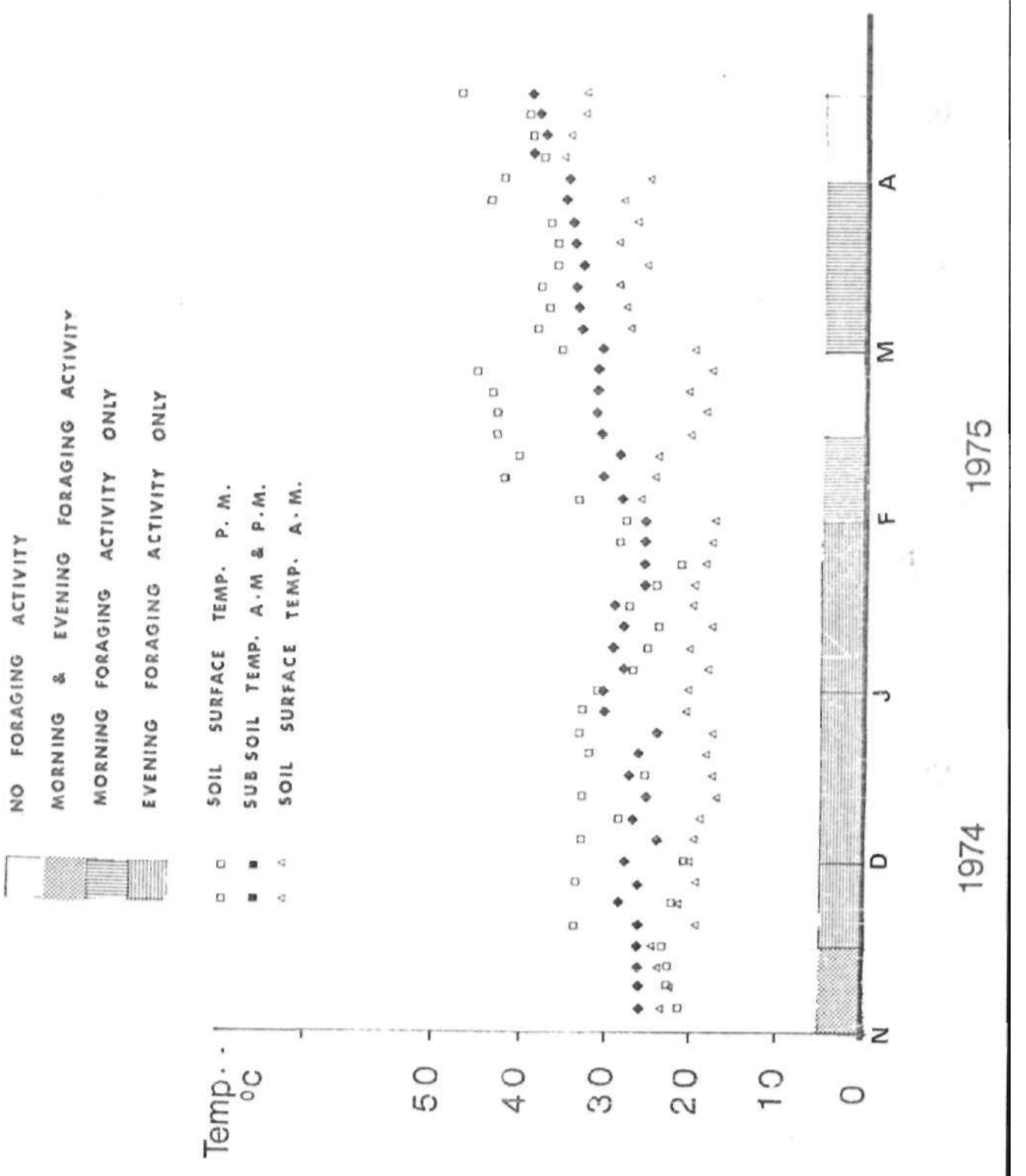

NO FORAGING ACTIVITY
MORNING & EVENING FORAGING ACTIVITY
MORNING FORAGING ACTIVITY ONLY
EVENING FORAGING ACTIVITY ONLY
SOIL SURFACE TEMP. P. M.
SUB SOIL TEMP. A.M & P.M.
SOIL SURFACE TEMP. A. M.
Temp. °C
50
40
30
20
10
0
N
D
J
F
M
A
1974
1975

Figure 10.

temperatures were above 35°C foraging activity did not occur. There was therefore a lower temperature threshold of 20°C and an upper temperature threshold of 35°C, below or above which foraging was restricted.

2.8.1 Foraging frequency at different soil surface temperatures (Morning and Evening activity)

The indication of an upper threshold of 35°C and lower temperature threshold of 20°C led to the investigation of a probable preferred temperature within this range at which foraging occurred. Table 31 shows soil surface temperatures between 20°-35°C and the percentage frequency at which foraging activity (morning and evening periods) occurred at these temperatures.

It was observed that during the twenty occasions at which foraging was recorded in the evening period, foraging occurred as often as (10%) at 21°C, as at 35°C. Similarly, on eleven occasions when morning foraging was recorded, it occurred as often as (8%) at 21° as at 29°C, the lowest and highest soil surface temperatures respectively recorded on these occasions. There was therefore no indication of preferred temperature with upper and lower threshold values of 20° and 35°C.

2.8.2 Differences between nest temperature and soil surface temperature and how these affected daily foraging pattern

Differences between deep nest temperatures and soil surface temperatures during morning and evening periods respectively were compared to see whether the termites responded to changes in temperature.

The results are shown for both periods in Tables 32a and 32b with observations made on 26 days and 28 days respectively during morning and evening foraging periods.

Table 31. Foraging frequency at different soil surface temperatures.

Foraging Frequency	Soil surface temperatures °C															
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Morning foraging activity	0	8	0	9	0	9	27.5	18	8	8	0	0	0	0	0	0
Evening foraging activity	0	10	5	0	10	10	0	15	10	0	0	0	10	15	5	10

Results indicated that during morning hours, temperatures deep in the nest (40 cm) showed less variation and were warmer than soil surface temperatures. The difference between nest and soil surface temperatures ranged from 0.75°-13.6°C. On the 26 days of observations, nest temperatures were warmer 81% of the times with only a day when nest and soil surface temperatures were the same; and soil surface temperatures 15% of the times warmer than nest temperature. During this period differences between nest and soil surface temperatures did not seem to have an important effect on the daily foraging pattern, since foraging occurred when nest temperatures were warmer than soil surface temperature as well as when soil surface temperatures were warmer than nest temperatures. However, on the three out of four occasions when soil surface temperatures were warmer than nest temperatures, no foraging occurred.

During the evening periods observations made on 28 days, showed that nest temperatures were warmer 57% of the times than soil surface temperatures which were 39% of the times warmer than nest temperatures. The range of temperatures at which nest temperatures were warmer than soil surface was closer (1.0°-9.16°C) during the evening hours than in the morning hours (0.75°-13.6°C) indicating that the greatest difference between nest and soil surface temperatures occurred early in the mornings. Similarly, during this period temperature differences did not affect foraging.

Holdaway and Gay (1948) observed that in mound building, wood-eating Nasutitermes exi tiosus in Australia, t peratures in the centre nursery chamber were always higher than soil or air temperature and also showed less variation.

Table 32a. Differences between nest temperature and soil surface temperature and the effect on daily foraging pattern. (Morning temperature differences)

Date		Deep nest °C.	Soil surface °C.	Temp. diff. soil surface cooler than nest by °C.	Soil surface warmer than nest by °C.	Morning foraging activity
Nov.	13	25	23	2	-	+
	14	25	22	3	-	+
	15	24	23	1	-	+
	16	24	24	0	-	+
	27	22.7	24	-	1.30	0
	28	32	28	4	-	0
	29	23	25	-	2	0
	30	31.6	28.5	3.1	-	0
Dec.	12	32	20.4	11.8	-	0
	14	32.2	18.60	13.6	-	0
Jan.	22	21.5	19.3	2.2	-	0
	23	21.5	18.75	3.25	-	0
	24	21.0	16.75	4.25	-	0
	25	21.8	16.50	5.30	-	0
Feb.	5	26.75	26.0	0.75	-	+
	6	28.0	24.6	3.40	-	+
	7	29.0	23.0	6.0	-	+
	8	28.50	20.60	7.90	-	+
March	19	29.0	29.75	-	0.75	+
	20	31.5	26.67	4.83	-	+
	21	31.5	28.20	3.30	-	+
	22	33.5	25.60	7.90	-	+
April	2	33.8	34.5	-	1.3	0
	3	34.5	32.6	1.9	-	0
	4	35.0	30.8	4.2	-	0
	5	34.5	29.30	5.20	-	0

+ indicate when foraging occurred

0 " no. foraging

Table 32b. Differences between nest temperature and soil surface temperature and the effect on daily foraging pattern. (Evening temperature differences)

Date		Deep nest °C.	Soil surface °C.	Temp. diff. soil surface cooler than nest by °C.	Soil surface warmer than nest by °C.	Evening foraging activity
Nov.	13	25	21	4	-	+
	14	24	22	2	-	+
	15	24	23	1	-	+
	16	24	24	0	-	+
	27	29.2	34.5	-	5.3	+
	28	27.0	21.0	6	-	+
	29	30.3	34.5	-	4.2	+
	30	29.66	20.5	9.16	-	+
Dec.	11	30.16	33.3	-	3.14	+
	12	20.8	28.3	-	8.5	+
	13	30.8	33.2	-	3.6	+
	14	25.66	24.5	1.16	-	+
Jan.	22	30.3	24.2	6.1	-	+
	23	30.0	21.50	8.5	-	+
	24	30.66	28.50	2.46	-	+
	25	31.00	27.33	3.67	-	+
Feb.	5	36.0	33.8	2.2	-	+
	6	36.0	42.0	-	6	0
	7	32.8	40.2	-	7.4	0
	8	37.66	42.60	-	4.9	0
March	19	41.16	35.20	5.9	-	0
	20	42.0	36.66	5.3	-	0
	21	42.30	44.0	-	1.7	0
	22	39.75	42.33	-	2.58	0
April	2	43.5	36.83	6.67	-	0
	3	42.5	38.08	4.42	-	0
	4	43.5	39.00	4.5	-	0
	5	42.5	48.0	-	5.50	0

+ indicate when foraging occurred

0 " no. foraging

2.8.3 Relative humidity and effect on foraging

Relative humidity was measured by means of a portable hygrometer during foraging hours. The soil surface temperatures and relative humidity on different dates of foraging both morning and evening periods were recorded as shown in Tables 33a and 33b. These parameters were recorded at the start of foraging which in the case of morning hours was roughly between (05.30-06.30 hrs) and when foraging holes were about to close (08.30-09.30 hrs) and during evening hours beginning from (16.30-17.30 hrs) and ending roughly about (18.30-20.0 hrs).

The results showed that during morning hours foraging started when morning soil surface temperatures were between (21.5-29.0°C) and relative humidities ranging from 60-85%. At the end of foraging temperatures ranged from 35°-40°C and relative humidities were low ranging from 18-48%. During the evening hours, soil surface temperatures were in the range of 28-35.0°C when foraging started and relative humidities at the range of 24-46%. Towards the end of foraging, temperatures were fairly lower ranging from 20.5-31.5°C and relative humidities fairly high (50-82%). These results indicated that during morning hours, high temperatures and low relative humidities limited foraging in other words temperatures were limiting at their higher values above 35°C while relative humidity was limiting at its lower value. During the evening periods, the position was not very clear since temperatures were still reasonably high for foraging. However relative humidities were higher ranging from (50-82%) as opposed to 24-46% at the beginning of the evening foraging activity. There was a suggestion however that during this period temperatures were limiting at their lower values and relative humidities at their higher values. These results corroborated with those of Bodot (1967b) who showed that T. trinervius which harvested grass in the open, displayed a negative correlation with mean minimum relative humidity; in other words temperatures

Table 33a. Soil surface temperature and relative humidities at the beginning and end of foraging. (Morning period)

Date	S. surface °C at start of foraging (05.30-06.30 hrs)	R.H. (%) at start of foraging	S. surface °C at end of foraging (08.30-09.30 hrs)	R.H. (%) at end of foraging
6/ 2/75	26.0	85	37.0	36
7/ 2	24.9	80	36.0	24
8/ 2	22.0	84	39.0	18
6/ 3	27.0	67	36.5	37
7/ 3	29.0	60	38.0	43
8/ 3	21.5	65	40.0	26
19/ 3	26.0	68	36.0	24
21/ 3	26.0	77	38.5	48
22/ 3	28.3	70	35.0	47

Table 33b. Soil surface temperature and relative humidities at the beginning and end of foraging. (Evening period)

Date	S. surface °C at start of foraging (16.30-17.30 hrs)	R.H. (%) at start of foraging	S. surface °C at end of foraging (18.30-20.00 hrs)	R.H. (%) at end of foraging
30/11/74	33.0	24	26.0	70
11/12/74	32.0	32	29.0	68
12/12	32.5	37.5	26.5	77
13/12	33.5	30	30.5	59
14/12	32.5	36	26.0	75
18/12	31.0	42	27.0	67
25/12	32.5	45	28.0	78
9/ 1/75	28	30	20.5	82
10/ 1/	28.5	33	23.5	58
11/ 1	30.0	27	25.0	52
5/ 2	35.0	46	31.5	50

were limiting at their higher values while relative humidities were limiting at their lower values.

3. Discussion

1. A strong preference for A. gayanus was indicated, when T. geminatus was presented with a range of choice of grass species. Although laboratory results might not necessarily reflect the true picture of field situation, field observations on food selection seemed to corroborate these laboratory results. Furthermore, from the vegetation analysis of the species present in the study area, A. gayanus was not shown to be the most abundant species, thus its preferential attack by the termites would seem to suggest some degree of selectivity by T. geminatus. The results indicated that other species tested were palatable to some degree, however, there were indications that C. gigranteus and Cyperus sp. were least preferred but total avoidance of any species was not demonstrated. Sands (1961a) showed that T. geminatus accepted many different species of grass, though Aristida kerstingii Pilger and Cymbopogon citratus (Hochst) were list favoured of all. Watson et al (1970) noted differences in food preference amongst at least nine species of Drepanotermes in Australia.

2. Quantitative field estimates of foraging and food consumption by grass harvesting termite are limited. Watson and Gay (1970) noted that moderately sized nests of Drepanotermes perniger in Australia was capable of opening 1000 or more holes/ha during the summer, and that larger nests opened active holes numbering 4000-5000/ha. These foraging holes were used for at least an hour but commonly for 2-3 hours. An estimate of 30-40 pieces of forage/minute was carried underground with the average weight of stored pieces approximately 0.6 mg. Harvesting rates were estimated at 1 kg dry weight/nest/annum while at heavier infestations, several hundred kilograms/ nest/yr were said to have been removed.

Nel (1968) noted that Hodotermes mossambicus in South Africa carried back to

the nest pieces of grass (mean weight 6.4 mg), with maximum rates of harvesting of approximately 100 pieces/hole/5 minutes, with a mean of 20 pieces/hole/5 minutes. He estimated that this species removed 14.6 kg/ha/yr or 1% of the total production of dry material. Basson (1972) working on the same species in a different area estimated that H. mossambicus removed 274 kg/ha/yr from the veld in South Africa. Lepage (1973) estimated that M. subhyalinus consumed 53 kg/ha/yr of litter. Bodine (1973) working on Gnathamitermes tubiformans estimated that this species removed 360 kg/ha/yr of grass or 12% of the nett primary production. Josens (1972) working in Lamto, Ivory Coast estimated Trinervitermes sp. to have consumed 6-44 kg/ha/yr.

Results of this study showed that in the Mokwa area of the Southern Guinea savanna zone of Nigeria, foraging by T. geminatus was an early morning or late afternoon activity lasting for 1-4 hours daily. The number of foraging holes was estimated at 306/ha. The rate of harvesting was about 53.38 pieces/hole/5 minutes with maximum rates of about 160-220 pieces/hole/5 minutes. Mean dry weight of fragments carried underground varied from 1.0-2.0 mg . Foraging activity in terms of rate of grass-harvesting/m^2/day and hence the mean weight of grass harvested in g/m^2/day was highest in the months of February and March than in other months within the year (Fig. 9). However, during the last quarter of February (19/2 - 22/2/75), there was a resurgence of the cold harmattan weather which prevented the termites from foraging within the period in all the plots.

The mean quantity of grass cut down and carried back to the nest was estimated at 60.33 kg/ha/yr. Quantity cut down but left as litter on the soil surface was estimated at 17.99 kg/ha/yr, approximately 29.8% of the quantity cut down; giving a total of 78.32 kg/ha/yr as the quantity of grass harvested.

Since no weight difference was detected between outgoing workers and ingoing laden workers after 30 minutes of foraging, the quantity of food ingested during the first 30 minutes after commencement of foraging was assumed as the most likely estimate. This quantity was calculated as 26.1 kg/ha/yr for grass carriers and 73.0 kg/ha/yr for non-grass carriers. As actual measurements of the weights of the later category of workers were not made, the figure of 73 kg/ha/yr estimated as the quantity of food ingested was probably unlikely and consequently unreliable. If the estimate was therefore based on the quantity of food consumed by the grass-carrying workers alone, then the amount (26.1 kg/ha/yr) represented a significant proportion (33.3%) of the total quantity of grass cut down.

The grass removed by T. geminatus and hence made unavailable to cattle amounted to 104.33 kg/ha/yr. When this quantity is related to total grass production (2944 kg/ha/yr) Table 30, the quantity removed by T. geminatus amounted to 3.54% of total grass produced, hence T. geminatus did not appear to be economically significant in the Mokwa area. Cattle, on the other hand, consumed approximately 48.0% of the total primary production, therefore competition with T. geminatus was unlikely in this locality. However, the lack of competition could further be attributed to the fact that in this locality, grazing intensity by cattle was low and also termites were able to feed on grass (litter) unavailable to cattle.

3. The occurrence of diurnal pattern of foraging mostly in species which forage in the open has been noted by several workers. Kalshoven (1958) observed this pattern in the 'black termites', Hospitalitermes sp. in Malaysia and Indo China. Sands (1961b) noted that most of the foraging in T. geminatus took place in the night and could also take place during the day in dull weather. Bodot (1967b) noted that in the Ivory Coast Trinervitermes trinervius foraged all the year round. Nel (1968) noted that

Hodotermes mossambicus foraged during the day in winter but in summer could forage early or late in the evening. Gay and Calaby (1970) noted diurnal foraging in Drepanotermes spp. and Haverty et al (1974) noted similar day and night foraging pattern by Heterotermes aureus (Synder) in the Sonoran desert of Arizona. Observations in Mokwa throughout the period of study showed that foraging parties of T. geminatus emerged twice during a 24 hour period. Foraging was an early morning and/or late afternoon activity from (06.00-09.30 hours) and from (16.30-19.30 hours). This meant that foraging occurred largely during daylight and in the last half hour of the morning period, and first half hour of the evening period was carried out in bright sunlight. The time at which foraging commenced and the duration of the foraging period appeared to depend partly on the prevailing weather conditions; and partly by the requirements of the colony. Rain inhibited foraging and one day's rainfall was capable of inhibiting foraging for a week or two. High winds were observed to cause the closure of foraging holes and hence the cessation of foraging. The daily pattern of foraging of T. geminatus, however seemed to be determined largely by soil surface, temperatures and relative humidity.

GENERAL DISCUSSION

Most of the points raised by this study have been discussed at the end of the appropriate sections, but a few general considerations remain.

As there are no well authenticated reports of termite damage to pastures in Nigeria, it is of interest to predict whether or not a potential for damage exists. As indicated, T. geminatus is the only species with the potential for removing significant quantities of grass that would otherwise be consumed by livestock. At the study area, estimates of harvesting rate of 104 kg/ha/yr of grass were made for an estimated population of 203 termites/m^2. Annual grass production was calculated at approximately 3000 kg/ha/yr. In this situation, the amount harvested by T. geminatus would appear to be an insignificant proportion (less than 4%) of the total grass produced. However, Sands (1965) estimated populations of T. geminatus at 500-1250/m^2 near Zaria and if it is assumed that the rate of harvesting is directly proportional to population density, these particular populations could harvest 375-940 kg of grass/ha. This would represent 10-30% of the expected grass production at Zaria of less than 3000 kg/ha (de Leeuw, 1971), a significant proportion of expected production. In the light of the above, it is necessary to consider the role of grass harvesting termites in pasture ecosystems and the circumstances under which they may be in competition with grazing livestock.

1. Most of the grass removed by T. geminatus is dry and dead and is not fresh green material, as harvesting is largely curtailed during the rainy season. As a result, they do not seem to contribute directly to the loss in photosynthetic potential of pastures.

However, the removal of dry grass and other organic debris from the soil surface promotes loss of soil by erosion by exposing the soil to wind

and rain. This point is illustrated by the denudation of the South African veld by grass-harvesters (Hodotermitinae). Coaton (1954); Anon. (1960) noted that the removal of the grass cover by termites led to the encroachment of the 'karoo' or scrub, which poorly protected the soil and bound the particles less efficiently than the grass it replaced. The end result was the transformation of the veld into wasteland.

2. In pastures that support notable populations of mound-building termites, the influence of the termites on the quantity, distribution of organic matter and other plant nutrients, and on the cycling of plant nutrients may be of considerable importance. In the absence of termites, one can only speculate on the possible fate of the organic matter (plant debris) in pastures. One possibility is that the dry material with its nutrients would fall to the ground surface, and as is the case in temperate pastures where earthworms and other microorganisms are abundant, would be broken down by such organisms and be incorporated into the soil. On the other hand, in tropical pastures, where earthworms are scarce and termites are the dominant group of soil animals, (Wood, 1975) the organic matter would possibly accumulate undecomposed and become a fire hazard.

Grass harvesters forage for food over a wide area away from their nests and return the materials so gathered to it. The degredation or consumption of the plant tissues collected, and the use of the excreted end products of digestion for mound building and lining of galleries, result in their removal from participation in the plant/soil system for long periods and hence may have an influence on the soil organic matter content. The accumulation of the organic matter in mounds would therefore appear to involve the transference of fertility from the surrounding soil to the mounds where invariably plants are unable to grow.

3. Most pasture grasses are perennial. During the dry season the aerial structures die and form a protective mulch over the shallow root systems, which often regenerate following the rains in the wet season. The consumption of dry grass and other plant debris by termites results in the removal of this mulch and exposes the root systems to intensive insolation in the dry season, leading to their death or at best diminishing their chances of regeneration. In improved pastures, this activity may necessitate resowing of the pastures, as indeed was the case in an area near Katsina (Kaduna State) where extensive areas of pasture (Andropogon gayanus) had to be resown. The activity of the termites was aggravated by the drought which ended in 1974 (Johnson, Ohiagu & Wood - Tour reports 1974).

4. There are other ways in which the activities of grass harvesting termites might be harmful in pastures. Most of these termites construct mounds which occupy ground that would otherwise support pasture. Naude, (1934) and Coaton (1948) suggested that in South Africa, the area occupied by mounds of Trinervitermes trinervoides (Sjostedt) constituted a significant proportion of the total area available, although no data were given to substantiate the claim. Lee and Wood (1971) indicated that in certain areas in Africa and Asia, mound building grass-eating termites occupied 10%-30% of the area. In the Mokwa area, however, this is not considered to be a threat, as even at maximum densities of the dominant mound building species, the area occupied by mounds is very small ($<$ 2% of the total area).

Another detrimental effect may be that mounds of Trinervitermes spp. are constructed from soil brought to the surface from deeper horizons and so are deficient in organic matter and other constituents necessary for plant growth. When these mounds are subsequently decomposed and redistributed by rain and wind, the resulting soil is also nutrient deficient and support sparse vegetation.

5. The beneficial role which grass harvesting termites may play in pasture ecosystems has not been fully assessed, but some of their activities may resemble those of earthworms in temperate grasslands. However, the similarity between termites and earthworms is best illustrated with another group of termites called 'humus feeders' (e.g. Cubitermes sp.). In Europe, the weight of earthworms (Lumbricidae) in pastures can be greater than the weight of grazing livestock (Russel, 1959), and in permanent pastures, their influence is recognised. These include their beneficial physical effects on soils resulting from the burrowing, ingestion of soil and organic matter and deposition of castes on the soil surface or beneath the soil. These activities enhance soil aeration, drainage and water absorption and limit soil erosion by reducing run off; also plant materials are incorporated into the soil by earthworm activity. Grass harvesting termites especially T. geminatus has been observed defecating while foraging on grass resulting in a recycling of ingested material, a situation akin to earthworm activity. However the proportion of materials recycled in this way would appear to be negligible when compared with the amount 'locked up' in mounds. Furthermore, through their extensive galleries in mounds and surrounding soil, aeration and water absorption of the soil are enhanced. Though there is lack of information on the effects of the network of galleries concentrated in the vicinity of nests of mound building termites on the growth of plants, these galleries must have some effects similar to the burrowing in soil by earthworms.

6. In termites, energy locked up in termite population and their mounds must be dissipated and this is where predation on termites and decomposition of termitaria seem to be of significance in the nutrient cycle. The pathway of nutrient return to the ecosystem appears to be through (a) predation, (b) transfer to the bodies of emigrant alates and (c) by decomposition of mounds.

(a) Predation: Termites, especially those which forage on the surface of the soil are preyed on by ants of various species which mill around foraging holes at the time when termites are foraging. However, quantitative estimates on predation are lacking. Sheppe (1970) found that the main ant predators of the surface foraging termites such as Hodotermes, Trinervitermes and several Macrotermitinae in Zambia, were Myrmicaria eumenoides (Gerst) and Pheidole megacephola (Fabr.). Perhaps the most spectacular predation occurs on alate reproductives during colony foundation. Lee and Wood (1971) regard this type of predation as opportunistic since the flight of alates are seasonal and cannot therefore provide a regular food supply. Wood and Sands (in press) quote Ward (1965) as considering alates of termites as contributing significantly to the diet of certain weaver birds (Quelea) in the Sahalian zone of West Africa, as the swarms came at a time when the normal diet of seeds was unavailable. Eventually, when these predators die and decompose nutrients are released to the soil.

(b) Dispersal of bodies of alates: After the mass flight of alates, which in T. geminatus may make up 3% of mound populations, shed termite wings are seen on the soil surface, which may contribute to nutrient content of the soil when they decompose. Furthermore, the total amount of nitrogen leaving the colony annually in the bodies of alates of T. geminatus, based on the annual production of alates from individual colonies (Sands, 1965), has been estimated at 7.0 mg/m^2 (Lee & Wood, 1971). When it is realised that the majority of alates perish before a colony is established, the bodies of termites would seem to make a significant contribution to the dispersal of nitrogen and other nutrients. This factor is likely to be especially important in areas of low rainfall where leaching is minimal.

(c) The decomposition of mounds may in some cases contribute positively

to the nutrient status of the surrounding soils. Some termite mounds contain, relative to the surrounding soils, more carbon, nitrogen, calcium and slightly more potassium and more exchangeable calcium and magnesium (Lee & Wood, 1971), the redistribution of which, enriches the surrounding soil. It has also been recognised for many years that mounds of certain Macrotermitinae support a more luxuriant vegetation than the surrounding areas. The important factors responsible for this plant growth stimulation on termitaria include among others, chemically altered soils and improvement of drainage in areas subject to waterlogging. On the contrary, field observations indicate that mounds of Trinervitermes sp. do not appear to support plant growth even when abandoned by the termites. Similar observations have been recorded for mounds of Cubitermes spp., Amitermes spp. and Coptotermes sp. (Glover et al, 1964; Lee & Wood, 1971). In addition to the poor soil from which mounds are constructed, Lee and Wood (1971) found substances in the excreta of Nasutitermes exi tiosus in Australia which inhibited microbial activity. Although these substances were unidentified, if it is assumed that their presence is a general phenomenon in most termite excreta, this might partially explain the lack of plant growth observed in mounds of Trinervitermes spp.

7. Since grass harvesting termites prefer dry material to green vegetation, it is pertinent to speculate on how they might be in competition with cattle which prefers green to dry grass. In the dry season, especially during periods of drought, when suitable grazing material in unavailable to cattle, they may be left with no alternative but to eat the dried grass. The removal of this material by termites at this time could result in competition between termites and cattle for the available food material. On the other hand, grazing by cattle results in the removal of green vegetation, which as in the study area accounted for 48% of the total

grass production. Grazing may therefore lead to a loss of photosynthetic potential and production as well as removal of leaves that would become dried grass suitable for termites. All these processes are likely to reduce the amount of food subsequently available to termites during the dry season.

As already indicated, grazed pastures support in addition to grass-eating termites many other termite species which feed on wood, various kinds of plant debris, dung and soil. Their total biomass may exceed that of grazing livestock. In the study area, the biomass of T. geminatus is estimated at approximately 10 kg/ha and the total biomass of all termite species at 75 kg/ha, while cattle even at a high stocking rates (Sokoto Gudali bulls at 1 beast/ha/6 months), will not exceed 50 kg/ha. As a result, the impact of termites on pastures might seem in some circumstances to be greater than those of grazing livestock, but it is virtually certain that their effects would be relatively greater in over grazed pastures particularly in periods of drought when the potential for grass production is lowered by poor management or low rainfall. Despite these considerations, present evidence suggests that grass-harvesting termites in the Southern Guinea savanna zone of Nigeria may be regarded as low-level competitors to be tolerated or possibly managed, in ways which will prevent them from becoming more abundant, rather than treated as important pests. This is perhaps fortunate because chemical control, besides being uneconomic, could have overall detrimental effects on pasture ecosystems through destruction of organisms, including some termite species that are important in maintaining soil structure and fertility.

SUMMARY AND CONCLUSIONS

The thesis is divided into four major sections. The first section deals mainly with the review of the general aspects of the biology and ecology of Trinervitermes spp. Sections II, III and IV discuss specifically, the biology, population and food consumption of the most abundant species in this genus - T. geminatus. Results and discussions are given within each section, but the main results are summarized below.

1. The study site, an area of secondary savanna woodland covering 2.5 hectares was divided into 4 plots, two of which were grazed and two ungrazed. A botanical survey of the vegetation was carried out to determine which species of grass were dominant and which were present in each of the four plots. Even though, there was variation in ground cover and species composition in the plots, H. dissoluta and A. gayanus were the dominant species of grass and made up 50% of the herbaceous vegetation.

2. Four species of Trinervitermes were present in the study area occupying slightly different ecological niches. One might argue as Ross (1957) did, that the species were able to coexist because in this area, interspecific competition for food or space was not the chief factor governing the density of population of the species. There was evidence to show that there could be mutual aggression between colonies of the same species, presumably an attempt to maintain a fairly well defined colonial territory over which to forage for food.

3. The species is polycalyic, with highly aggregated mounds in which four to five low domed shaped mounds constituted a colony. Each colony had a large mound used for breeding and other smaller mounds. An average of 60-70% of the mounds were used for storing grass collected from the surrounding area. The stored grass provided food for the termites especially

during the wet season with little or no foraging activity.

4. Mound density was estimated by direct counts in the field and mound turnover was also determined. Even though no definite conclusion could be drawn based on 2 years counts on the effect of grazing on the mortality, loss and recruitment of mounds, indications were that grazing influenced the rate at which mounds were abandoned and lost, probably through trampling and buffetting by cattle. Equally by creating open spaces, it also influenced the formation of new mounds of T. geminatus. The area occupied by these mounds, which would otherwise support pasture, constituted an insignificant proportion of the total, (< 2%).

5. Standing grass biomass, litter biomass and rate of decomposition were estimated in the study area. There was remarkable reduction in standing grass biomass at the end of the dry season, as a result of conversion to litter at this time. However, because of the high rate of decomposition in the dry season, litter biomass was at a minimum during the same period.

While consumption by cattle was estimated as half the total grass production, it was apparent that in the ungrazed plots, more than half of the net production was being removed by decomposer organisms.

6. Nutrient analysis of stored grass, standing grass and grass litter indicated that the primary food of this species was low in nitrogen and other nutrients. The lower C:N ratio recorded in stored grass as compared with standing grass or litter, indicated the influence of micro-organisms as well as the moisture and temperature regimes in the mounds.

7. Two methods were adopted in sampling mound populations. The first method involved taking core samples from mounds and relating the number of termites in the core to total mound population. This proved unreliable and was subsequently abandoned. The second method was much more reliable even

though laborious and time-consuming. It involved whole mound sampling which was however limited to 20 mounds taken over a period of one month at three monthly intervals. Termites in the mounds were heat extracted and counted.

8. A linear relationship was obtained when the size of the sampled mounds, measured as the sum of two arcs at right angles, was plotted against log numbers of the population, indicating that mound size was a good index of total numbers of termites in the mound. The linear regression equation obtained from the data at each sampling period was used in calculating the termite population in the mounds at the plots at the different periods. Population density of the study area was estimated at $203/m^2$. There was no significant difference between population densities in grazed and ungrazed plots. Similar population densities were estimated for the three species of Trinervitermes in the primary savanna woodland area. Estimated termite populations were low in the Mokwa area and probably conservative, because of the obvious difficulties in finding all termites within any particular mound present at the same time.

9. Seasonal variation in population was indicated, populations being low during the dry season (December-April) coinciding with the period of intense foraging and predation; increasing with the onset of the rains (May) and reaching a peak around June/July and falling off again Sept./ October following the flight of alates and the commencement of foraging.

10. The foraging behaviour of T. geminatus was described. Grass cutting and grass carrying were shown to be the function of the young foraging workers, which constituted approximately 30% of the foragers. The function of the old workers remained undetected.

11. T. geminatus harvested standing grass which was cut into pieces and

carried back via foraging holes at the soil surface and subterranean galleries to its nest. During this activity a certain proportion of the harvested grass was 'wasted' and some quantity ingested. Harvesting started slowly, gradually building up to peak rates (maximum recorded was 220 pieces/5 minutes) before declining rapidly. The shape of the mean activity curve was constant for different holes on the same day, though the amplitude differed due to variation in harvesting rate at different holes; but differed from day to day largely due to the time at which foraging ceased. The onset of foraging (morning and evening) were relatively constant but the length of the foraging period varied, averaging approximately 2-3 hours daily.

12. A method was developed for quantifying the quantity of grass harvested. Different holes were used on successive days and in other to express the amount harvested quantitatively the following procedure was adopted.

(a) A random selection of holes were made for single counts of the number of pieces of grass harvested per 5 minutes.

(b) Counting of total number of holes open in the sampling area and also determining the duration of the foraging period.

(c) Selection of three active holes for repeated half hour interval counts of the number of pieces of grass harvested/5 minutes throughout the entire foraging period.

(d) Determining the mean weight of grass fragments carried back to the nest and using this in calculating the daily harvesting rates.

13. The quantity of grass cut down but left as litter as well as quantity ingested while foraging were estimated and from these results, it was estimated that foragers removed grass at the rate of 104.32 kg/ha/yr representing 3.5% of the annual production of grass.

14. Cattle consumption was estimated as 48% of the total grass production and although both termites and cattle showed preference for the grass species, A. gayanus, they hardly competed for it, partly, as a result of the low intensity of grazing in the area and on the ability of the termites to feed on grass unavailable to cattle. Therefore, T. geminatus was neither in competition with cattle nor did it cause any economic damage on pastures in this area of Southern Guinea savanna zone of Nigeria.

15. Since grass harvesting occurred during the dry season, probably resulting in the removal of grass tussocks that would otherwise regrow following rains, the impact of T. geminatus was likely to be felt much more during periods of drought, especially in high termite density area and particularly in overgrazed pastures.

16. Time of commencement and duration of foraging appeared to depend partly on environmental factors and partly by the requirements of the colony. Morning foraging activity was limited by low soil surface temperatures and high relative humidity while the converse was true for evening foraging activity.

A low and high temperature thresholds were estimated at 20°C and 35°C respectively. Rain completely inhibited foraging. Temperature differences between nest and soil surface did not appear to have an important effect on daily foraging pattern.

17. Predation by lizards, mantids and grasshoppers, as well as a number of ants especially Crematogaster sp., Megaponera sp. and Myrmicaria were recorded in the field. Although the soldiers protected foraging parties against the predators, for example, the various ant species, those termites that were left on the soil surface after the closure of the foraging holes were rapidly carried away.



PLATE 1. Mounds of Trinervitermes spp. in the field.



PLATE 2. Mound of T. geminatus broken to show stored grass frag ments.



PLATE 3. Mound building activity of T. geminatus.



PLATE 4. Grass harvesting activity - foragers cutting down standing grass tussock.



PLATE 5. Foraging party with grass carrying workers returning to the foraging hole.



PLATE 6. Bin showing layout of grass tussocks used for laboratory preference studies.



PLATE 7. Monitoring temperature of mound and surrounding soil, with the 'Grant' temperature recorder in one of the experimental plots.

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APPENDIX I(a). BOTANICAL ANALYSIS - POINT QUADRAT METHOD.

PLOT No. A.

FORAGING STRIPS

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
1	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-		
2	76	-	-	-	-	-	16	-	-	-	-	-	-	8	-		
3	-	-	-	-	-	37.50	-	-	4.16	-	-	-	-	37.5	20.8		
4	-	96.7	-	-	-	-	-	-	-	-	-	-	-	-	3.2		
5	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-		
6	5.88	26.47	-	61.7	-	-	-	-	-	-	-	-	-	-	2.94		
7	25.0	-	35.7	-	-	17.86	-	-	-	-	-	-	-	21.4	-		
8	14.28	-	-	-	-	28.6	9.5	-	-	-	-	-	-	38.0	9.52		
9	-	-	-	-	-	37.5	-	-	-	-	-	-	-	29.16	33.3		
10	-	30.0	-	60.0	-	-	5.0	-	-	-	-	-	-	-	5.0		
11	-	91.7	-	-	-	-	-	-	-	-	-	-	-	-	8.3		
12	17.85	67.85	-	-	-	-	-	-	-	-	-	-	-	-	14.3		
13	3.57	92.85	-	-	-	-	-	-	-	-	-	-	-	-	3.57		
14	65.0	10	-	5.0	-	5.0	-	-	-	-	-	-	-	10.0	5.0		
15	61.53	38.46	-	-	-	-	-	-	-	-	-	-	-	-	-		
16	4.0	32.0	-	-	-	60.0	-	-	-	-	-	-	-	4.0	-		
17	59.1	-	9.1	-	-	-	-	-	18.2	-	-	-	-	13.6	-		
18	85.00	-	5.0	-	-	-	-	-	-	-	-	-	-	10.0	-		
19	-	30.4	-	-	-	-	-	-	-	-	-	-	60.85	-	8.69		
20	77.7	-	-	-	-	-	-	-	-	-	-	-	-	16.7	5.5		
21	55.5	3.70	-	29.6	-	-	-	-	3.70	-	-	-	-	3.70	3.70		
22	-	81.5	-	13.15	-	-	2.63	-	-	-	-	-	-	-	2.63		

APPENDIX I(a). Continued

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
23	45.83	41.66	-	-	-	-	-	-	-	-	-	-	-	12.5	-		
24	22.22	70.37	-	-	-	-	-	-	-	-	-	-	-	7.40	-		
25	66.66	4.16	8.33	-	-	-	-	-	8.33	-	-	-	-	4.16	8.33		
26	70.00	10.00	-	-	-	-	-	-	-	-	-	-	-	20.0	-		
27	-	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-		
28	-	86.95	-	-	-	-	-	-	-	-	-	-	-	4.35	8.69		
29	-	95.45	-	-	-	-	-	-	4.54	-	-	-	-	-	-		
30	-	68.96	-	-	-	24.13	-	-	6.89	-	-	-	-	-	-		
	755.12	1279.18	58.13	169.45	-	210.59	33.13	-	45.82	-	-	-	60.85	240.47	143.47		
$\bar{x}$	25.17	42.64	1.94	5.64	-	7.02	1.10	-	1.53	-	-	-	2.02	8.0	4.78		

APPENDIX I(b). BOTANICAL ANALYSIS - POINT QUADRAT METHOD.

PLOT No. A.

GRASS PRODUCTION AREA

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
1	-	80.0	-	-	-	16.0	-	-	4.0	-	-	-	-	-	-		
2	-	86.9	-	-	-	-	-	-	-	-	-	-	-	8.69	4.35		
3	-	96.15	-	-	-	-	-	-	-	-	-	-	-	3.85	-		
4	-	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-		
5	-	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-		
6	-	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-		
7	-	65.5	-	-	-	31.83	-	-	-	-	-	-	-	3.45	-		
8	-	86.36	-	13.64	-	-	-	-	-	-	-	-	-	-	-		
9	-	81.82	-	-	-	4.54	-	-	-	-	-	-	-	9.09	4.54		
10	-	69.4	-	-	-	-	-	-	-	-	-	-	-	22.2	8.33		
11	-	95.0	-	-	-	-	-	-	5.0	-	-	-	-	-	-		
12	-	90.32	-	-	-	-	-	-	3.22	-	-	-	-	3.22	3.22		
13	-	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-		
14	9.67	87.1	-	-	-	-	-	-	-	-	-	-	-	3.22	-		
15	13.79	24.13	-	-	-	48.27	-	-	3.44	-	-	-	-	3.44	6.89		
16	10.34	41.37	-	-	-	65.5	-	-	-	-	-	-	-	-	-		
17	75.0	5.00	-	-	-	20.0	-	-	-	-	-	-	-	-	-		
18	-	88.8	-	-	-	11.1	-	-	-	-	-	-	-	-	-		
19	-	91.30	-	-	-	-	-	-	-	-	-	-	-	4.35	4.35		
20	-	68.42	-	-	-	31.57	-	-	-	-	-	-	-	-	-		
21	-	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-		
22	-	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-		

APPENDIX I(b). Continued

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
23	3.57	82.14	-	-	-	7.14	-	-	3.57	-	-	-	-	3.57	-		
24	80.95	19.0	-	-	-	-	-	-	-	-	-	-	-	-	-		
25	-	90.9	-	-	-	3.0	-	-	6.0	-	-	-	-	-	-		
26	22.50	-	-	-	-	60.0	-	-	-	-	-	-	-	15.0	2.50		
27	21.87	68.75	-	-	-	9.38	-	-	-	-	-	-	-	-	-		
28	38.1	19.0	-	-	-	9.52	-	-	-	-	-	-	-	23.8	9.52		
29	4.54	2.27	-	59.1	-	29.5	-	-	-	-	-	-	-	4.52	-		
30	20.58	67.6	-	-	-	5.88	-	-	-	-	-	-	-	5.88	-		
	300.91	2107.23	-	72.74	-	353.23	-	-	25.23	-	-	-	-	114.30	43.69		
$\bar{x}$	10.03	70.24	-	2.42	-	11.77	-	-	0.84	-	-	-	-	3.81	1.45		

APPENDIX I(c). Continued

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
23	50.0	-	14.28	-	-	-	-	-	7.14	-	-	-	-	28.57	-		
24	51.7	20.68	-	-	-	-	17.2	-	-	-	-	-	-	6.89	3.44		
25	73.7	-	-	-	-	-	-	-	21.0	-	-	-	-	5.26	-		
26	8.0	64.0	-	-	-	16.0	8.0	-	-	-	-	-	-	4.00	-		
27	8.69	-	-	-	-	13.0	-	-	21.7	-	-	-	-	52.17	4.3		
28	16.7	-	61.11	-	-	11.11	-	-	-	-	-	-	-	11.11	-		
29	50.0	-	-	-	-	-	-	-	3.84	-	7.69	-	-	23.07	15.38		
30	7.40	-	-	-	-	11.11	22.22	-	14.8	-	-	-	-	37.0	7.40		
	935.85	477.66	204.33	-	-	286.92	206.52	-	254.18	-	7.69	-	-	430.09	195.69		
$\bar{x}$	31.19	15.92	6.81	-	-	9.56	6.88	-	8.47	-	0.26	-	-	14.34	6.52		

APPENDIX I(c). **BOTANICAL ANALYSIS - POINT QUADRAT METHOD.**

PLOT No. B.

FORAGING STRIPS

% Composition of each species/**quadrat**

Quadrat No.	SPECIES SYMBOLS															
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
1	35.7	-	-	-	-	28.57	-	-	14.28	-	-	-	-	-	21.43		
2	10.0	-	-	-	-	-	45.0	-	30.0	-	-	-	-	15.0	-		
3	63.15	21.0	-	-	-	-	-	-	10.5	-	-	-	-	5.26	-		
4	-	-	-	-	-	10.0	60.0	-	-	-	-	-	-	10.0	20.0		
5	31.25	-	-	-	-	37.5	-	-	31.25	-	-	-	-	-	-		
6	33.3	-	-	-	-	-	-	-	53.3	-	-	-	-	13.3	-		
7	-	76.92	-	-	-	3.85	-	-	-	-	-	-	-	11.5	7.69		
8	-	88.8	-	-	-	-	-	-	-	-	-	-	-	-	11.1		
9	2.94	88.2	-	-	-	-	-	-	-	-	-	-	-	-	8.82		
10	-	-	-	-	-	28.57	-	-	14.28	-	-	-	-	42.85	14.28		
11	84.2	-	-	-	-	-	-	-	-	-	-	-	-	15.78	-		
12	-	-	-	-	-	63.63	-	-	9.09	-	-	-	-	27.27	-		
13	92.3	-	-	-	-	3.85	-	-	-	-	-	-	-	3.85	-		
14	6.25	-	-	-	-	18.75	18.75	-	-	-	-	-	-	43.75	12.50		
15	83.3	-	-	-	-	-	-	-	-	-	-	-	-	8.33	8.33		
16	87.5	4.16	-	-	-	-	8.33	-	-	-	-	-	-	-	-		
17	21.0	-	15.79	-	-	10.52	-	-	-	-	-	-	-	26.3	26.3		
18	24.0	52.0	-	-	-	-	4.0	-	-	-	-	-	-	20.0	-		
19	28.57	61.90	-	-	-	-	-	-	-	-	-	-	-	-	9.52		
20	31.57	-	63.15	-	-	-	-	-	-	-	-	-	-	-	5.26		
21	8.33	-	50.0	-	-	4.16	12.50	-	12.50	-	-	-	-	8.33	4.16		
22	26.3	-	-	-	-	26.3	10.5	-	10.5	-	-	-	-	10.5	15.78		

APPENDIX I(d). BOTANICAL ANALYSIS - POINT QUADRAT METHOD.

PLOT No. B.

GRASS PRODUCTION AREA

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
1	-	92.8	-	-	-	-	-	-	-	-	-	-	-	3.57	3.57	-	
2	47.4	5.25	-	-	-	5.25	-	-	15.7	-	-	-	-	15.7	15.7	-	
3	5.55	33.3	11.11	-	16.6	-	-	-	16.6	-	-	-	-	11.11	5.55	-	
4	-	96.7	-	-	-	-	-	-	-	-	-	-	-	-	3.22	-	
5	64.3	14.3	-	-	-	-	-	-	-	-	-	-	-	-	21.4	-	
6	32.14	21.4	-	-	-	3.57	-	-	-	-	-	-	-	32.14	-	10.7	
7	8.33	-	-	-	-	20.83	-	-	12.50	29.16	-	-	-	12.50	8.33	4.16	
8	-	-	-	30.0	-	15.0	-	-	-	35.0	-	-	-	20.0	-	-	
9	25.0	-	-	-	-	8.33	8.33	-	20.8	-	-	-	-	20.8	16.6	-	
10	-	-	-	36.0	-	-	-	-	4.0	-	-	-	-	52.0	8.0	-	
11	28.0	-	-	-	-	20.0	-	-	12.0	-	-	-	-	36.0	4.0	-	
12	24.3	-	8.10	16.2	-	-	-	-	21.6	5.40	-	-	-	13.5	-	10.8	
13	69.5	-	-	-	-	26.0	-	-	-	-	-	-	-	-	-	4.3	
14	-	-	-	24.1	-	-	-	-	6.89	-	-	-	-	51.7	10.3	6.89	
15	19.23	53.8	-	-	-	-	-	-	-	-	-	-	-	19.23	7.69	-	
16	-	70.4	-	-	-	29.6	-	-	-	-	-	-	-	-	-	-	
17	17.4	69.56	-	-	-	4.34	-	-	-	-	-	-	-	8.69	-	-	
18	57.14	-	-	21.4	-	7.14	-	-	-	-	-	-	-	14.28	-	-	
19	-	76.7	-	-	-	-	-	-	-	-	-	-	-	13.95	9.30	-	
20	16.00	-	-	-	-	44.0	-	-	-	-	-	-	-	28.0	12.0	-	
21	-	96.3	-	-	-	-	-	-	-	-	-	-	-	-	3.70	-	
22	-	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

APPENDIX I(d). Continued

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
23	-	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
24	-	92.3	-	-	-	11.5	-	-	3.8	-	-	-	-	-	3.8	-	
25	-	80.0	-	-	-	-	-	-	-	-	-	-	-	4.0	16.0	-	
26	40.7	-	-	-	-	-	-	-	7.40	-	-	-	-	37.0	14.8	-	
27	-	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
28	-	96.5	-	-	-	-	-	-	3.4	-	-	-	-	-	-	-	
29	-	72.4	-	13.79	-	13.79	-	-	-	-	-	-	-	-	-	-	
30	-	94.1	-	-	-	-	-	-	-	-	-	-	-	2.94	2.94	-	
	454.99	1365.81	19.21	141.49	16.6	209.35	8.33	-	124.69	69.56	-	-	-	397.11	166.90	36.85	
$\bar{x}$	15.17	45.53	0.64	4.72	0.55	6.98	0.28	-	4.16	2.32	-	-	-	13.24	5.36	1.23	

APPENDIX I(e). BOTANICAL ANALYSIS - POINT QUADRAT METHOD.

PLOT No. C.

FORAGING STRIPS

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
1	26.1	65.2	-	-	-	-	-	-	4.34	-	-	-	-	-	4.34		
2	82.75	-	-	-	-	-	-	-	6.89	-	-	-	-	10.3	-		
3	88.0	8.0	-	-	-	-	4.0	-	-	-	-	-	-	-	-		
4	20.8	41.6	-	-	-	-	12.50	-	-	-	-	-	-	12.50	12.50		
5	7.69	3.84	-	-	-	3.84	30.76	-	7.69	3.84	-	7.69	-	23.0	11.53		
6	10.71	35.7	-	-	-	-	-	-	17.85	-	-	3.57	-	21.4	10.71		
7	6.25	-	-	-	12.50	-	-	-	43.75	-	-	-	-	18.75	18.75		
8	-	-	-	-	-	-	-	-	20.68	-	-	10.34	-	48.3	20.68		
9	-	83.3	-	-	-	-	-	-	-	-	-	-	-	11.11	5.55		
10	22.2	66.6	-	-	-	-	-	-	3.70	-	-	-	-	3.70	3.70		
11	40.0	40.0	-	-	-	-	-	-	-	-	-	12.0	-	8.0	-		
12	21.42	42.8	-	28.57	-	-	28.57	-	-	-	-	-	-	-	-		
13	20.69	44.8	-	31.0	-	-	-	-	-	-	-	-	-	-	3.44		
14	-	14.28	-	9.52	-	33.3	-	-	4.76	-	28.57	-	-	4.76	4.76		
15	14.8	-	22.2	22.2	-	11.11	-	-	25.9	-	-	-	-	3.70	-		
16	-	70.58	-	17.6	11.76	-	-	-	-	-	-	-	-	-	-		
17	-	4.00	-	24.0	24.0	4.0	-	-	20.0	-	-	-	-	20.0	4.0		
18	28.57	-	-	9.52	-	14.28	23.8	-	9.52	-	-	-	-	14.28	-		
19	41.66	37.5	-	-	-	-	-	-	4.16	-	-	-	-	16.6	-		
20	16.6	-	20.8	4.16	-	12.5	-	-	4.16	-	-	-	-	37.5	4.16		
21	27.58	17.24	-	41.37	-	6.89	-	-	-	-	6.89	-	-	-	-		
22	-	20.0	20.0	36.0	12.0	-	-	-	4.0	-	8.0	-	-	-	-		

APPENDIX I(e). Continued

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
23	32.25	32.25	6.4	16.12	3.22	-	6.4	-	-	-	-	-	-	3.22	-		
24	29.16	-	-	37.5	-	-	-	-	16.6	-	-	-	-	12.50	4.15		
25	48.0	-	-	-	-	24.0	16.0	-	-	-	-	-	-	8.0	4.0		
26	48.0	-	-	40.0	-	4.0	-	-	-	-	-	-	-	4.0	4.0		
27	-	25.0	-	24.0	-	40.0	-	-	-	-	-	-	-	5.0	-		
28	23.0	23.0	-	-	-	15.38	-	-	23.0	-	-	-	-	7.69	7.69		
29	35.0	-	-	-	-	35.0	-	-	10.0	-	-	-	-	20.0	-		
30	5.88	2.94	-	38.23	-	5.88	-	-	5.88	-	-	-	-	32.3	8.8		
	697.11	678.63	69.4	379.79	63.48	210.18	122.03	-	232.88	3.84	43.46	33.60	-	346.61	132.76		
$\bar{x}$	23.24	22.62	2.31	12.66	2.12	7.0	4.06	-	7.76	0.128	1.448	1.12	-	11.55	4.42		

APPENDIX I(f). BOTANICAL ANALYSIS - POINT QUADRAT METHOD.

PLOT No. C.

GRASS PRODUCTION AREA

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
1	10.81	70.27	-	-	-	-	16.21	-	-	-	-	-	-	-	2.70		-
2	28.57	52.3	-	-	-	-	-	-	4.76	-	-	-	-	9.52	4.76		-
3	25.81	41.93	-	32.25	-	-	-	-	-	-	-	-	-	-	-		-
4	22.2	48.14	-	-	-	-	-	-	3.70	-	-	-	18.52	7.40	-		-
5	50.0	-	-	-	-	27.3	-	-	18.18	-	-	-	-	4.54	-		-
6	48.14	-	-	-	-	11.11	22.2	-	-	-	-	-	-	3.70	-		14.8
7	39.13	-	-	26.0	-	7.40	7.40	-	4.34	-	-	-	-	7.40	4.34		-
8	31.57	21.0	-	-	-	36.84	-	-	-	-	-	-	-	5.26	5.26		-
9	9.37	56.25	-	18.75	-	12.50	-	-	-	-	-	-	-	3.12	-		-
10	32.0	48.0	-	-	-	12.0	-	-	-	-	-	-	-	8.0	-		-
11	8.69	39.13	-	52.17	-	-	-	-	-	-	-	-	-	-	-		-
12	24.0	52.0	-	8.0	-	16.0	-	-	-	-	-	-	-	-	-		-
13	25.92	48.14	-	25.92	-	-	-	-	-	-	-	-	-	-	-		-
14	15.38	42.30	-	-	-	3.84	23.07	-	-	-	-	-	-	7.69	7.69		-
15	20.0	44.0	-	4.0	-	-	-	-	12.0	-	-	-	-	12.0	8.0		-
16	26.08	52.17	-	-	-	-	-	-	17.39	-	-	-	-	-	4.34		-
17	6.25	56.25	-	25.0	-	-	-	-	-	-	-	-	-	12.50	-		-
18	52.38	-	-	-	-	28.57	-	-	-	-	-	-	-	14.28	4.76		-
19	35.0	-	-	30.0	-	15.0	-	-	-	-	-	-	-	15.0	5.0		-
20	34.61	11.53	-	-	-	11.32	26.92	-	3.84	-	-	-	-	7.69	3.84		-
21	7.40	44.4	-	-	-	14.81	25.92	-	7.41	-	-	-	-	-	-		-
22	66.66	-	-	-	-	-	24.24	-	-	-	-	-	-	9.1	-		-

APPENDIX I(f). Continued

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
23	13.79	6.89	-	-	-	6.89	-	-	13.79	-	-	-	-	27.58	-		31.0
24	53.84	3.85	-	7.69	-	30.76	-	-	-	-	-	-	-	-	3.55		-
25	12.00	-	-	32.0	8.0	36.0	-	-	4.00	-	-	-	-	4.00	4.00		-
26	70.83	-	-	-	-	-	-	-	-	-	-	-	-	20.83	8.33		-
27	55.0	-	-	-	-	10.0	-	-	10.0	-	-	-	-	20.0	5.0		-
28	19.23	-	-	53.84	-	7.69	-	-	3.84	-	-	-	-	15.34	-		-
29	47.82	-	-	-	-	8.69	-	-	4.34	-	-	-	-	30.43	8.69		-
30	-	23.80	-	52.38	-	19.05	-	-	-	-	-	-	-	-	4.76		-
	892.48	762.35	-	368.0	8.0	315.98	145.96	-	107.59	-	-	-	18.52	245.42	85.32		45.80
$\bar{x}$	29.74	25.41	-	12.27	0.27	10.53	4.86	-	3.59	-	-	-	0.62	8.18	2.82		1.53

APPENDIX I(g). BOTANICAL ANALYSIS - POINT QUADRAT METHOD.

PLOT No. D.

FORAGING STRIPS

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
1	36.11	36.11	-	-	-	2.77	-	-	5.55	5.55	-	-	-	5.55	2.77	5.55	
2	28.00	48.00	-	-	-	-	-	-	12.00	-	-	-	-	8.00	4.00	-	
3	-	63.63	-	-	-	-	-	-	9.09	-	-	-	-	27.27	-	-	
4	40.74	-	-	-	-	-	-	-	14.8	-	-	22.22	-	7.40	14.81	-	
5	43.47	26.08	-	8.69	-	-	17.39	-	-	-	-	-	-	4.34	-	-	
6	21.23	43.47	-	21.73	13.04	-	-	-	-	-	-	-	-	-	-	-	
7	14.28	17.85	-	28.57	-	25.00	-	-	-	-	-	-	-	14.28	-	-	
8	21.42	7.14	-	39.28	-	32.14	-	-	-	-	-	-	-	-	-	-	
9	29.41	26.47	8.82	5.88	5.88	17.64	-	-	-	-	-	-	-	2.94	2.94	-	
10	25.0	37.50	-	-	4.16	8.33	16.16	-	-	-	-	-	-	4.16	4.16	-	
11	17.85	28.57	-	-	-	17.85	28.57	-	-	-	-	-	-	7.14	-	-	
12	20.0	45.0	-	-	-	30.0	-	-	-	-	-	-	-	5.0	-	-	
13	60.0	12.0	-	-	-	-	-	-	8.00	-	-	-	-	16.00	4.00	-	
14	29.16	29.16	-	29.16	-	8.33	-	-	4.16	-	-	-	-	-	-	-	
15	20.00	32.00	-	4.00	-	20.00	-	-	12.00	-	-	-	-	8.0	4.00	-	
16	25.92	44.4	-	-	-	7.40	7.40	-	-	-	-	-	-	14.81	-	-	
17	12.50	12.50	-	29.16	-	12.50	25.0	-	-	-	-	-	-	8.33	-	-	
18	40.0	8.00	-	-	-	8.00	-	12.00	8.00	-	-	-	-	20.0	4.0	-	
19	10.34	65.5	-	-	-	-	-	-	6.89	-	-	-	-	17.24	-	-	
20	35.48	3.22	-	9.67	-	9.67	25.80	-	3.22	-	-	-	-	12.90	-	-	
21	52.17	-	-	39.13	-	-	-	-	4.35	-	-	-	-	4.35	-	-	
22	23.33	40.0	-	10.0	6.66	6.66	-	-	3.33	-	-	-	-	6.66	3.33	-	

APPENDIX I(g). Continued

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
23	41.37	20.69	-	-	-	-	31.0	-	-	-	-	-	-	6.89	-	-	
24	33.57	46.42	-	-	-	17.85	-	-	7.14	-	-	-	-	25.0	-	-	
25	35.29	17.64	-	14.70	-	23.52	-	-	-	-	-	-	-	5.88	2.94	-	
26	-	54.28	-	34.28	5.7	5.7	-	-	-	-	-	-	-	-	-	-	
27	48.38	6.45	-	6.45	-	12.90	-	-	6.45	-	-	-	-	19.35	-	-	
28	18.18	12.12	-	21.21	-	12.12	-	15.15	12.12	-	-	-	-	9.09	-	-	
29	70.96	-	-	9.67	-	12.90	-	-	-	-	-	-	-	6.45	-	-	
30	28.12	18.75	9.37	25.00	-	15.62	-	-	-	-	-	-	-	3.12	-	-	
	853.05	802.95	18.19	336.58	35.44	306.90	151.82	27.15	117.10	5.55	-	22.22	-	270.15	46.95	5.55	
$\bar{x}$	28.44	26.76	0.60	11.22	1.18	10.23	5.06	0.91	3.90	0.185	-	0.74	-	9.00	1.57	0.18	

APPENDIX I(h). BOTANICAL ANALYSIS - POINT QUADRAT METHOD.

PLOT No. D.

GRASS PRODUCTION AREA

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
1	12.50	83.33	-	-	-	-	-	-	-	-	-	-	-	4.16	-		
2	25.0	70.0	-	-	-	-	-	-	5.0	-	-	-	-	-	-		
3	9.52	57.14	-	14.28	-	-	14.28	-	-	-	-	-	-	-	4.76		
4	19.04	71.42	-	-	-	-	-	-	4.76	-	-	-	-	4.76	-		
5	13.0	73.9	-	-	-	-	-	4.34	8.69	-	-	-	-	-	-		
6	50.0	16.66	-	-	-	-	11.11	-	-	-	-	-	-	11.11	11.11		
7	16.0	84.0	-	-	-	-	-	-	-	-	-	-	-	-	-		
8	-	91.30	-	-	-	-	-	-	-	-	-	-	-	8.69	-		
9	-	33.3	-	55.5	-	-	-	-	-	-	-	-	-	5.55	5.55		
10	60.0	20.0	-	-	-	5.0	-	5.0	-	-	-	-	-	10.0	-		
11	28.0	36.0	-	-	-	-	36	-	-	-	-	-	-	-	-		
12	10.71	42.85	-	42.85	-	-	-	-	-	-	-	-	-	-	3.57		
13	-	39.28	-	60.71	-	-	-	-	-	-	-	-	-	-	-		
14	13.63	81.81	-	-	-	-	-	-	4.54	-	-	-	-	-	-		
15	21.42	50.0	-	-	-	21.42	-	-	-	-	-	-	-	3.57	3.57		
16	-	66.66	-	-	-	-	4.16	-	4.16	-	-	-	-	20.83	4.16		
17	19.44	33.33	-	-	-	41.66	-	-	-	-	-	-	-	2.77	2.77		
18	54.16	25.0	-	-	-	16.6	-	-	4.16	-	-	-	-	-	-		
19	64.0	24.0	-	-	-	-	8.0	-	4.0	-	-	-	-	-	-		
20	6.45	74.19	-	-	-	-	-	-	6.45	-	-	-	-	9.67	3.22		
21	10.71	25.00	-	-	-	-	-	-	-	-	-	-	-	14.28	-		
22	58.82	11.76	-	26.47	-	-	2.94	-	-	-	-	-	-	-	-		

APPENDIX I(h). Continued

% Composition of each species/quadrat

Quadrat No.	SPECIES SYMBOLS																
	A.g.	H.d.	C.g.	C.n.	E.t.	M.i.	C.sp.	C.d.	B.b.	CH.g.	I.c.	P.p.	B.j.	SS	LL	R.e.	D.d.
23	-	25.0	-	56.25	-	-	-	-	6.25	-	-	-	-	12.50	-		
24	35.0	15.0	-	-	5.0	-	-	-	10.0	15.0	-	-	-	20.0	-		
25	2.94	55.88	-	35.29	-	-	-	-	-	-	-	-	-	5.88	2.94		
26	-	71.42	-	-	-	-	-	-	7.14	-	-	-	-	10.7	10.7		
27	-	51.85	-	-	-	-	25.92	-	14.81	-	-	-	-	3.70	3.70		
28	4.0	42.0	-	-	-	8.0	4.0	-	4.0	-	-	-	-	28.0	-		
29	66.66	14.81	-	-	-	-	7.40	-	3.70	-	-	-	-	7.40	-		
30	63.15	-	-	-	-	-	26.31	-	5.26	-	-	-	-	5.26	-		
	664.15	1436.89	-	291.35	5.0	92.68	140.12	9.34	92.92	15.0	-	-	-	183.57	61.31		
$\bar{x}$	22.14	47.89	-	9.71	0.16	3.09	4.67	0.31	3.09	0.50	-	-	-	6.12	2.04		

Legend to Appendices Ia - Ih

A.g.	=	Andropogon gayanus
H.d.	=	Hyparrhenia dissoluta
C.g.	=	Cymbopogon giganteus
C.n.	=	Ctenium newtonii
E.t.	=	Eragrostis tremula
M.i.	=	Microchloa indica
C.sp.	=	Cyperus species
C.d.	=	Cynodon dactylon
B.b.	=	Bracharia brizantha
Ch.g.	=	Chloris gayana
I.c.	=	Imperata cylindrica
P.p.	=	Pennisetum pedicellatum
B.j.	=	Brachiaria jubata
R.e.	=	Rottboellia exaltata
D.d.	=	Digitaria diagonalis
SS	=	Small shrubs
LL	=	Leaf litter

APPENDIX II(a). POPULATION ESTIMATES OF T. GEMINATUS AND QUANTITY OF GRASS STORED IN MOUNDS.

December 1973 - January 1974 Samples

Mound No.	Size Arc I + II (cm)	Total popn.	% Composition of different castes in popn.						Quantity of food (grass)
			Major Sold.	Minor Sold.	Workers	Nymph	Larvae	Alates	
1	62.72	1,073	4.05	13.76	61.9	0.08	-	-	24.75
2	* 49.28	* 857	6.7	14.3	53.48	2.95	1.06	-	23.21
3	-	-	-	-	-	-	-	-	-
4	123.20	14,402	4.5	9.9	58.4	0.89	11.68	-	-
5	103.04	1,026	5.2	19.7	66.9	0.4	-	-	27.74
6	136.64	9,976	4.08	8.7	73.9	-	0.39	-	-
7	112.0	3,689	2.9	14.7	64.1	0.13	0.08	-	8.46
8	147.84	11,987	4.3	14.4	57.4	-	5.1	-	-
9	* 47.04	* 81	2.5	8.6	77.8	-	-	-	5.25
10	* 76.16	* 307	5.2	22.5	44.3	0.3	-	-	-
11	201.60	59,959	3.9	7.7	70.9	1.0	4.5	-	-
12	147.84	6,126	4.9	10.5	68.4	0.07	0.14	-	78.18
13	145.60	15,644	3.37	8.7	68.7	1.8	2.2	-	40.63
14	114.24	35,236	2.5	10.9	70.9	0.07	2.3	-	91.48
15	94.08	9,915	4.9	9.1	70.0	0.48	1.3	-	2.50
16	141.12	17,076	3.1	5.9	74.7	2.0	4.3	-	71.48
17	170.24	38,647	4.2	8.8	71.0	0.5	2.38	-	102.19
18	145.60	33,340	2.4	9.7	66.7	1.2	7.52	-	16.82
19	* 91.84	* 364	7.0	17.0	70.0	-	5.5	-	10.40
20	176.96	34,490	3.6	7.8	75.0	1.4	0.5	-	171.63
	2287.04	292,586	88.09	222.66	1264.48	13.27	48.95		674.72
$\bar{x}$	120.37	19,505.73	4.63	11.72	66.55	0.88	3.26		48.19

* Nos. ≥1000 are not used in calculating mean population and not used in regression of size and popn.

APPENDIX II(b). POPULATION ESTIMATES OF T. GEMINATUS AND QUANTITY OF GRASS STORED IN MOUNDS.

April - May 1974

Mound No.	Size Arc I + II (cm)	Total popn.	% Composition of different castes in popn.						Quantity of food (grass)
			Major Sold.	Minor Sold.	Workers	Nymph	Larvae	Alates	
21	150.08	4,976	2.4	11.7	85.7	0.02	0.16	-	-
22	150.08	40,478	3.2	17.95	71.9	-	6.98	-	-
23	125.44	4,195	3.0	6.0	90.9	0.04	0.14	-	13.43
24	109.76	1,642	9.0	18.0	65.0	1.8	5.5	-	-
25	56.00	3,689	9.0	15.0	69.0	0.16	6.0	-	6.60
26	62.72	2,267	4.5	14.8	46.4	-	-	-	5.17
27	125.44	1,891	12.0	18.0	50.0	12	8.0	-	-
28	-	-	-	-	-	-	-	-	-
29	60.48	4,189	4.0	16.0	67.5	-	12.7	-	4.83
30	43.23	2,018	4.6	28.3	59.2	2.86	5.56	-	-
31	98.56	5,563	6.88	21.2	70.2	-	1.69	-	10.78
32	80.64	1,517	7.96	22.5	57.79	5.75	5.96	-	15.48
33	-	-	-	-	-	-	-	-	-
34	112.00	2,059	13.2	19.44	65.2	-	2.14	-	-
35	161.28	35,021	6.3	15.89	55.6	-	-	-	63.63
36	96.32	3,280	4.76	17.48	54.26	-	1.24	-	-
37	116.48	12,722	0.44	4.92	89.3	-	-	-	-
38	105.28	23,724	4.03	10.20	81.76	0.39	3.59	-	22.48
39	98.56	3,505	6.15	21.50	72.32	-	-	-	3.50
40	94.08	5,683	3.84	14.79	80.23	-	1.11	-	13.67
		158,422	105.26	327.87	1232.26	23.02	60.77	-	170.80
	$\bar{x}$	8,801.22	5.84	18.22	68.46	2.88	4.34	-	15.53

APPENDIX II(c). POPULATION ESTIMATES OF T. GEMINATUS AND QUANTITY OF GRASS STORED IN MOUNDS.

August - September 1974

Mound No.	Size Arc I + II (cm)	Total popn.	% Composition of different castes in popn.						Quantity of food (grass)
			Major Sold.	Minor Sold.	Workers	Nymph	Larvae	Alates	
41	155	18,512	10.2	9.2	71.9	-	0.07	8.3	-
42	104	4,136	4.5	15.6	79.6	-	0.16	0.03	68.20
43	120	20,047	5.5	7.3	85.0	-	-	2.3	16.14
44	105	23,619	4.2	7.8	86.0	-	-	-	-
45	105	1,274	4.4	11.2	83.8	-	0.07	0.47	5.27
46	95	27,512	8.6	16.8	71.0	-	3.4	-	82.55
47	210	63,468	5.2	6.3	80.0	-	1.5	6.8	62.27
48	135	15,700	6.6	9.5	83.8	-	-	-	-
49	100	18,645	6.4	3.2	90.3	-	-	-	12.35
50	150	74,897	12.6	2.5	84.8	-	-	0.08	13.40
51	150	38,593	8.4	9.8	80.3	0.42	0.99	-	-
52	117	16,397	6.7	21.0	67.4	-	4.8	-	30.60
53	180	40,832	7.3	11.2	78.5	2.10	0.83	-	31.20
54	125	16,182	7.47	12.4	79.3	0.62	0.28	-	-
55	107	21,065	8.7	12.68	78.4	-	0.18	-	8.02
56	125	49,284	7.4	13.7	77.0	1.8	-	-	-
57	120	20,710	8.2	8.3	81.2	1.4	0.92	-	37.45
58	127	13,144	9.0	13.5	76.3	0.30	0.9	-	59.31
59	112	17,537	7.3	8.13	83.6	0.58	0.02	-	49.59
60	100	33,595	4.0	6.6	85.8	-	3.4	-	-
		535,149	142.37	281.41	1604.0	7.22	17.52	17.97	476.35
	$\bar{x}$	26,757.5	7.11	14.07	80.20	1.03	1.25	2.99	36.64

APPENDIX II(d). POPULATION ESTIMATES OF T. GEMINATUS AND QUANTITY OF GRASS STORED IN MOUNDS.

December 1974 - January 1975

Mound No.	Size Arc I + II (cm)	Total popn.	% Composition of different castes in popn.						Quantity of food (grass)
			Major Sold.	Minor Sold.	Workers	Nymph	Larvae	Alates	
61	170	11,236	2.43	6.09	66.30	0.66	16.0	-	183.00
62	135	5,234	18.68	13.98	54.58	0.06	12.69	-	192.23
63	183	9,536	14.12	11.55	70.88	-	3.45	-	119.00
64	119	2,498	10.88	21.12	61.86	-	0.13	-	82.90
65	130	8,183	13.22	23.30	60.45	0.43	2.58	-	100.66
66	90	3,231	11.77	24.85	61.04	0.09	2.28	-	68.86
67	195	22,593	5.51	12.74	79.01	-	2.73	-	323.32
68	120	17,268	5.28	11.29	83.29	-	0.13	-	201.96
69	135	20,307	7.02	15.27	76.83	0.12	0.77	-	213.40
70	132	16,169	8.04	19.64	67.90	0.64	3.77	-	287.73
71	143	18,799	13.72	11.29	72.15	-	2.82	-	48.79
72	148	13,968	13.76	11.35	69.68	-	5.22	-	189.80
73	147	39,297	11.96	13.47	71.56	-	3.01	-	194.90
74	98	2,591	13.35	12.86	73.76	-	-	-	49.16
75	122	14,375	7.97	7.91	77.65	-	6.48	-	63.05
76	115	4,692	10.22	14.09	70.82	-	4.86	-	8.14
77	145	43,396	6.69	6.92	78.96	-	7.43	-	176.13
78	105	2,474	7.35	6.45	86.19	-	-	-	158.67
79	262	47,066	6.06	8.20	80.91	-	4.82	-	183.00
80	138	8,765	7.86	7.21	77.52	-	7.39	-	12.75
		311,678	201.89	274.85	1441.34	2.00	86.56	-	2857.45
	$\bar{x}$	15,583.9	10.09	13.74	72.06	0.33	4.81	-	142.87

APPENDIX II(e). POPULATION ESTIMATES OF T. GEMINATUS IN THE ZUGURMA BUSH OF THE PRIMARY SAVANNA WOODLAND.

September - October 1974

Mound No.	Size Arc I + II (cm)	Total popn.	% Composition of different castes in popn.						Quantity of food (grass)
			Major Sold.	Minor Sold.	Workers	Nymph	Larvae	Alates	
Z 1	197.12	13,716	7.38	7.95	84.04	-	0.62	-	-
" 2	185.9	24,650	10.44	3.64	85.14	-	0.78	-	65.70
" 3	150.0	37,643	8.66	7.64	83.70	-	-	-	-
" 4	135.0	15,911	8.09	6.91	84.82	-	0.18	-	39.49
" 5	200.0	83,456	7.22	11.74	81.04	-	-	-	211.49
" 6	80.0	12,428	8.30	8.75	81.29	-	1.66	-	-
" 7	110.0	1,409	11.71	10.88	77.21	-	-	-	26.92
" 8	135.0	15,751	9.60	7.35	79.68	-	3.34	-	7.85
" 9	115.0	20,379	8.00	9.56	79.93	-	2.51	-	-
" 10	285.0	34,288	8.26	9.63	78.61	-	3.50	-	32.44
" 11	164.0	51,570	10.21	9.72	76.06	-	4.01	-	10.86
" 12	225.0	64,508	8.06	11.54	77.96	-	2.43	-	48.37
" 13	140.0	40,411	8.20	9.27	78.87	-	3.66	-	-
" 14	175.0	100,901	5.17	3.18	87.47	-	4.18	-	11.90
" 15	155.0	11,020	5.15	7.59	87.27	-	-	-	72.49
" 16	112.0	13,709	8.33	10.29	77.18	-	4.20	-	24.40
" 17	160.0	23,096	3.69	15.19	81.10	-	-	-	4.45
" 18	105.0	7,000	-	-	-	-	-	-	-
" 19	137.0	37,518	7.09	9.61	78.93	-	4.37	-	48.76
" 20	117.0	11,171	4.11	7.25	88.64	-	-	-	44.89
		620,535	147.67	167.69	1584.94	-	35.44	-	650.0
	$\bar{x}$	31,026.75	7.77	8.83	81.52	-	2.73	-	46.63

Z refers to the Zugurma primary woodland.

APPENDIX III(a). TERMITE POPULATIONS/MOUND CALCULATED FROM REGRESSIONS DURING DIFFERENT SAMPLING PERIODS.

Block No. A.		Dec. 1973 - Jan. 1974	April - May 1974	August - Sept. 1974
Mound No.	Sum of Arcs (cm)	Regression Equation	Regression Equation	Regression Equation
		Y = 2.44 + 0.012X	Y = 2.96 + 0.007X	Y = 3.41 + 0.007X
5	109.76	5,720	5,350	15,100
6	62.72	1,556	2,510	7,064
8	123.20	8,290	6,643	18,730
12	71.68	2,000	2,900	8,162
13	76.16	2,260	3,113	9,400
16	51.52	1,130	2,093	6,320
21	94.08	3,700	4,155	12,560
25	40.32	839.2	1,750	5,275
29	73.92	2,124	3,003	9,070
30	62.72	1,556	2,510	7,064
272	42.56	893	1,811	5,470
279	42.56	893	1,811	5,470
284	58.24	1,380	1,253	7,042
285	76.16	2,260	3,113	9,400
286	44.80	950	1,880	5,670
287	31.36	655	1,511	4,574
291	64.96	1,660	2,600	7,850
296	38.08	789	1,685	5,090
297	38.08	789	1,685	5,090
298	72.20	2,025	2,920	8,820
301	85.12	2,893	3,597	10,840
302	44.80	950	1,880	5,670
303	56.00	1,292	2,250	6,792
304	125.44	8,816	6,890	20,800
305	47.04	1,011	1,950	5,880
307	89.60	3,270	3,870	11,660
310	71.68	2,000	2,900	8,162
311	143.36	14,500	9,194	27,800
312	78.40	2,400	3,222	9,745
313	53.76	1,220	2,170	6,551

APPENDIX III(a). Continued

Block No. A.		Dec. 1973 - Jan. 1974	April - May 1974	August - Sept. 1974
Mound No.	Sum of Arcs (cm)	Regression Equation	Regression Equation	Regression Equation
		Y = 2.44 + 0.012X	Y = 2.96 + 0.007X	Y = 3.41 + 0.007X
317	71.68	2,000	2,900	8,162
318	64.96	1,660	2,600	7,850
322	105.28	5,051	4,970	15,030
323	85.12	2,893	3,597	10,840
324	143.36	14,500	9,194	27,800
326	22.40	511.4	1,310	3,685
327	138.88	12,800	8,560	25,830
329	58.24	1,380	1,253	7,042
330	87.36	3,080	2,003	11,290
331	179.20	38,950	16,400	49,500
332	136.64	12,020	8,251	24,920
333	31.36	655.1	1,513	4,574
334	103.04	4,750	4,801	14,500
337	53.76	1,220	2,170	6,551
338	64.96	1,660	2,600	7,850
340	4.48	-	-	-
342	67.20	1,772	2,695	8,140
343	136.64	12,020	8,251	24,920
344	69.44	1,880	2,793	8,440
350	80.64	2,560	3,350	10,110
351	62.72	1,550	2,510	7,064
352	56.00	1,292	2,250	6,792
353	105.28	5,051	4,980	15,030
354	136.64	12,020	8,251	24,920
355	53.76	1,220	2,170	6,551
356	116.48	6,883	5,962	18,000
357	100.80	4,463	4,630	14,000

APPENDIX III(b). December 1974 - January 1975

Block A.

Mound No.	Sum of Arcs (cm)	Y = 3.04 + 0.007X	Mound No.	Sum of Arcs (cms)	Y = 3.04 + 0.007X
5	35	1,930	56	106	6,053
6	71	3,440	57	93	4,910
7	60	2,884	62	163	15,200
9	50	2,455	63	140	10,500
10	78	3,855	65	148	11,910
11	71	3,440	66	45	22,650
12	89	4,603	67	120	7,590
13	72	3,500	68	54	2,620
14	74	3,614	69	175	18,410
15	98	5,321	70	45	2,265
16	26	1,670	71	86	4,385
18	68	3,281	72	104	5,861
25	40	2,090	73	73	3,560
28	39	2,050	74	203	28,910
29	95	5,070			
30	97	5,235			
33	81	4,040			
34	104	5,861			
36	135	9,660			
38	145	11,350			
39	66	3,180			
40	152	12,710			
41	124	8,091			
42	64	3,075			
43	43	2,193			
44	102	5,675			
45	69	3,334			
46	74	3,614			
47	27	1,695			
48	35	1,930			

APPENDIX IV(a). TERMITE POPULATIONS/MOUND CALCULATED FROM REGRESSIONS DURING DIFFERENT SAMPLING PERIODS.

Block No. B.		Dec. 1973 - Jan. 1974	April - May 1974	August - Sept. 1974
Mound No.	Sum of Arcs (cm)	Regression Equation	Regression Equation	Regression Equation
		Y = 2.44 + 0.012X	Y = 2.96 + 0.007X	Y = 3.41 + 0.007X
34	76.16	2,260	3,113	9,400
35	60.48	1,465	2,420	6,814
36	51.52	1,130	2,093	6,320
37	87.36	3,080	2,003	11,290
38	96.32	3,943	4,310	12,200
39	33.60	697	1,570	4,420
40	80.64	2,560	3,350	10,110
41	114.24	6,470	5,750	16,210
42	125.44	8,816	6,890	20,800
43	82.88	2,720	3,470	9,780
44	91.84	3,495	4,010	11,300
45	100.80	4,463	4,630	14,000
46	89.60	3,280	3,880	10,900
47	24.64	544.1	1,360	3,824
49	73.92	2,125	3,003	8,462
50	49.28	1,075	2,020	5,690
51	80.64	2,560	3,350	10,110
52	147.84	16,400	9,883	27,860
53	47.04	1,011	1,945	5,490
54	35.84	741.5	1,625	4,580
57	51.52	1,130	2,093	6,320
58	31.36	655.1	1,511	4,574
59	143.36	14,500	9,194	27,800
61	80.64	2,560	3,350	10,110
62	87.36	3,080	2,003	11,290
63	82.88	2,720	3,470	9,780
65	100.80	4,463	4,630	14,000
66	60.48	1,465	2,430	6,814
70	103.04	4,750	4,800	14,500
72	71.68	2,000	2,900	8,162

APPENDIX IV(a). Continued

Block No. B.		Dec. 1973 - Jan. 1974	April - May 1974	August - Sept. 1974
Mound No.	Sum of Arcs (cm)	Regression Equation	Regression Equation	Regression Equation
		Y = 2.44 + 0.012X	Y = 2.96 + 0.007X	Y = 3.41 + 0.007X
73	64.96	1,660	2,600	7,850
74	132.16	10,610	7,680	21,630
75	89.60	3,275	3,870	10,900
76	42.56	893	1,811	5,470
77	64.96	1,660	2,600	7,850
78	103.04	4,750	4,800	14,500
79	69.44	1,880	2,790	8,440
80	71.68	2,000	2,900	8,162
81	76.16	2,260	3,113	9,400
86	141.12	14,600	8,870	25,000
88	67.20	1,772	2,695	8,140
91	94.08	3,700	4,155	12,560
92	136,64	12,020	8,251	24,920
94	47.04	1,011	1,945	5,490
99	168.00	28,600	13,700	38,550
102	91.84	3,495	4,010	11,300
103	85.12	2,893	3,597	10,840
104	102.04	4,750	4,800	14,500
105	31.36	655	1,511	4,574
109	22.40	511	1,310	3,952
110	76.16	2,260	3,113	9,400
111	49.28	1,075	2,020	5,690
112	73.92	2,124	3,003	9,070
114	87.36	3,080	2,003	11,290
119	35.84	741	1,625	4,580
120	58.24	1,380	1,253	7,042
121	64.96	1,660	2,600	7,850
122	42.56	893	1,811	5,470
123	73.92	2,124	3,003	9,070
124	20.16	481	1,263	3,560

APPENDIX IV(a). Continued

Block No. B.		Dec. 1973 - Jan. 1974	April - May 1974	August - Sept. 1974
Mound No.	Sum of Arcs (cm)	Regression Equation	Regression Equation	Regression Equation
		Y = 2.44 + 0.012X	Y = 2.96 + 0.007X	Y = 3.41 + 0.007X
125	60.48	1,465	2,430	6,814
126	29.12	613	1,460	4,110
128	51.52	1,130	2,093	6,320
131	62.72	1,550	2,510	7,064
231	53.76	1,220	2,170	6,551
237	31.36	655	1,513	4,574
240	78.40	2,400	3,222	9,745
241	4.48	-	-	-
242	147.84	16,400	9,883	27,860
243	114.24	6,470	5,750	16,210
244	53.76	1,220	2,170	6,551
248	4.48	-	-	-
249	33.60	697	1,560	4,420
250	29.12	613	1,460	4,110
251	80.64	2,560	3,350	10,110
252	40.32	839	1,750	5,275
254	100.80	4,463	4,630	14,000
257	4.48	-	-	-
258	78.40	2,400	3,222	9,745
259	67.20	1,772	2,695	8,140
260	85.12	2,893	3,597	10,840
261	127.68	9,380	7,141	20,130
262	62.72	1,550	2,510	7,064
264	42.56	893	1,811	5,470
265	103.04	4,750	4,800	14,500
266	53.76	1,220	2,170	6,551
267	44.80	950	1,880	5,670
268	35.84	741.5	1,625	4,580
270	116.48	6,883	5,962	18,000

APPENDIX IV(b). December 1974 - January 1975

Block B.

Mound No.	Sum of Arcs (cm)	Y = 3.04 + 0.007X	Mound No.	Sum of Arcs (cm)	Y = 3.04 + 0.007X
2	82	4,113	39	51	2,495
3	110	6,460	40	140	10,500
4	68	328	41	52	2,535
5	85	4,315	42	98	5,321
6	86	4,385	43	69	3,334
7	53	2,580	44	135	9,561
8	117	7,230	46	116	7,112
9	64	3,075	47	50	2,455
10	79	3,920	50	62	2,980
11	147	11,730	52	48	2,380
12	146	11,540	54	114	6,890
16	155	13,340	55	69	3,334
17	97	5,236	57	33	1,870
19	48	2,380	58	107	6,152
20	27	1,700			
21	51	2,495			
22	92	4,830			
23	70	3,390			
24	165	15,700			
25	71	3,440			
26	91	4,751			
27	73	3,560			
28	148	11,920			
29	97	5,236			
30	166	15,920			
31	66	3,180			
32	110	6,460			
35	54	2,620			
36	159	14,230			
38	80	3,981			

APPENDIX V(a). TERMITE POPULATIONS/MOUND CALCULATED FROM REGRESSIONS DURING DIFFERENT SAMPLING PERIODS.

Block No. C.		Dec. 1973 - Jan. 1974	April - May 1974	August - Sept. 1974
Mound No.	Sum of Arcs (cm)	Regression Equation	Regression Equation	Regression Equation
		Y = 2.44 + 0.012X	Y = 2.96 + 0.007X	Y = 3.41 + 0.007X
1	185.92	46,900	18,250	51,440
2	123.20	8,290	6,643	18,730
3	103.04	4,750	4,800	14,500
4	40.32	839	1,750	5,275
5	53.76	1,220	2,170	6,551
6	143.36	14,500	9,194	27,800
7	145.60	15,400	9,532	26,900
8	127.68	9,380	7,141	20,130
9	82.88	2,720	3,470	9,780
10	96.32	3,943	4,310	12,200
11	107.52	5,380	5,160	14,530
12	120.96	7,790	6,410	18,100
13	80.64	2,560	3,350	10,110
14	69.44	1,880	2,793	8,440
16	40.32	839	1,750	5,275
17	114.24	6,470	5,750	16,210
18	35.84	741	1,625	4,580
20	56.00	1,292	2,250	6,792
27	105.28	5,051	4,980	14,030
28	136.64	12,020	8,251	24,920
29	129.92	9,980	7,410	20,900
30	120.96	7,790	6,410	18,100
31	116.48	6,883	5,962	18,000
34	112.00	6,081	5,552	15,640
35	78.40	2,400	3,222	9,745
38	123.20	8,290	6,643	18,730
39	64.96	1,660	2,600	7,850
40	123.20	8,290	6,643	18,730
43	49.28	1,075	2,020	5,690
44	58.24	1,380	1,253	7,042

APPENDIX V(a). Continued

Block No. C.		Dec. 1973 - Jan. 1974	April - May 1974	August - Sept. 1974
Mound No.	Sum of Arcs (cm)	Regression Equation	Regression Equation	Regression Equation
		Y = 2.44 + 0.012X	Y = 2.96 + 0.007X	Y = 3.41 + 0.007X
45	87.36	3,080	2,003	11,290
47	71.68	2,000	2,900	8,162
48	58.24	1,380	1,253	7,042
51	107.52	5,380	5,160	14,530
52	156.80	21,000	11,420	32,200
54	107.52	5,380	5,160	14,530
55	120.96	7,790	6,410	18,100
56	116.48	6,883	5,962	18,000
58	91.84	3,495	4,010	11,300
60	40.32	839	1,750	5,275
61	87.36	3,080	2,003	11,290
62	71.68	2,000	2,900	8,162
64	44.80	950	1,880	5,670
68	4.48	-	-	-
69	4.48	-	-	-
70	98.56	4,195	4,470	12,600
71	4.48	-	-	-
73	47.04	1,011	1,945	5,490
74	91.84	3,495	4,010	11,300
75	42.56	893	1,811	5,470
76	89.60	3,280	3,880	10,900
78	35.84	741	1,625	4,580
79	60.48	1,465	2,430	6,814
80	33.60	697	1,570	4,420
86	67.20	1,772	2,695	8,140
87	62.72	1,550	2,510	7,064
88	100.80	4,463	4,630	14,000
89	42.56	893	1,811	5,470
90	78.40	2,400	3,222	9,745
95	78.40	2,400	3,222	9,745

APPENDIX V(a). Continued

Block No. C.		Dec. 1973 - Jan. 1974	April - May 1974	August - Sept. 1974
Mound No.	Sum of Arcs (cm)	Regression Equation	Regression Equation	Regression Equation
		Y = 2.44 + 0.012X	Y = 2.96 + 0.007X	Y = 3.41 + 0.007X
102	35.84	741	1,625	4,580
103	47.04	1,011	1,945	5,490
104	87.36	3,080	2,003	11,290
105	53.76	1,220	2,170	6,551
109	76.16	2,260	3,113	9,400
110	44.80	950	1,880	5,670
111	38.08	789	1,685	5,090
112	109.76	5,720	5,350	15,100
114	67.20	1,772	2,695	8,140
119	38.08	789	1,685	5,090
120	40.32	839	1,750	5,275
121	89.60	3,280	3,880	10,900
122	78.40	2,400	3,222	9,745
123	38.08	789	1,685	5,090
124	26.88	579	1,410	3,965
125	69.44	1,880	2,793	8,440
126	22.40	511	1,310	3,685
128	35.84	741	1,625	4,580
130	58.24	1,380	1,253	7,042
132	4.48	-	-	-
133	78.40	2,400	3,222	9,745
134	85.12	2,893	3,597	10,840
136	89.60	3,280	3,880	10,900
144	82.88	2.720	3,470	9,780
145	136.64	12,024	8,251	24,920
146	35.84	741	1,625	4,580

APPENDIX V(b). December 1974 - January 1975

Block C.

Mound No.	Sum of Arcs (cm.)	Y = 3.04 + 0.007X	Mound No.	Sum of Arcs (cm.)	Y = 3.04 + 0.007X
4	49	2,415	38	55	2,661
5	47	2,340	39	59	2,840
6	78	3,855	40	109	6,351
7	107	6,152	41	78	3,855
9	60	2,884	44	90	4,680
10	103	5,770	45	127	8,492
11	134	9,505	46	66	3,180
12	27	1,695	48	67	3,230
13	160	14,450	49	130	8,912
14	134	9,505	50	26	1,670
15	188	22,700	52	43	2,193
16	160	14,450	53	28	1,722
17	118	7,345	54	55	2,661
18	169	16,710	55	153	12,910
20	153	12,910	56	81	4,040
21	151	12,500	57	80	3,981
22	163	15,200	58	102	5,675
24	107	6,152	59	114	6,890
25	121	7,710	60	110	6,460
26	119	7,464	61	45	2,265
27	118	7,345	62	135	9,660
28	35	1,930	65	61	2,931
29	133	9,354	66	60	2,884
30	126	8,355	67	42	2,160
31	103	5,770	68	33	1,870
32	168	16,400	69	179	19,640
33	206	30,340	70	101	5,585
34	37	1,991	71	96	5,152
35	65	3,113	72	63	3,030
37	53	2,580	73	91	4,754

APPENDIX V(b). Continued

Mound No.	Sum of Arcs (cm.)	Y = 3.04 + 0.007X	Mound No.	Sum of Arcs (cm.)	Y = 3.04 + 0.007X
74	227	42,550			
75	103	5,770			
77	89	4,603			
78	119	7,464			
80	80	3,981			
81	57	2,750			
82	85	4,315			
83	69	3,334			
84	53	2,580			
85	103	5,770			
86	135	9,660			
87	158	14,000			
88	94	4,990			
89	57	2,750			
91	106	6,053			
92	50	2,455			
93	120	7,590			
95	44	2,230			
96	125	8,222			
97	106	6,053			
98	65	3,113			
99	75	3,673			
100	37	1,991			
101	67	3,230			
102	63	3,025			
103	62	2,980			
104	137	9,980			

APPENDIX VI(a). TERMITE POPULATIONS/MOUND CALCULATED FROM REGRESSIONS DURING DIFFERENT SAMPLING PERIODS.

Block No. D.		Dec. 1973 - Jan. 1974	April - May 1974	August - Sept. 1974
Mound No.	Sum of Arcs (cm.)	Regression Equation	Regression Equation	Regression Equation
		Y = 2.44 + 0.012X	Y = 2.96 + 0.007X	Y = 3.41 + 0.007X
150	82.88	2,720	3,470	9,780
151	94.08	3,710	4,155	11,710
152	96.32	3,943	4,310	12,200
153	105.28	5,051	4,970	15,030
155	118.72	7,322	6,182	17,420
156	69.44	1,880	2,793	8,440
157	109.76	5,720	5,350	15,100
158	67.20	1,772	2,695	8,140
159	127.68	9,380	7,141	20,130
161	112.00	6,081	5,552	15,640
162	49.28	1,075	2,020	5,690
163	58.24	1,380	1,253	7,042
164	100.80	4,463	4,630	14,000
165	20.16	481	1,263	3,560
168	49.28	1,075	2,020	5,690
170	73.92	2,124	3,003	9,070
172	38.08	789	1,685	5,090
174	118.72	7,322	6,182	17,420
176	132.16	10,610	7,680	21,630
179	172.48	32,340	14,700	41,430
180	109.76	5,720	5,350	15,100
183	107.52	5,380	5,160	14,530
184	150.08	17,420	10,300	28,900
185	125.44	8,820	6,890	19,450
189	80.64	2,560	3,350	10,110
190	69.44	1,880	2,793	8,440
191	112.00	6,081	5,552	15,640
192	114.24	6,470	5,750	16,210
193	62.72	1,550	2,510	7,064
201	145.60	15,400	9,532	26,900

APPENDIX VI(a). Continued

Block No. D.		Dec. 1973 - Jan. 1974	April - May 1974	August - Sept. 1974
Mound No.	Sum of Arcs (cm)	Regression Equation	Regression Equation	Regression Equation
		Y = 2.44 + 0.012X	Y = 2.96 + 0.007X	Y = 3.41 + 0.007X
202	165.76	26,900	13,200	37,200
203	49.28	1,075	2,020	5,690
204	40.32	839	1,750	5,275
205	35.84	741.5	1,625	4,580
206	22.40	511.5	1,310	3,685
207	49.28	1,075	2,020	5,690
208	125.44	8,820	6,890	19,450
209	49.28	1,075	2,020	5,690
210	96.30	3,943	4,310	12,200
211	112.00	6,081	5,552	15,640
212	38.08	789	1,685	5,090
213	35.84	741.5	1,625	4,580
214	73.92	2,124	3,003	9,070
215	105.28	5,051	4,970	15,030
216	100.80	4,463	4,630	14,000

APPENDIX VI(b). December 1974 - January 1975

Block D.

Mound No.	Sum of Arcs (cm.)	Y = 3.04 + 0.007X	Mound No.	Sum of Arcs (cm.)	Y = 3.04 + 0.007X
4	112	6,670	39	80	3,981
5	83	4,180	44	121	7,710
6	131	9,055	45	36	1,960
8	77	3,793	46	104	5,861
9	40	2,090	47	88	4,530
11	165	15,650	48	42	2,155
12	38	2,023	49	92	4,830
13	37	1,991	50	112	6,670
14	168	16,450	51	104	5,861
15	69	3,334	52	84	4,245
16	68	3,281			
17	185	21,630			
18	78	3,855			
21	50	2,455			
22	118	7,345			
23	96	5,152			
24	148	11,920			
25	88	4,530			
26	137	9,975			
27	125	8,222			
28	36	1,960			
29	92	4,830			
30	42	2,155			
31	141	10,640			
32	104	5,861			
33	54	2,620			
34	55	2,661			
35	42	2,155			
37	84	4,245			
38	74	3,614			

APPENDIX VII(a). POPULATION OF MOUNDS CALCULATED FROM REGRESSION ZUGURMA PLOTS.

PLOT 13

Serial No.	Sum of arcs (cm)		Regression Equation = 3.59 + 0.0048X
1		21	4,905
2		112	13,420
3		162	23,320
4		36	5,792
5		69	8,341
6		167	24,640
7		45	6,395
8		115	13,850
9		115	13,850
10		27	5,243
11	*(oc)	36	5,792
12		144	19,110
13	*(oc)	110	13,120
14		124	15,310
15		125	15,450
16		35	5,730
17		125	15,450
18		147	19,750
19		73	8,720
20		120	14,650
21		40	6,052
22		35	5,730
23		29	5,361
24	*(oc)	113	13,550
25		109	13,000
26		102	12,010
27		162	23,320
28		107	12,700
29		83	9,735
30		80	9,420
31		67	8,150

APPENDIX VII(a). Continued

Serial No.	Sum of arcs (cm)	Regression Equation = 3.59 + 0.0048X
32	40	6,052
33	68	8,250
34	54	7,065
35	60	7,551
36	176	27,220
37	149	20,200
38	130	16,350
39	146	19,540
40	130	16,350
41	195	33,600
42	104	12,250
43	65	7,980

T. geminatus Mean Population/mound = 13,045

* T. occidentalis " = 10,820

Other species NIL

APPENDIX VII(b). POPULATION OF MOUNDS CALCULATED FROM REGRESSION ZUGURMA PLOTS.

PLOT 14

Serial No.	Sum of arcs (cm)	Regression Equation = 3.59 + 0.0048X
1	67	8,150
2	109	13,000
3	109	13,000
4	121	14,820
5	103	12,150
6	46	6,470
7	58	7,385
8	149	20,200
9	(oc) 99	11,620
10	161	23,050
11	(oc) 132	16,730
12	66	8,070
13	164	23,840
14	80	9,420
15	110	13,120
16	112	13,420
17	105	12,420
18	134	17,110
19	110	13,120
20	94	11,000
21	**(tog) 100	11,750
22	84	9,845
23	149	20,200
24	72	8,622
25	152	20,850
26	65	7,980
27	188	31,100
28	114	13,730
29	198	34,750
30	29	5,361
31	193	32,850

APPENDIX VII(b). Continued

Serial No.	Sum of arcs (cm)	Regression Equation = 3.59 + 0.0048X
32	165	24,100
33	130	16,350
34	143	18,900
35	70	8,430
36	103	12,150
37	177	27,520
38	175	26,900
39	70	8,430
40	(oc) 73	8,720
41	210	43,250
42	110	13,120
43	75	8,912
44	182	29,050
45	124	15,320
46	130	16,350
47	104	12,250
48	89	10,400
49	44	6,325
50	59	7,470
51	57	7,305
52	86	10,010
53	92	10,720
54	115	13,850
55	111	13,250
56	155	21,550
57	41	6,121
58	69	8,341
59	140	18,300
60	26	5,185

T. geminatus	Mean Population/mound	=	15,087
T. occidentalis	"	=	12,356
** T. togoensis	"	=	11,750

APPENDIX VII(c). POPULATION OF MOUNDS CALCULATED FROM REGRESSION ZUGUIRMA PLOTS.

PLOT 15

Serial No.	Sum of arcs (cm.)		Regression Equation = 3.59 + 0.0048X
1	56		7,224
2	47		6,540
3	79		9,315
4	35		5,730
5	177		27,520
6	40		6,052
7	161		23,050
8	97		11,350
9	49		6,685
10	89		10,400
11	50		6,761
12	42		6,190
13	117		14,200
14	31		5,480
15	33		5,603
16	69	(oc)	8,341
17	54	(oc)	7,065
18	53	(oc)	6,990
19	34		5,665
20	52	(oc)	6,912
21	74		8,813
22	121		14,820
23	46		6,470
24	69	(oc)	8,341
25	179		28,130
26	109		13,000
27	130		16,350
28	77		9,112
29	87		10,150
30	33	(tog)	5,603
31	40	(oc)	6,052

APPENDIX VII(c). Continued

Serial No.	Sum of arcs (cm)		Regression Equation = 3.59 + 0.00148X
32	(oc)	5	4,110
33		49	6,685
34		78	9,250
35	(tog)	80	9,420
36	(tog)	74	8,813
37	(tog)	119	14,500
38		159	22,550
39	(tog)	40	6,052
40	(oc)	60	7,551
41		86	10,010
42		25	5,125
43		73	8,720
44		59	7,465
45		100	11,750
46		25	5,125
47		65	7,980
48		53	6,990
49		39	5,985
50		96	11,220
51		104	12,250
52		95	11,120
53		151	20,650
54		105	12,420
55		36	5,792
56		35	5,730
57		91	10,640
58		44	6,325
59		121	14,820
60		120	14,650
61	(tog)	93	10,900
62		55	7,145
63		126	15,650

APPENDIX VII(c). Continued

Serial No.	Sum of arcs (cm)	Regression Equation = 3.59 + 0.0048X
64	67	8,150

T. geminatus	Mean Population/mound	=	10,792
T. togoensis	"	=	9,214
T. occidentalis	"	=	6,920

APPENDIX VII(c). Continued

Serial No.	Sum of arcs (cm.)	Regression Equation = 3.59 + 0.0048X
64	67	8,150

T. geminatus	Mean Population/mound	=	10,792
T. togoensis	"	=	9,214
T. occidentalis	"	=	6,920

APPENDIX VII(d). POPULATION OF MOUNDS CALCULATED FROM REGRESSION ZUGURMA PLOTS.

PLOT 16

Serial No.	Sum of arcs (cm)		Regression Equation = 3.59 + 0.0048X
1	(oc)	69	8,341
2		32	5,541
3		57	7,305
4		93	10,900
5		126	15,650
6	(oc)	49	6,685
7	(tog)	48	6,613
8	(tog)	92	10,720
9		165	24,100
10		157	22,050
11		130	16,350
12		69	8,341
13		71	8,530
14		62	7,720
15		107	12,700
16		56	7,220
17		106	12,550
18		144	19,110
19		187	30,730
20	(tog)	41	6,121
21		133	1,695
22		25	5,125
23		19	4,800
24		91	11,650
25		42	6,190
26		38	5,925
27		129	16,200
28		132	16,740
29		164	23,840
30		80	9,420
31		100	11,750

APPENDIX VII(d). Continued

Serial No.	Sum of arcs (cm)	Regression Equation = 3.59 + 0.0048X
32	145	19,320
33	52	69,120
34	80	9,420
35	88	10,350
36	87	10,150
37	58	7,393
38	82	9,630
39	81	9,522
40	111	1,325
41	(tog) 32	5,541
42	(oc) 146	19,540
43	72	8,622
44	62	7,720
45	54	7,065
46	37	5,855
47	(tog) 37	5,855
48	50	6,761
49	38	5,925
50	(tog) 86	10,010
51	18	4,745
52	38	5,925
53	(tog) 57	7,305
54	(tog) 22	4,962
55	57	7,305
56	76	9,012

T. geminatus	Mean Population/mound	=	11,939
T. togoensis	"	=	7,141
T. occidentalis	"	=	11,522

APPENDIX VIII(a). RATE OF GRASS HARVESTING (number of grass fragments/ 5 minutes/foraging hole) BY T. GEMINATUS, LENGTH OF FORAGING PERIOD AND NUMBER OF FORAGING HOLES ON 5 STRIPS 3 x 30 m.
(Symbols as in text).

PLOT A (Ungrazed)

Date	$\bar{x}rt_2$	$\bar{x}rt_1$	$\bar{x}st_1$	$\bar{x}st_2$	t_2	n	Rate/m^2/day*
4/ 5/74	13.8	12.7	21.3	23.1	165	4	6.78
13/ 6/74	16.33	54.5	75.50	22.62	120	3	3.62
14/11/74	21.50	48.08	37.00	16.54	195	8	11.47
30/11/74	16.2	25.67	24.86	15.69	150	5	5.23
14/12/74	0.00	0.00	0.00	0.00	0.00	0	0.00
21/12/74	20.75	36.67	30.00	16.98	165	12	14.94
11/ 1/75	42.82	53.33	46.71	37.50	210	11	39.60
25/ 1/75	19.00	25.00	30.00	22.80	165	9	15.05
7/ 2/75	49.40	99.50	80.00	39.70	180	16	50.82
22/ 2/75	0.00	0.00	0.00	0.00	0.00	0	0.00
8/ 3/75	19.5	49.75	36.66	14.37	165	45	47.42
22/ 3/75	22.74	63.00	74.33	26.83	150	12	21.46
4/ 4/75	0.00	0.00	0.00	0.00	0.00	0	0.00

* Calculated from equation 2. (See text)

APPENDIX VIII(b). DRY WEIGHT OF GRASS HARVESTED BY T. GEMINATUS/FORTNIGHT.

Date	**Mean rate/m^2/day	Mean dry wt. of 100/grass pieces	Mean wt./m^2/day (g)	Mean wt./m^2/fortnight
1/ 5- 4/ 5/74	4.60	0.124	0.006	0.080
12/ 6-14/ 6/74	2.01	0.165	0.0033	0.046
13/11-16/11/74	10.04	0.107	0.010	0.140
27/11-30/11/74	2.33	0.100	0.0023	0.0322
11/12-14/12/74	0.00	0.00	0.00	0.00
18/12-21/12/74	12.69	0.15	0.019	0.266
8/ 1-11/ 1/75	49.54	0.141	0.070	0.980
22/ 1-25/ 1/75	19.24	0.141	0.027	0.378
5/ 2- 8/ 2/75	34.10	0.204	0.069	0.966
19/ 2-22/ 2/75	0.00	0.00	0.00	0.00
5/ 3- 8/ 3/75	57.33	0.174	0.099	1.386
19/ 3-22/ 3/75	15.73	0.218	0.034	0.476
2/ 4- 4/ 4/75	0.00	0.00	0.00	0.00

** As calculated from equation 3. (See text)

APPENDIX VIII(c). RATE OF GRASS HARVESTING (number of grass fragments/ 5 minutes/foraging hole) BY T. GEMINATUS, LENGTH OF FORAGING PERIOD AND NUMBER OF FORAGING HOLES ON 5 STRIPS 3 x 30 m.
(Symbols as in text).

PLOT B (Grazed)

Date	$\bar{x}rt_2$	$\bar{x}rt_1$	$\bar{x}st_1$	$\bar{x}st_2$	t_2	n	Rate/m^2/day*
1/ 5/74	26.89	43.0	52.5	32.1	150	7	14.98
2/ 5/74	14.8	48.0	106.5	32.70	175	10	25.42
3/ 5/74	26.5	65.0	68.9	28.1	200	8	20.00
4/ 5/74	27.7	25.5	42.60	46.3	190	9	35.2
12/ 6/74	16.7	20.0	18.80	15.70	120	3	2.512
13/ 6/74	37.75	77.50	75.50	36.8	165	8	21.59
14/ 6/74	29.60	61.50	61.29	29.50	180	5	11.80
13/11/74	43.23	56.10	46.2	34.91	164	8	20.36
14/11/74	15.00	15.00	13.00	13.00	117	3	2.028
15/11/74	47.68	36.33	32.75	42.98	210	11	44.13
16/11/74	17.92	51.00	48.12	18.99	225	14	26.59
27/11/74	25.0	41.3	27.60	16.7	165	5	6.12
28/11/74	13.8	19.25	18.63	13.36	135	7	5.6
29/11/74	22.00	22.17	31.8	31.56	165	3	6.94
30/11/74	14.8	48	106	32.68	165	10	23.96
11/12/74	4.20	10.25	28.25	11.58	105	7	3.78
12/12/74	9.33	10.66	32.83	28.73	165	7	14.75
13/12/74	8.50	71.0	73.20	8.76	175	9	6.13
14/12/74	12.25	29.0	51.33	21.68	180	8	13.88
18/12/74	30.75	38.33	30.00	24.07	135	6	8.67
19/12/74	10.40	46.40	42.14	9.45	195	13	10.65
20/12/74	14.71	72.40	65.83	13.38	195	10	11.60
21/12/74	20.33	26.50	21.00	16.11	120	15	12.89
8/ 1/75	14.16	29.16	28.75	13.96	189	21	24.62
9/ 1/75	15.93	29.2	28.33	15.46	150	15	15.46
10/ 1/75	28.89	43.33	50.78	33.86	285	11	47.18
11/ 1/75	17.83	41.33	38.67	16.68	210	14	21.80

APPENDIX VIII(c). Continued

Date	$\bar{x}rt_2$	$\bar{x}rt_1$	$\bar{x}st_1$	$\bar{x}st_2$	t_2	n	Rate/m^2/day*
22/ 1/75	22.71	38.0	32.80	19.60	165	17	24.44
23/ 1/75	22.93	56.00	49.14	20.12	225	14	28.17
24/ 1/75	30.75	50.60	48.14	29.26	210	6	16.38
25/ 1/75	20.44	32.0	33.60	21.46	135	13	16.74
5/ 2/75	33.75	76.00	86.14	40.84	293	50	87.98
6/ 2/75	18.11	40.00	61.33	27.77	150	20	37.02
7/ 2/75	28.75	76.50	78.14	29.37	180	36	84.58
8/ 2/75	10.13	34.00	56.00	16.68	210	11	17.12
19/2-22/2	-	-	-	-	-	-	-
5/ 3/75	15.87	31.00	38.60	19.76	150	51	67.18
6/ 3/75	17.64	35.00	42.28	21.30	195	66	121.83
7/ 3/75	21.47	28.66	43.28	32.42	180	45	116.71
8/ 3/75	11.94	33.3	47.50	17.03	195	54	79.70
19/ 3/75	19.33	51.33	71.00	26.73	255	18	54.53
20/ 3/75	0.00	0.00	0.00	0.00	0.00	0	0.00
21/ 3/75	16.42	57.50	60.00	17.13	130	36	35.63
22/ 3/75	43.09	72.50	59.40	35.30	145	33	75.07
2/4- 5/4	-	-	-	-	-	-	-
							$\bar{x}$ 31.47

* Calculated from equation 2. (See text)

APPENDIX VIII(d). DRY WEIGHT OF GRASS HARVESTED BY T. GEMINATUS/FORTNIGHT.

Date	**Mean rate/m^2/day	Mean dry wt. of 100/grass pieces	Mean wt./m^2/day (g)	Mean wt./m^2/fortnight
1/ 5- 4/ 5/74	23.9	0.124	0.030	0.420
12/ 6-14/ 6/74	11.97	0.165	0.020	0.280
13/11-16/11/74	23.28	0.107	0.025	0.349
27/11-30/11/74	10.66	0.100	0.011	0.154
11/12-14/12/74	9.60	0.120	0.012	0.168
18/12-21/12/74	10.95	0.150	0.016	0.224
8/ 1-11/ 1/75	22.27	0.141	0.039	0.546
22/ 1-25/ 1/75	21.43	0.141	0.030	0.420
5/ 2- 8/ 2/75	56.68	0.204	0.115	1.610
19/ 2-22/ 2/75	0.00	0.00	0.00	0.00
5/ 3- 8/ 3/75	96.35	0.174	0.167	2.338
19/ 3-22/ 3/75	55.08	0.218	0.120	1.680
2/ 4- 5/ 4/75	0.00	0.00	0.00	0.00

** As calculated from equation 3. (See text)

APPENDIX VIII(e). RATE OF GRASS HARVESTING (number of grass fragments/ 5 minutes/foraging hole) BY T. GEMINATUS, LENGTH OF FORAGING PERIOD AND NUMBER OF FORAGING HOLES ON 5 AREA 3 x 30 m.

(Symbols as in text).

PLOT C (Grazed)

Date	$\bar{x}rt_2$	$\bar{x}rt_1$	$\bar{x}st_1$	$\bar{x}st_2$	t_2	n	Rate/m^2/day*
4/ 5/74	7.5	24.0	53.2	16.62		5	12.20
13/ 6/74	56.2	94.50	86.25	51.29	65	5	7.41
14/11/74	20.3	9.6	13.8	29.18	150	3	5.84
30/11/74	12.10	36.75	29.1	9.58	180	10	7.66
14/12/74	36.00	37.20	33.91	32.81	120	5	8.75
21/12/74	42.71	65.50	55.40	38.12	165	21	58.70
11/ 1/75	19.61	35.50	28.0	15.47	210	19	27.43
25/ 1/75	20.17	36.50	42.33	23.39	195	15	30.40
7/ 2/75	49.57	99.67	89.50	44.51	210	13	54.00
22/ 2/75	0.00	0.00	0.00	0.00	0.00	0	0.00
8/ 3/75	19.35	56.66	40.83	13.94	180	42	46.84
22/ 3/75	24.07	54.00	98.75	44.02	255	11	54.88
4/ 4/75	0.00	0.00	0.00	0.00	0.00	0	0.00

* Calculated from equation 2. (See text)

APPENDIX VIII(f). DRY WEIGHT OF GRASS HARVESTED BY T. GEMINATUS/FORTNIGHT.

Date	**Mean rate/m^2/day	Mean dry wt. of 100/grass pieces	Mean wt./m^2/day (g)	Mean wt./m^2/fortnight
1/ 5- 4/ 5/74	8.28	0.124	0.010	0.140
12/ 6-14/ 6/74	4.11	0.165	0.007	0.098
13/11-16/11/74	5.11	0.107	0.0055	0.076
27/11-30/11/74	3.64	0.199	0.004	0.056
11/12-14/12/74	8.75	0.120	0.007	0.098
18/12-21/12/74	49.86	0.150	0.074	1.036
8/ 1-11/ 1/75	34.31	0.141	0.049	0.686
22/ 1-25/ 1/75	38.86	0.141	0.055	0.770
5/ 2- 8/ 2/75	36.18	0.204	0.073	1.033
19/ 2-22/ 2/75	0.00	0.00	0.00	0.00
5/ 3- 8/ 3/75	56.63	0.174	0.098	1.372
19/ 3-22/ 3/75	40.26	0.218	0.077	1.228
2/ 4- 4/ 4/75	0.00	0.00	0.00	0.00

** As calculated from equation 3. (See text)

APPENDIX VIII(g). RATE OF GRASS HARVESTING (number of grass fragments/ 5 minutes/foraging hole) BY T. GEMINATUS, LENGTH OF FORAGING PERIOD AND NUMBER OF FORAGING HOLES ON 5 STRIPS 3 x 30 m.
(Symbols as in text).

PLOT D (Ungrazed)

Date	$\bar{x}rt_2$	$\bar{x}rt_1$	$\bar{x}st_1$	$\bar{x}st_2$	t_2	n	Rate/m^2/day*
4/ 5/74	13.44	21.5	26.2	16.06	150	3	3.31
13/ 6/74	60.5	61.0	67.50	66.95	145	2	8.63
14/11/74	38.0	42.25	51.55	46.36	270	7	38.94
30/11/74	26.29	47.0	51.25	28.7	204	7	18.21
14/12/74	27.5	31.5	52.86	46.89	210	2	8.75
21/12/74	26.80	21.67	23.00	28.44	225	14	39.81
11/ 1/75	18.25	24.40	20.25	15.15	145	12	11.39
25/ 1/75	18.80	44.0	40.75	17.41	150	6	6.96
7/ 2/75	22.91	53.0	64.29	27.79	195	12	28.90
22/ 2/75	0.00	0.00	0.00	0.00	0.00	0	0.00
8/ 3/75	24.14	39.75	36.13	21.94	210	21	43.00
22/ 3/75	18.85	62.33	47.30	14.19	165	33	34.33
4/ 4/75	0.00	0.00	0.00	0.00	0.00	0	0.00

* Calculated from equation 2. (See text)

APPENDIX VIII(h). **DRY WEIGHT OF GRASS HARVESTED BY T. GEMINATUS/FORTNIGHT.**

Date	**Mean rate/m^2/day	Mean dry wt. of 100/grass pieces	Mean wt./m^2/day (g)	Mean wt./m^2/fortnight
1/ 5- 4/ 5/74	2.25	0.124	0.003	0.042
12/ 6-14/ 6/74	4.79	0.165	0.008	0.112
13/11-16/11/74	34.09	0.107	0.036	0.510
27/11-30/11/74	8.09	0.100	0.008	0.112
11/12-14/12/74	6.05	0.120	0.0073	0.102
18/12-21/12/74	33.81	0.150	0.050	0.710
8/ 1-11/ 1/75	14.25	0.141	0.020	0.280
22/ 1-25/ 1/75	8.90	0.141	0.013	0.182
5/ 2- 8/ 2/75	19.36	0.204	0.039	0.546
19/ 2-22/ 2/75	0.00	0.00	0.00	0.00
5/ 3- 8/ 3/75	51.98	0.174	0.090	1.26
19/ 3-22/ 3/75	25.18	0.218	0.055	0.77
2/ 4- 4/ 4/75	0.00	0.00	0.00	0.00

** As calculated from equation 3. (See text)

APPENDIX IX. QUANTITY OF GRASS CUT DOWN BUT LEFT AS 'LITTER' IN RANDOM QUADRATS ESTIMATED FROM JANUARY - APRIL 1975.

Date	PLOT B		PLOT C		PLOT D	
	Wt. harvested & carried back $g/m^2/day$	Dry wt. harvested & left as litter $g/m^2/day$	Wt. harvested & carried back $g/m^2/day$	Dry wt. harvested & left as litter $g/m^2/day$	Wt. harvested & carried back $g/m^2/day$	Dry wt. harvested & left as litter $g/m^2/day$
22/1/75		0.0000		0.0255		0.0210
23/1/75		0.0315		0.0130		0.0315
24/1/75		0.0000		0.0220		0.0000
25/1/75		0.0355		0.0140		0.0535
22/1-25/1 $\bar{x}$	0.030	0.0167	0.055	0.0186	0.0130	0.028
5/2/75		0.000		0.000		0.000
6/2/75		0.000		0.000		0.000
7/2/75		0.0345		0.0250		0.000
8/2/75		0.000		0.000		0.000
5/2- 8/2 $\bar{x}$	0.1150	0.0086	0.073	0.0063	0.039	0.000
19/2/75		0.0010		0.0005		0.000
20/2/75		0.0590		0.0005		0.000
21/2/75		0.0010		0.0335		0.000
22/2/75		0.000		0.0000		0.000
19/2-22/2 $\bar{x}$	0.0000	0.0153	0.0000	0.0086	0.0000	0.0000

APPENDIX IX. Continued

Date	PLOT B		PLOT C		PLOT D	
	Wt. harvested & carried back $g/m^2/day$	Dry wt. harvested & left as litter $g/m^2/day$	Wt. harvested & carried back $g/m^2/day$	Dry wt. harvested & left as litter $g/m^2/day$	Wt. harvested & carried back $g/m^2/day$	Dry wt. harvested & left as litter $g/m^2/day$
5/3/75		0.020		0.000		0.0170
6/3/75		0.000		0.000		0.0000
7/3/75		0.019		0.0160		0.0192
8/3/75		0.026		0.0300		0.0680
5/3- 8/3 $\bar{x}$	0.167	0.011	0.098	0.0115	0.090	0.0261
19/3/75		0.020		0.0230		0.0127
20/3/75		0.000		0.0000		0.0000
21/3/75		0.094		0.0130		0.0295
22/3/75		0.000		0.0000		0.0000
19/3-22/3 $\bar{x}$	0.120	0.0285	0.112	0.0090	0.0550	0.011
2/4/75		0.0230		0.000		0.0035
3/4/75		0.0000		0.000		0.0000
4/4/75		0.0000		0.000		0.0000
5/4/75		0.0300		0.000		0.0000
2/4- 5/4 $\bar{x}$	0.0000	0.0132	0.0000	0.000	0.000	0.00087
Total	0.4320	0.0932	0.340	0.054	0.1970	0.066
$\bar{x}$	0.072	0.0155	0.057	0.009	0.033	0.011

APPENDIX X. RELATING FORAGING CYCLE TO SUBSOIL AND SOIL SURFACE TEMPERATURES.

November 1974 - April 1975

Date	Morning hours (06.00-10.00)		Evening hours (16.30-19.30)		Foraging Cycle			
	Subsoil Temp. °C	Soil Surface Temp °C	Subsoil Temp. °C	Soil Surface Temp °C	Morning Activity only	Evening Activity only	Morning and Evening activity	No Foraging activity
Nov. 13	26	23	26	21	-	-	+	-
" 14	26	22	26	22	-	-	+	-
" 15	26	23	26	23	-	-	+	-
" 16	26	24	26	24	-	-	+	
" 27	24	19	28	34.5	-	+	-	-
" 28	28	22	28	21.0	-	+	-	-
" 29	25	19	28	34.5	-	+	-	-
" 30	28.5	21	27	20.5	-	+	-	-
Dec. 11	22	16.5	25.5	33.3	-	+	-	-
" 12	28	20.4	26.3	28.3	-	+	-	-
" 13	24.5	17.0	26.4	33.2	-	+	-	-
" 14	29.0	18.60	25,6	24.5	-	+	-	-
" 18	25	18.2	28.9	32	-	+	-	
" 19	22	17.8	26.8	33.6	-	+	-	-
" 20	30	21.2	31.5	32.5	-	+	-	-
" 21	29	20.2	34.0	31.5	-	+	-	-

APPENDIX X. Continued

Date	Morning hours (06.00-10.00)		Evening hours (16.30-19.30)		Foraging Cycle			
	Subsoil Temp °C	Soil Surface Temp °C	Subsoil Temp. °C	Soil Surface Temp °C	Morning Activity only	Evening Activity only	Morning and Evening activity	No Foraging activity
Jan. 8	26.0	18.7	29	26.70	-	+	-	-
" 9	29.2	20.5	27.8	25.0	-	+	-	-
" 10	27.0	17.60	28.5	23.7	-	+	-	-
" 11	29.5	19.70	29.5	27.3	-	+	-	-
" 22	25.0	19.3	26.5	24.2	-	+	-	-
" 23	25.0	28.75	26.0	21.50	-	+	-	-
" 24	25.0	16.75	26.0	28.20	-	+	-	-
" 25	25.3	16.50	26.0	27.33	-	+	-	-
Feb. 5	27.3	26.0	32.0	33.8	-	-	+	-
" 6	28.0	24.6	32.5	42.0	+	-	-	-
" 7	28.5	23.0	30.65	40.2	+	-	-	-
" 8	28.2	20.6	32.1	42.60	+	-	-	-
" 19	29	18.7	34.5	42.50	-	-	-	0
" 20	31	21.0	32.5	43.6	-	-	-	0
" 21	31.2	17.8	31.7	45.4	-	-	-	0
" 22	32.8	19.4	29.5	28.0	-	-	-	0

APPENDIX X. Continued

Date	Morning hours (06.00-10.00)		Evening hours (16.30-19.30)		Foraging Cycle			
	Subsoil Temp °C	Soil Surface Temp °C	Subsoil Temp. °C	Soil Surface Temp °C	Morning Activity only	Evening Activity only	Morning and Evening activity	No Foraging activity
Mar. 5	30.0	27.0	36.5	35.5	+	-	-	-
" 6	29	28	38.0	37.8	+	-	-	-
" 7	30.5	29	37.5	36.6	+	-	-	-
" 8	27.2	25.5	38.0	37.2	+	-	-	-
" 19	30	29.7	36	35.20	+	-	-	-
" 20	31.0	26.67	36.6	36.6	+	-	-	-
" 21	32.0	28.20	38.0	44.0	+	-	-	-
" 22	32.6	25.60	37.5	42.33	+	-	-	-
April 2	36.5	34.5	39.6	36.8	-	-	-	0
" 3	35.0	32.6	39.6	38.0	-	-	-	0
" 4	35.0	30.8	39.57	39.00	-	-	-	0
" 5	36.0	29.30	39.5	48.0	-	-	-	0

+ Indicates when foraging occurred.

0 " no foraging both morning and evening periods.